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Doctoral Dissertation

Carbon Pricing in Vietnam: Simulations of Environmental and Economic Impacts with a Computable General Equilibrium Model

ベトナムにおけるカーボンプライシングの環境および経済への影響：
数値解析的一般均衡モデルにおけるシミュレーション分析

Global Governance Program

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ABSTRACT

The increase in greenhouse gas (GHG) emissions causing climate change has been a substantial topic in recent years. Carbon pricing, a market-based solution, has been widely implemented around the world to constrain emissions. The Vietnamese government with ambitious GHG emissions reduction targets in its Nationally Determined Contributions (NDC) introduced carbon pricing in the Revised Environmental Protection Law 2020. However, research on carbon pricing in Vietnam is still limited, and the potential impacts of this policy are unclear. This dissertation simulates the environmental and economic impacts of carbon pricing in Vietnam by using computable general equilibrium (CGE) models.

This study examines the pure impacts of carbon pricing mechanisms including carbon taxes and emissions trading schemes (ETS). The results show that both carbon taxes and ETS have positive impacts on emissions reduction but induce negative impacts on the economy and welfare. Under the carbon tax policy, with US$1/t$CO_2eq, US5/tCO_2eq, and US$10/t$CO_2$eq, the country is able to reduce its emission levels by 0.2% - 4.5% (0.47 - 9.90 MtCO_2eq) at the cost of GDP reduction of 0.11% - 2.32%. Moreover, fewer sectors covered by carbon tax cause lighter economic and welfare loss but lower emissions reduction. On the other side, under ETS, to achieve the latest Vietnam's NDC emissions reduction targets of 9% and 15.8%, carbon prices are estimated at US$23.3/t$CO_2$eq and US$56.6/tCO_2eq, respectively. The economy is substantially affected by the ETS with a drop in GDP by 1.6% and 3.69% and a welfare decline by VND 55.8 trillion and VND 128.3 trillion. At the sectoral level, both carbon tax and ETS have an impact on industry restructuring, the industries with high carbon intensity all shrink their production greater than other industries. Specifically, the electricity sector is the main contributor to emissions reduction in Vietnam, but its output suffers most from the carbon pricing policy. A significant decline in its output could raise concerns about electricity security for economic development.

To mitigate the adverse impacts of carbon pricing on economic growth and welfare, this study simulates carbon pricing revenue redistribution scenarios to households and government activities. This study shows that revenue recycling policies could lighten the negative impacts of carbon pricing on economic growth and welfare. While carbon pricing revenue reused for government activities leads to better improvement in GDP, the revenue transferring to households generates better effects on welfare. However, recycling policies could reduce the environmental impacts of the carbon tax and exacerbate the negative impact on the electricity output of ETS.

This study suggests that Vietnam should implement a lower carbon price or lower emissions reduction targets at the early stages of carbon pricing, which would assist businesses in adapting the new policy. The carbon price level or emissions reduction targets could be gradually raised in the subsequent stages to ensure the achievement of the goals of the NDC. In addition, the government should pay attention to the electricity generation sector. Supplemental policies should be established to ensure stable electricity supply as well as improving technology toward reducing the carbon intensity of this sector. The policy assessment at both the macro level as well as the industry level for each stage is necessary to adjust goals as well as design appropriate mechanisms throughout carbon pricing implementation. Lastly, this study still has limitations such as not considering energy transition and technological innovation, further research should be conducted to improve understanding of carbon pricing in Vietnam.

Key Words: carbon pricing; carbon tax; ETS; environment; economic; impacts; recycling policies; revenue; CGE model; Vietnam.

CERTIFICATION

This is to certify that, to the best of my knowledge, the content of this dissertation is my own work and that all the assistance received in preparing this thesis and sources have been acknowledged. This dissertation has not been submitted for any other degree or qualification.

Tokyo, June 2024

Nguyen Phuong Thao

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All remaining mistakes of this dissertation are mine.

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LIST OF ABBREVIATIONS

ASEAN	Association of Southeast Asian Nations
BaU	Business-as-usual scenario
CGE	Computable General Equilibrium
ETS	Emission Trading Scheme
EU ETS	European Union Emissions Trading Scheme
EV	Equivalent Variation
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
GTAP	Global Trade Analysis Project Model
IMF	International Monetary Fund
IO	Input-Output
IPCC	Intergovernmental Panel on Climate Change
NDC	Nationally Determined Contributions
SAM	Social Accounting Matrix
tCO_2eq	Ton of Carbon Dioxide Equivalent
UNDP	United Nations Development Programme
UNFCCC	United National Framework Convention on Climate Change
US	United States
VND	Vietnam đồng – Vietnamese currency
WB	World Bank

Chapter 1. Introduction

1.1 Background and Problem Statement

Climate change poses a threat to human life and ecosystems in various ways. According to IPCC (2023), the global surface temperature in the last decade (2011-2020) was 1.09°C (0.95°C–1.20°C) higher than in 1850–1900. To slow down global warming, the Paris Agreement, a legally binding international treaty on climate change, set an overarching target to limit "the increase in the global average temperature to well below 2°C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels". The increasing GHG emissions over the centuries caused by human activities have been a substantial contributor to climate change.

To curb emissions, many global efforts have been initiated. The first international agreement on climate change is the United Nations Framework Convention on Climate Change (UNFCCC) signed in 1992, followed by the Kyoto Protocol signed in 1997 (entered into force in 2005) and the Paris Agreement signed in 2015 (entered into force in 2016). These agreements provided the basis for coping with climate change globally. Since the early 21st century, policy frameworks in various forms have been established on national and international levels to tackle the increasing GHG emissions (IPCC, 2014). These international engagements to mitigate climate change motivated emissions reduction initiatives. Carbon pricing initiatives were introduced in the early 1990s and have taken off internationally to mitigate emissions. The two types of carbon pricing are generally known as a carbon tax and an emissions trading scheme (ETS). While carbon tax provides a certainty of a carbon price and the emissions reduction level is uncertain, ETS sets a target for emissions reduction following the international commitment and generates price uncertainty. Until 2022, carbon pricing has been implemented/scheduled in 71 jurisdictions around the world (including 37 carbon taxes and 34 ETSs) to mitigate emissions such as Ireland, Australia, Chile, and Japan (World Bank, 2022).

In recent years, research on impact assessments and designing carbon pricing has increased rapidly owing to the rising demand for implementing carbon pricing in many countries and subnational regions. Previous studies have confirmed the positive impact of carbon pricing in emissions mitigation (e.g. Mardones and Ortege (2021); Tang and Bao (2016); Meng et al. (2018); Choi et al. (2017); Nong et al. (2020); Lin and Jia (2017); Lin and Jia (2018); Wissema and Dellink, 2007; Meng et al., 2013; Antosiewicz et al., 2022). However, previous studies have mainly focused on carbon tax or ETS impacts separately, and few studies compare these two policies. Therefore, there remains controversy about which is better between carbon tax and ETS. In addition, previous studies also showed that carbon pricing could generate revenue and the reuse revenue can affect the effectiveness of the carbon pricing, but research on carbon pricing revenue reuses is limited. The harmony level of carbon tax and ETS with recycling policies and how to utilize carbon pricing revenue remains questionable. Moreover, the previous literature mostly focused on major emitters or developed countries/regions such as the EU, China, and Australia (Babatunde et al., 2017; Nong et al., 2020). There is a lack of study in developing countries, especially in countries that are scheduling/considering carbon pricing.

In Vietnam, after a long period mainly following economic growth policies, the country has achieved a high economic growth rate with an average of 6.7% in 1991-2022. However, along with that, total GHG emissions in Vietnam have increased continuously from 20.6 $MtCO_2eq$ in 1991 to 321.4 $MtCO_2eq$ in 2021. Realizing the role of environmental actions in the country, the government has established ambitious targets presented in many recent international commitments. In Vietnam's Nationally Determined Contribution (NDC) 2015, Vietnam committed to reducing its GHG emissions by 8% and 25% in comparison with the business as usual (BAU) scenario by 2030 with domestic resources and international support, respectively. These figures were revised to 9% and 27% in NDC 2020 respectively. In the latest NDC updated in 2022, the figures are 15.8% and 43.5% respectively. Recently, in the 26th session of the Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) in 2021, Vietnam pledged to reach its net-zero carbon emission target by 2050. Given these targets, Vietnam adopted the Revised Environmental Protection Law in 2020 and introduced carbon pricing in the country. Following this Law, in 2022, in Decree No. 06/2022/ND-CP on Mitigation of Greenhouse Gas (GHG) Emissions and Protection of Ozone Layer, Vietnam outlines a roadmap for ETS implementation with a pilot ETS in 2026 before launching a full ETS in 2028 and set the provisions for developing a national ETS corresponding to Vietnam's NDC. In addition, the country also has been considering a carbon tax under this Law. However, the specific structure and rules have not been established yet because there is a lack of research in this field. There was one study on ETS in Vietnam by Nong et al. (2020). They showed that a relatively high carbon price of \$109.32/tCO_2eq would lead to a decrease of 4.57% in real GDP, allowing Vietnam to achieve its target of reducing 8% emissions in the energy and transportation sectors and 20% in the agriculture sector in 2020 if only these sectors join in ETS market. The price and emissions reduction costs would be reduced significantly if all sectors participate in the market. However, the emissions reduction targets set in this research are quite far from Vietnam's current NDC.

In summary, although carbon pricing has been proven to be an effective tool in emissions mitigation, its impacts on the economy are not clearly understood. The previous studies mostly focused on carbon tax and ETS separately, there is a lack of research comparison among these mechanisms. In addition, research on reuse carbon pricing revenue remains questionable in the literature. Moreover, the existing studies have mainly been conducted for in major emitters or developed countries/regions, the research in developing countries including Vietnam is limited, which causes difficulties in implementing carbon pricing in the country. Therefore, this dissertation fills the gap by analyzing the impacts of carbon pricing including carbon tax and ETS in Vietnam, comparing their pure impacts, and analyzing carbon pricing impacts under different revenue redistribution policies. Then, this dissertation suggests policy implications to support carbon pricing implementation in Vietnam.

1.2 Research Objectives

The main objective of this dissertation is to analyze the impacts of carbon pricing including carbon tax and ETS on the macro-economic and sectoral levels in Vietnam. Carbon pricing creates a mechanism of putting a price on emissions, thus emitters have to pay costs for their emissions generation. The emissions costs will be added to production costs, which results in changing consumption, investment, production, and other variables in the economy. This dissertation examines all changes in the economy, welfare, and environment introduced by carbon pricing. In addition, carbon pricing can raise revenue through tax collection or carbon permit auctions. And in order to mitigate the adverse impacts of carbon pricing, the revenue can be used for improving economic growth and welfare. In this study, carbon pricing revenue is assumed to be recycled to government activities and to households through reduced income tax. This dissertation compares the impact of revenue recycling options in order to determine the impacts of recycling policies on carbon pricing.

The specific research objectives include:

1. To examine the pure impacts of a carbon tax on the economy and environment at macro and sectoral levels in Vietnam.

2. To examine the pure impacts of ETS on the economy and environment at macro and sectoral levels in Vietnam.

3. To examine the impacts of carbon pricing under various revenue recycling policies

1.3 Research Methodology

To examine the impacts of carbon pricing options in Vietnam, this research employs static Computable General Equilibrium (CGE) models. The standard CGE model reflects the economy by describing the behaviors of all economic agents in a given time period. The model incorporates a system of equations with some assumptions including perfect competition, and the optimization assumption (cost minimization or profit maximization, and utility maximization). The CGE models are dominant for simulating the impacts of new policies and have been widely developed for analyzing the impacts of climate change policies including carbon pricing and carbon pricing revenue redistribution options. CGE has advantages in describing the economy with all agents in the model (World Bank, 2018). Therefore, when new policies are introduced, the model would show changes in all variables.

In this study, in addition to standard economic accounts, the environmental account is also integrated into the CGE models for Vietnam. Therefore, environmental policies can be modeled, and then the environmental impact and economic impact can be explored easily. There are four main blocks in this model including production, income & expenditure, environment, and market equilibrium. While production, income & expenditure, and market equilibrium mainly remain unchanged, the environmental block will be adjusted to model carbon pricing mechanisms such as carbon tax, ETS, and revenue redistribution options. These CGE models are based on a Social Accounting Matrix (SAM) database that is mainly constructed from the latest Input-Output (IO) table of Vietnam in 2016 and other data is collected from the System of National Accounts (SNA) in Vietnam for the year 2016. The sectoral emissions data is compiled from the EORA database for the year 2016.

These models accurately describe Vietnam's economy, so it helps to improve the estimated results. In addition, different from previous studies, there are improvements in setting the models. The carbon tax models allow imposing a carbon tax on industries more flexibly instead of fixing carbon tax on fossil fuel commodities. The carbon tax rate also reflects more accurately the principle of higher taxation for carbon-intensive industries, and lower taxation for less carbon-intensive industries. In addition, taxing output will more fully capture the emissions released from the production processes of industries because emissions come not only from combusting fossil fuels but also from other activities such as emissions from using land in agricultural production, and emissions from using chemicals. In the ETS models, the research is based on the current plan for implementing ETS in Vietnam, so it allows for assessing the impacts of actual policies on the country.

1.4 Research Outline

This thesis consists of six chapters. Among them, Chapters 3, 4, and 5 are the core, which corresponds to three academic papers regarding the impacts of carbon pricing policy in Vietnam.

Chapter 1. Introduction

Research background, problem statement, and objectives are first introduced, followed by methodology, research outline, and expected contribution of the research.

Chapter 2. Climate change and emissions mitigation efforts

This chapter provides an overview of climate change and greenhouse gas emissions in the world and in Vietnam. In this chapter, policy measures including carbon pricing to mitigate emissions are discussed in terms of theory and practice. Vietnam's efforts, emissions targets, and carbon pricing plan are also introduced in this chapter.

Chapter 3. The potential impacts of a carbon tax in Vietnam

Based on the current carbon prices in literature and practice in different countries, this chapter suggests the carbon prices and sector coverages for Vietnam from the lowest to higher levels for matching with some countries with the same economic situation or the same region. This chapter will show the potential pure impacts of different carbon prices and different sector coverages on the environment and the economy in Vietnam.

Chapter 4. The potential impacts of a carbon emission trading scheme in Vietnam

Based on Vietnam's NDC targets, this chapter sets ETS targets and scenarios. By comparing the change in macroeconomic variables, sectoral outputs, and other variables before and after introducing ETS in the model, this chapter shows the potential pure environmental and economic impacts of ETS in Vietnam. In addition, based on the emissions reduction levels under the carbon tax scheme in Chapter 3, this chapter also sets an ETS scenario with the same emissions reduction level in Chapter 3 and gives some comparisons between carbon tax and ETS impacts.

Chapter 5: Carbon pricing with revenue redistribution policies

In this chapter, the revenue raised from carbon pricing policies is assumed to be recycled to government activities and to households through income tax reduction with the expectation of reducing the negative impacts of carbon pricing on economic growth and welfare. This chapter compares and contrasts the outcome of carbon pricing without revenue redistribution and with various revenue redistribution options with respect to macroeconomic impacts and sectoral impacts. This chapter shows the impacts of revenue redistribution on carbon pricing effectiveness. In addition, by comparing carbon tax revenue and ETS revenue recycling policies, this chapter shows the harmony levels of carbon pricing mechanisms with revenue redistribution policies.

Chapter 6. Discussions and conclusions

This chapter reviews the research and presents the main findings, further discussions, conclusions, and policy implications. In this chapter, the limitations and suggestions for further research are also discussed.

1.5 Expected Contribution of the Research

Firstly, the research measures the impacts of carbon pricing in Vietnam. Carbon pricing is simulated with a variety of pure scenarios and revenue recycling options. The research shows the potential impacts of carbon pricing on mitigation emissions in the country. However, carbon pricing would have negative impacts on economic growth, welfare, and sectoral outputs. In addition, carbon pricing revenue is expected to lighten the adverse impacts of such policies. There are different impacts with different carbon prices, sector coverages, emissions reduction levels, and recycling policy options. The findings contribute to designing and implementing carbon pricing in Vietnam, this study is a base for some policy implications in the country.

Secondly, this study develops static national CGE models for Vietnam by using Vietnam's SAM. Therefore, these models simulate Vietnam's economy more accurately. In these models, carbon pricing mechanisms are modeled and the model setting is more flexible and realistic, which supports policymakers in the country in measuring the impacts of different carbon pricing scenarios, then assisting in designing carbon pricing and adjusting the policy.

Regarding the literature, carbon pricing has been analyzed quite widely in developed countries or major emitters. Previous studies showed the positive impacts of carbon pricing on mitigating emissions. However, there is a lack of consensus on which is better between CT and ETS. In addition, the impacts of reusing carbon pricing revenue policies have not been clear in the literature. Moreover, carbon pricing studies are limited in developing countries. This study is expected to enrich the literature on carbon pricing impacts in the literature by providing evidence on pure impacts of carbon tax and ETS as well as impacts under different revenue recycling policies. This study focuses on carbon pricing in developing countries, the case of Vietnam, thereby, it will serve as an example for countries with similar conditions that are considering/scheduling carbon pricing.

Chapter 2: Climate Change and Emissions Mitigation Efforts

This chapter overviews global climate change and GHG emissions. This chapter also discusses the emissions mitigation efforts as well as policy tools applied in the world and in Vietnam. This study shows that carbon pricing is the most popular market-based solution and plays an important role in mitigating emissions in many countries. With the context of emissions increasing in Vietnam, the government needs more actions to curb emissions. Carbon pricing introduced and scheduled in the Revised Environmental Protection Law in 2020 is expected to be an effective tool to support meeting Vietnam's emissions reduction targets in its NDC.

2.1 Climate change and GHG emissions

Climate change and carbon emissions

Scientists show that global warming is a result of increasing greenhouse gas concentrations. The increase in temperatures cause changes in precipitation patterns, storm severity, and sea level, which is commonly referred to as climate change. As the definition by IPCC (2014), "Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer". Meanwhile, the United Nations Framework Convention on Climate Change (UNFCCC) refers to a distinction between climate change attributable to human activities and climate variability attributable to natural causes and defines "climate change as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". Currently, according to IPCC (2023), global surface temperature in the last decade (2011-2020) was 1.09°C (0.95°C–1.20°C) higher than in 1850–1900.

The consistent scientific evidence shows that human activities, principally through GHG emissions, have unequivocally caused global warming and climate change. Most of these human-caused GHG emissions were carbon dioxide (CO_2) (accounted for 76% of total global GHG emissions), followed by methane (16%) and nitrous oxide (6%) (IPCC, 2014). Since the industrial revolution in the mid-1800s, emissions from human activity have increased substantially. Although the natural processes can absorb some of the anthropogenic CO_2 emissions generated each year, starting in about 1950, CO_2 emissions began exceeding the capacity of these processes to absorb carbon. This imbalance has resulted in a continued increase in atmospheric concentrations of GHG emissions. Carbon dioxide emissions have risen rapidly for the past 70 years, in which China and the US are leading countries. Concentrations of CO_2 in the atmosphere in 2021 were about 44% higher than the concentrations in 1850 (Figure 1). The combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation is the primary source of CO_2. Certain industrial processes and land-use changes also emit CO_2.

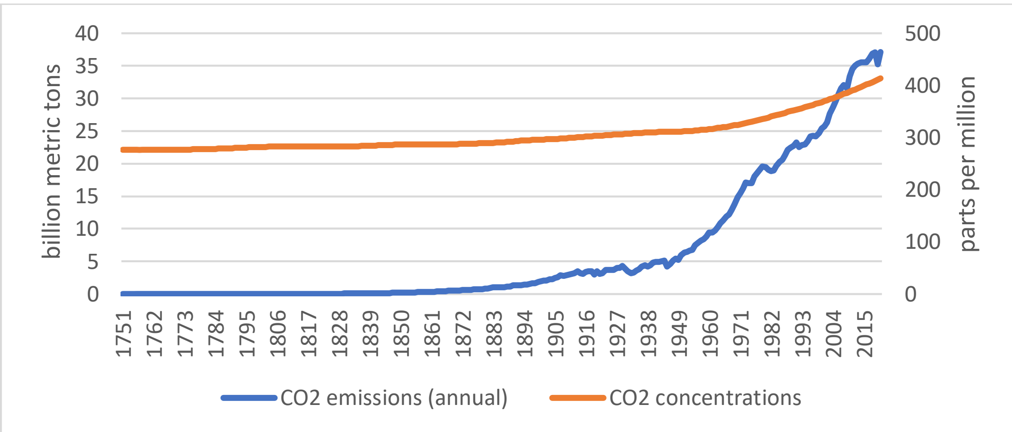


Figure 2.1. World carbon dioxide emissions and atmospheric carbon dioxide concentrations 1971-2021

Source: Adapted from Concentrations from Scripps Institute of Oceanography CO_2 program; emissions from Carbon Dioxide Information Analysis Center for 1751-1980 and U.S. Energy Information Administration for 1980-2021 and Our World in Data based on the Global Carbon Project (2022)

Global emissions mitigation efforts

As discussed above, the increasing GHG emissions which mainly is carbon emissions are responsible for climate change. The adverse effects of climate change such as rising sea-level causing flooding, loss of coastal lands; heat waves, affecting human health and causing droughts; such extreme weather events are already visible around the world, especially in the most vulnerable regions. Therefore, current global concern is about climate change mitigation and adaptation. Due to the global nature of carbon, a global approach and agreement is necessary. The first international agreement on climate change is the UNFCCC signed in 1992, followed by the Kyoto Protocol signed in 1997 (entered into force in 2005) and the Paris Agreement signed in 2015 (entered into force in 2016). While the UNFCCC is the primary platform for global actions to fight climate change, the Kyoto Protocol and the Paris Agreement highlight different instruments to cope with climate change. A market-based approach for mitigating GHGs was introduced in the Kyoto Protocol while broadened tools such as green finance, green bonds, etc., were included in the Paris Agreement. In the Paris Agreement, countries express their efforts in fighting against climate change through Nationally Determined Contributions (NDCs). These agreements form the basis for coping with climate change globally. Since the early 21st century, policy frameworks in various forms have been established on national and international levels to tackle the increasing GHG emissions (IPCC, 2014).

2.2 Emissions mitigation policy instruments

2.2.1 Fundamental theories of negative externalities and government intervention

The increase in industrial activities in countries leads to an increase in economic growth, but the production process could cause externalities, which may have positive or negative effects on other economic agents. Different production characteristics and structures might result in various externalities. However, in general, externalities involved in production lead to inefficient allocations of resources because market prices do not accurately reflect the additional benefits/costs imposed on third parties. Levels of production, as well as expenditures directed at controlling the externality, will be incorrect.

A negative externality is any action that adversely affects others who were not a party to the transaction (Stiglitz and Rosengard, 2015). Air and water pollution generated by firms in their production activities are cited as common examples of a negative externality. The level of production of negative externality-generating commodities will be excessive (overproduction).

Although some arguments assert that private markets can deal with negative externalities, government interventions are required. It is because the private remedies for negative externalities fail to deal with public good problems (free rider), imperfect information problems, transaction costs, and additional problems with litigation such as uncertainty about outcomes, and differential access (Stiglitz and Rosengard, 2015).

Government interventions to solve negative externalities involved in production fall into two broad categories: market-based solutions and regulations. Market-based solutions attempt to influence incentives to ensure economically efficient outcomes. By contrast, the government has used regulations to limit externalities.

Market-based solutions

The markets themselves lead to inefficient resource allocations when there are externalities, but market-based mechanisms can be used to ensure efficient behavior. Market-based solutions to negative externalities take two main forms: taxes and marketable permits.

In Figure 2.2, the private marginal cost does incorporate the externality costs involved in production. Point E is where equilibrium is realized. Here, the market price is P^E, while output is X^E. However, social marginal cost (SMC) is higher than PMC because it adds marginal externality costs to marginal private costs, the socially optimal point is E^* and the socially optimal price is P*. When negative externalities are present, market failures arise as market mechanisms cease to function efficiently and overproduction leads to forfeited surplus, a deadweight loss is ΔE*EF.

Before government interventions, firms produce at X^E and equilibrium is E. By imposing a properly calculated tax (equal to the marginal cost of externalities), the marginal private costs and marginal social costs are equated, the equilibrium point (E) moves to E* (the socially optimal point). Here, the firms produce at X* with optimal price is P* and the welfare equivalent to the prior deadweight cost is recovered through the tax (the left side of Figure 2.2). This tax is called corrective tax, or sometimes Pigouvian tax.

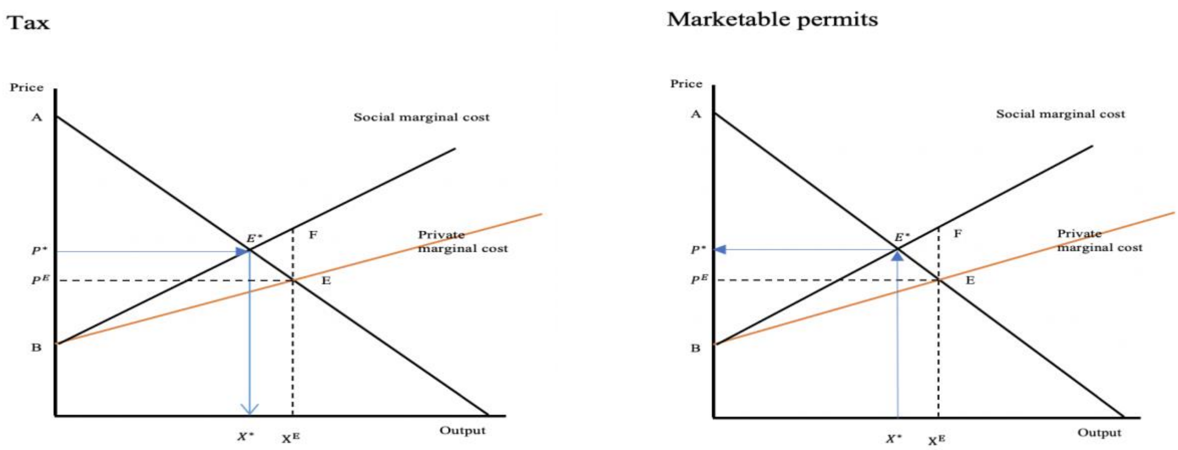


Figure 2.2. Taxes and Marketable permits

Source: Adapted from Environmental Economics, by Shunsuke Managi and Koichi Kuriyama, 2017

Fundamentally, the marketable permit is similar to the tax—both internalize the cost of externalities by establishing a price on them. The primary difference between the two is that where taxes specify a price on externalities and allow the market to determine the quantity of externality, a marketable permit sets the quantity and allows the market to determine the price (Figure 2.2). The government identifies the quantity of externality such as carbon emission level. Then, a limit, or cap, is placed on the total amount of externality that may be created, and this limit is either allocated or sold to firms in the form of permits/certificates. These limit the amount of externality that any single firm may generate. Because what the government cares about is the total amount of externality reduction, it allows firms to trade permits. A company that cuts its externalities could sell some of its permits to another company that wants to expand production (and hence increase its externalities). In equilibrium, firms will reduce externalities to a level such that the marginal cost of externality reduction is equal to the market price of the permits (the equilibrium point (E) moves to E^*- the socially optimal point). Like taxes, marketable permits use the market mechanism to ensure economic efficiency in the reduction of externality.

In theory, it is possible to achieve the same outcome (in terms of externality levels as well as economic efficiency) with either instrument - setting a price (for externality) leads to a particular quantity, and setting a quantity leads to the corresponding price. Both instruments can also raise revenue for the government. In order to implement optimal environmental policy (optimal tax/permits), governments require information related to both the marginal benefit curve and marginal externality cost. However, in reality, there are a lot of difficulties for policy authorities to acquire proper information. Even the governments have perfect information, they cannot always acquire sufficient information attainably such as environmental changes, technological developments, and others.

Governments need to consider the damages of uncertainty in choosing solutions. The damages incurred by uncertainty among taxes and tradable permits might result depending upon the comparative slopes of the marginal benefit and marginal externality cost curves. In the case where the slope of the marginal benefit curve is more than that of the marginal externality cost curve, the tax should be adopted since they inflict less social harm. However, in the opposite case where the marginal benefit curve is steeper than the marginal cost curve so a tradable permit system would inflict less social harm (Managi and Kuriyama, 2017; Pizer, 1997).

Regulations

In addition to market-based solutions, direct regulations are also considered by the governments to deal with negative externalities such as pollution. Government regulation forces polluters to incur costs associated with pollution control. Firms forced to reduce their pollution will face higher costs, shifting the market supply curve for polluting products to the left (reducing the supply of polluting products). The equilibrium quantity point should fall closer to the socially optimal level. Although regulations provide greater certainty, and strong incentives to meet the regulatory standards, such policies typically provide little or no incentive to reduce pollution below the standard, regardless of how low the cost to do so. Different from direct regulations, voluntary regulations are also implemented to mitigate emissions, but these measures have weak enforceability.

2.2.2 Carbon pricing and emissions mitigation

The relationship between economic growth and emissions has been a longstanding wide concern. Emissions are negative externalities caused by economic agents through the process of combusting fossil fuels and consuming goods or services. Although the government traditionally has relied on regulatory approaches such as emission standards, reporting requirements and emission licensing, etc., on mitigating emissions because of greater certainty, this measure has some disadvantages such as direct regulations requiring a large amount of information and high administration costs, and voluntary regulations having weak enforceability and transparency. Recently, market-based solutions have become widespread in curbing environmental externalities such as carbon emissions because of their advantages, such as reducing costs, stimulating technological innovation, and not requiring a great deal of information.

Currently, carbon pricing initiatives are the most popular market-based solution and play an important role in mitigating emissions in many countries. Since the early1990s, carbon pricing took off internationally with the introduction of flexibility mechanisms under the Kyoto Protocol. The basis for international recognition of cooperative carbon pricing approaches and the important role of carbon pricing was mentioned in Article 6 of the Paris Agreement and Decision 1 of COP 21 (Adoption of the Paris Agreement). Until 2022, carbon pricing has been implemented/scheduled in 71 jurisdictions around the world (including 37 carbon taxes and 34 ETSs) to mitigate emissions such as Ireland, Australia, Chile, and Japan (World Bank, 2022).

Carbon pricing is a mechanism that captures the costs of emissions, ties them to their sources by putting a price on the emissions emitted, and shifts the responsibility for these costs to those who generate the emissions. Instead of regulating exactly where and how emissions should be reduced, carbon pricing gives emitters the signal to reach the flexible and least-cost ways to lower their costs for emissions. Carbon pricing can touch all economic agents and affect their behaviors, therefore mobilizing the resources required for low-carbon economic growth.

Carbon pricing can take various forms but there are two main forms including (1) carbon tax and (2) emissions trading system (ETS). Under ETS, by setting the amount of emissions produced, the government issues carbon emissions permits (free of charge or auction). These permits can be traded, and emitters can choose between implementing internal abatement measures or acquiring emission units in the carbon market to comply with their emission targets, depending on the relative costs of these options. Therefore, an ETS establishes a market price for carbon emissions based on the supply and demand for permits. A carbon tax puts a direct price on emissions. As a result, carbon emissions reduction depends on how much emitters change their behavior in response to the tax.

While ETS provides certainty about emissions reductions with fluctuating prices in the market, a carbon tax offers certainty about the price with less certainty about emissions reduction. When designing a carbon pricing system, policymakers face choices among carbon taxes, ETS, and a hybrid system. There are several factors considered such as effects on the economy and environment, administration costs, price levels, coverages, relation to other mitigation instruments, use of revenues, competitiveness, political aspects, and coordination.

In theory, although the approaches differ, both a carbon tax and ETS can achieve the same result. However, in reality with uncertainty, carbon tax and ETS have different costs and effects on the economy and environment. Some arguments favor carbon taxes. First, this solution can provide certainty over future emissions prices, which supports firms' investment strategies. Secondly, all countries have tax collection systems, such that carbon taxes can take advantage of being integrated into such systems and reduce administration costs (Metcalf, 2021). In addition, revenues from carbon taxes can usually accrue to finance ministry for general purposes or redistribution to mitigate the negative effects of carbon taxes on the economy or promote positive impacts on the environment. Conversely, carbon taxes can politically challenge and face backlash from affected firms and citizens. In addition, the carbon tax has uncertainty with emissions reduction target. Carbon tax (carbon price) needs to be estimated and adjusted periodically to align with emissions goals. ETS has advantages but it also suffers from some drawbacks. ETS provides a solution with more certainty in emissions reduction targets. In addition, this mechanism is readily accommodated linking individual ETSs into a regional and global carbon market to improve the cost-effectiveness of mitigation among countries through scaling up. Moreover, carbon prices are not set directly by politicians, they are decided by the market. Therefore, alignment of prices with targets is automatic if emissions caps are consistent with mitigation goals. In contrast, ETS requires an entirely new administrative structure to set up and develop rules for the markets, which is costly. Price volatility under ETS can be problematic for firms in making long-term projects, unstable prices could push firms in higher risks. Finally, ETS could cause the conflict with other policies of reducing emissions. A policy enacted to mitigate emissions in sectors covered by the ETS might not reduce overall emissions but could only decrease the prices in the program (Ian et al., 2022).

In addition, practical studies on the effects of carbon pricing show that carbon trading and carbon taxes play an essential role in tackling carbon emissions (e.g. Carl and Fedor, 2016; Jiang et al., 2018). However, the emissions reduction levels and costs of ETS and carbon taxes vary obviously in reality (e.g. Wang et al., 2021; Zhou et al., 2019; Jia and Lin (2020); Antosiewicz et al., 2022). Policymakers overall will choose carbon pricing instruments depending on their national circumstances and their comprehensive strategy. An appropriate design of carbon pricing can promote behavior changes and mobilize valuable sources for reducing emissions. Therefore, studies on carbon pricing effects for each country are necessary for assisting carbon pricing policy decisions.

An issue of concern in parallel with carbon pricing is the allocation of carbon pricing revenues. While carbon pricing is proven to reduce carbon emissions, it can also lead to some negative effects on economic agents and citizens. Revenue raised from carbon pricing can be used in general budgets and be earmarked for other purposes. Productive uses of revenues can promote large gains in economic-environmental efficiency. For example, to offset the negative effects on enterprises or households, the government can distribute revenue through various channels such as reducing income taxes or corporate income taxes and lump-sum transfers to households or firms. To boost the emissions reduction targets, revenue can be earmarked for environmental investment such as technology improvement, subsidies for low carbon projects. Depending on overall economic conditions, policymakers would choose recycling policies combined with carbon pricing.

As discussed above, individual carbon emissions mitigation policies have merits and drawbacks (summary in Table 2.1). Therefore, currently, many countries choose policy mixes which are comprehensive policy packages including market-based solutions, recycling policies, and regulations to achieve their emissions targets. When multiple policies are adopted simultaneously, they can complement each other, then increasing efficacy. However, designing policy mixes must avoid conflict with one another or the detriments that their yield outweighs the benefits. In other words, policy mixes must aim to bolster each other, limit drawbacks, and maximize merits. To make policy packages executed smoothly, it is crucial to simulate their effects on all agents, and then choose the optimal combination.

Table 2.1. Comparative analyses of the mitigating policy measures

Carbon mitigation policies	Policy strengths	Policy weaknesses
Carbon tax	✓ Price certainty ✓ Administration is more straightforward ✓ Existing tax collection system can be utilized ✓ Compatible with overlapping instruments ✓ Revenues can be used for general purposes or recycled	➢ Emissions uncertain but tax rate can be periodically adjusted ➢ Can be politically challenging to implement new taxes, use of revenues ➢ Need to be estimated and adjusted periodically to align with emissions goals
ETS	✓ Certainty over emissions levels ✓ Alignment of prices with targets is automatic if emissions caps consistent with mitigation goals ✓ Can be connected with region/international emission market in the future	➢ Price volatility can be problematic for firms ➢ Require an entirely new administrative structure ➢ Overlapping instruments reduce emissions price without affecting emissions
Direct Regulations	✓ Enforceable by law	➢ Large amount of information required ➢ Does not stimulate technological innovation ➢ High administrative and oversight costs
Voluntary Regulations	✓ Less cost ✓ Peer organizations can apply pressure	➢ Enforceability is weak ➢ Transparency issues/ responsibility to explain could become problematic

Source: Adapted from Ian et al., *(2022) and Metcalf (2021)*

In summary, government actions are theoretically required in solving negative externalities from production. These actions improve economic efficiency by internalizing the cost of externalities such as emissions in the cost of production. Although each policy measure has advantages and disadvantages, typically, the optimal intervention depends on many factors such as the nature of externality, administration cost, and harmony with other policies, etc. As discussed above, in the case of carbon emissions in a single country, a carbon tax is often more suitable in terms of economic efficiency, administration cost, and harmony with other emissions reduction policies. In contrast, the ETSs are better when the countries/regions are interested in linking to the programs of other countries as linking can more easily equate the marginal costs of abatement across borders than can tax systems. In addition, market-based solutions can also be mixed with recycling revenue policies and regulations to enhance emission mitigation effects.

2.2.3 Carbon pricing revenue

Carbon pricing is not only a key tool to address climate change, but it is also an opportunity for substantially raising revenues in many countries. IMF (2019) estimated that with a carbon price of US$70/t$CO_2$eq could generate revenues of 1-3% of GDP for studied countries. World Bank (2019) showed that the revenues from carbon pricing in the world reached US$ 44.6 billion in 2018. The amount of revenue depends on the carbon price levels and sector coverages. Given carbon emissions reduction targets currently, carbon pricing revenues are forecast to continue their rapid growth. As carbon revenue grows, the aligned use of carbon revenues becomes increasingly important.

Carbon tax and ETS have different ways to create revenue. A carbon tax imposes on the carbon emissions of firms, then the government collects carbon tax from firms. On other the side, ETS can generate revenue through carbon permit auctions. The revenue is identified by the carbon permit price and the number of allowances sold. The government has many options to use this revenue. The overall impacts of carbon pricing vary substantially relying on how the carbon pricing revenue is used. As such, carbon revenue redistribution is a significant aspect of carbon pricing design. Carbon pricing should be considered comprehensively with the revenues used wisely.

There are several common uses of carbon revenues to achieve a wide range of objectives. For example, in the case of using revenues for the general budget, carbon revenues are allocated to the state budget without any specific indication of uses or specific targets. In this case, carbon revenue is for raising resource availability and supporting the economy. In many countries, especially developing countries, there is a lack of funds for critical investments, thus, these revenues can promote investment, job creation, etc. The challenge is that this use lacks clarity for the public about the impacts of carbon revenues on the environment. However, in practice, many countries use this way such as Chile, Finland, Iceland, Ireland, etc. (World Bank, 2017). Another option to use carbon revenue is recycling carbon revenue transferred to households through lump-sum transfers or income tax reductions. Under the carbon pricing policy, households might face higher prices and lower income which can reduce welfare. Therefore, carbon revenue would be used to reduce economic distortions caused by a carbon price. Recycling carbon revenue to households aims to reduce the negative impacts of the carbon pricing policy on households and improve welfare, allowing harnessing a "double dividend". In addition, other carbon revenue redistribution options with environmental targets can be considered including funding for green technology projects, climate investments, or subsidies for enterprises applying environment-friendly technology, and implementing renewable energy activities. Although the option of using carbon revenue directly for specific climate-related activities could lead to a double effect on climate change policy, the revenue use needs to be considered in light of the existing legal framework and situation of each country.

2.3 Vietnam's situation and efforts to mitigate GHG emissions

2.3.1 Vietnam context

Vietnam is a Southeast Asia country with a tropical monsoon climate. The country has climatic variations among the regions because of its long territory and diverse topography. In the northern areas, average temperatures are around 22–27.5°C in summer and 15–20°C in winter, the figures for the southern regions are 28–29°C in summer and 26–27°C in winter. The average temperatures among all regions tended to increase. Hutfilter et al. (2019) indicated that the extreme heat forecast for Vietnam is a higher than the world level.

The country has over 95 million inhabitants with steady population growth and structure. Vietnam witnessed a key political and economic transition in 1986, which shifted the country from a poor country to a lower middle-income country with a GDP per capita income of US$4163.5 in 2022.

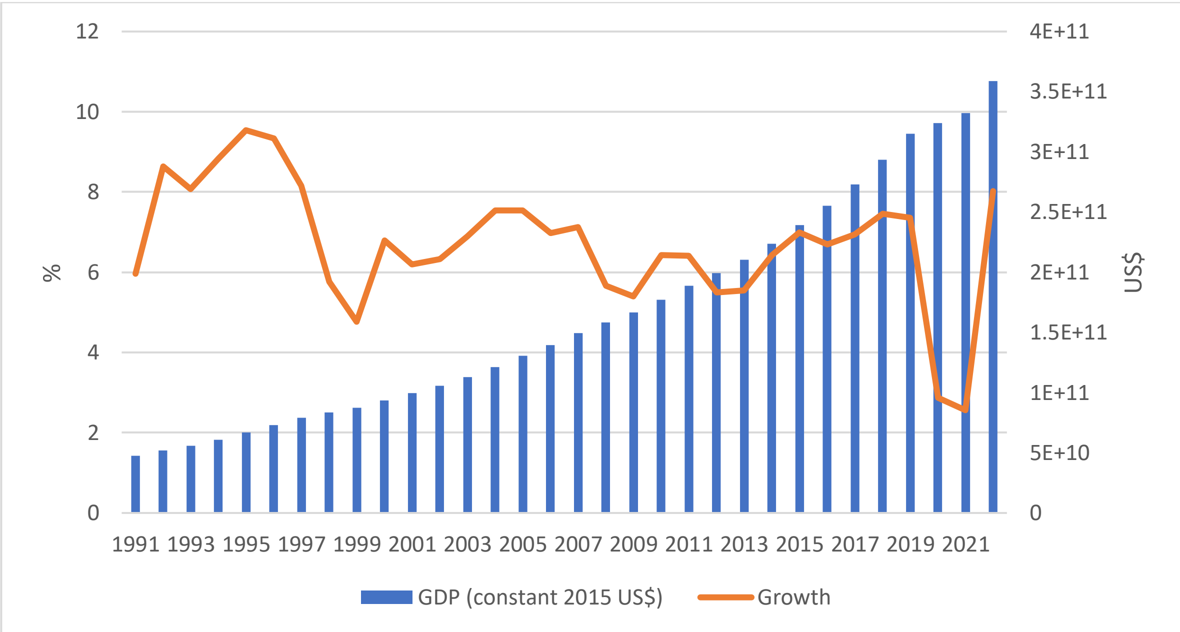


Figure 2.3. Economic growth in Vietnam

Source: World Bank

Vietnam has experienced a long period of impressive growth, with an average of 6.7%

in 1991-2022 (Figure 2.3)[1]. To achieve this growth, the country has focused on accumulating capital, labor, and exploring natural resources to expand the economy. However, in the Vietnam Socio-Economic Development Strategy 2021–2030, the country also recognizes that economic growth to date is unsustainable because it depends mainly on natural capital. Due to insufficient maintenance and the growing climate change risk, the country faces environmental and natural resource deterioration (World Bank, 2022).

Vietnam targets to be a high-income country in 2045. World Bank (2022) indicates that to achieve this target, Vietnam needs to change its development model by focusing on sustainable growth, in which economic growth goes together with environmental protection.

2.3.2 Greenhouse gas emissions in Vietnam

Vietnam is one of the world's very vulnerable countries ill-prepared to cope with extreme weather events. Climate change increases the existing substantial risks posed and adversely impacts human life and the economy. Without effective mitigation and adaptation policies, climate change would increasingly hamper the economy and undermine growth.

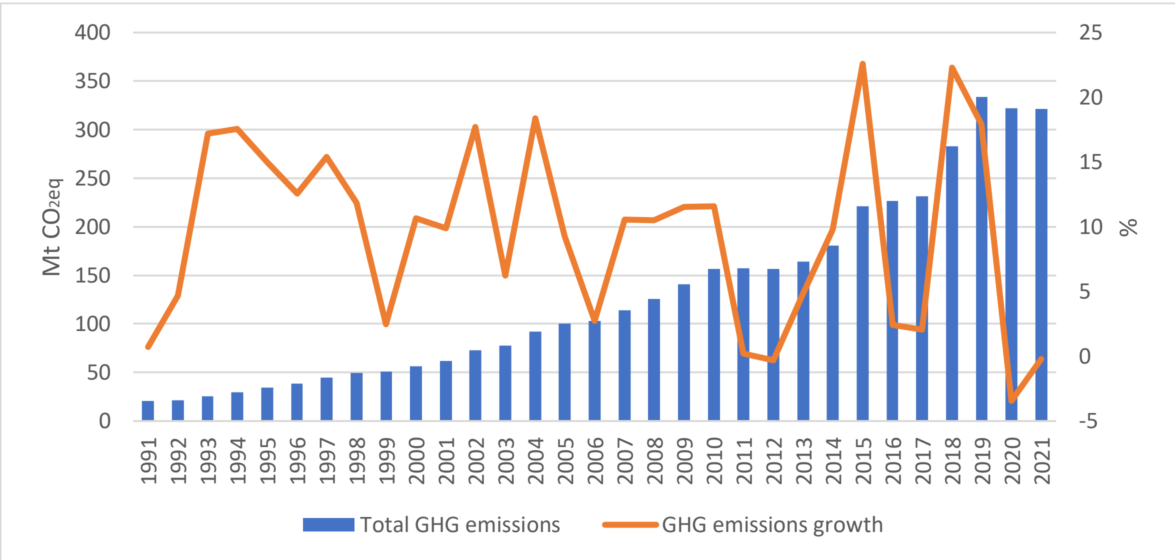


Figure 2.4. Total GHG Emissions in Vietnam

Source: Emissions Database for Global Atmospheric Research (EDGAR)

[1] The economic growth dropped in 2020-2021 due to Covid-19 and then recovered in 2022.

As mentioned above, rising emissions are the main reason causing climate change. The rapid economic growth with the expansion economic development model over 30 years has been supported by a coal-dependent energy supply causing the increase in carbon emissions. Figure 2.4 shows that GHG emission measured in carbon dioxide equivalents (CO_2eq) have increased continuously. During the period of 1991-2021, total carbon emissions have increased more than fifteen times from 20.6 $MtCO_2eq$ in 1991 to 321.4 $MtCO_2eq$ in 2021. Vietnam has one of the most carbon emissions-intensive economies in ASEAN (measured as emissions per unit of GDP) (see Appendix 2.1). In 2016, the electricity generation sector was the biggest contributor, accounting for 35% of emissions, followed by the manufacturing sector with 30%. The ratio of carbon emissions by sectors are demonstrated in Figure 2.5.

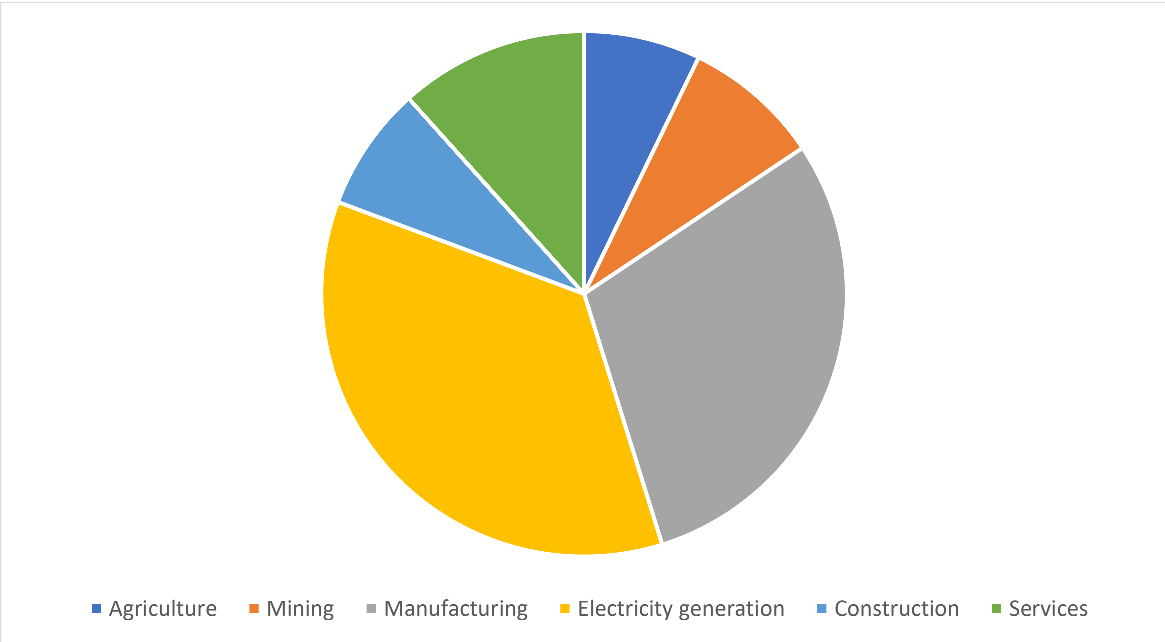


Figure 2.5. Vietnam GHG Emissions by sector in 2016

Source: Emissions Database for Global Atmospheric Research (EDGAR)

The electricity generation sector is the main contributor to emissions in Vietnam. However, as a developing country, the demand for electricity in production and consumption has increased dramatically with the electricity consumption per capita increasing fivefold from 2000 to 2014. Increasing electricity consumption leads to electricity generation also growing rapidly from 26.56 TWh in 2000 to 244.7 TWh in 2021 (Figure 2.6).

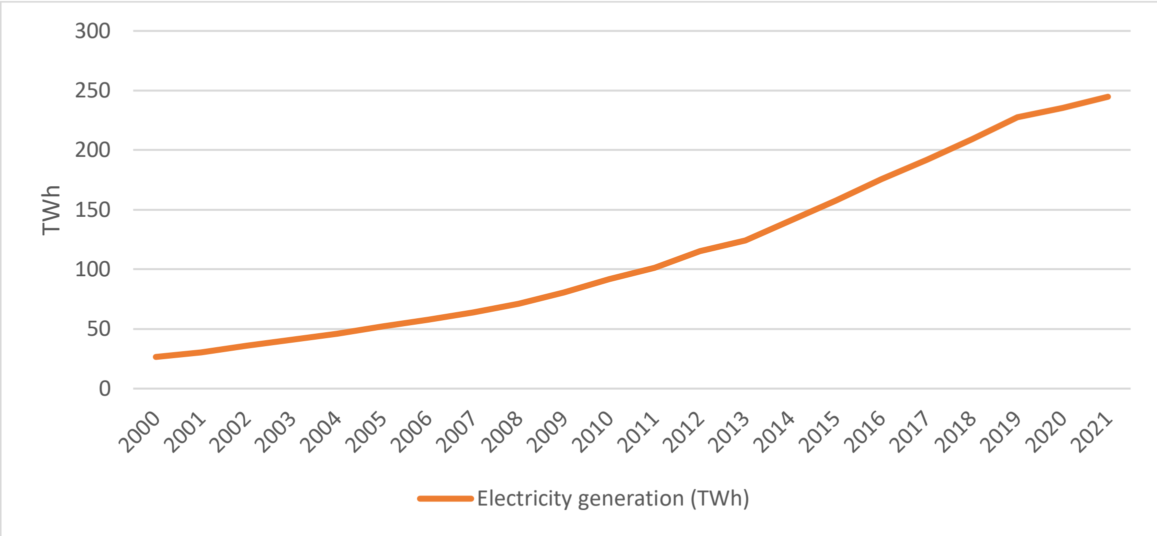


Figure 2.6. Electricity generation, 1990–2016

Source: Our World in Data based on BP Statistical Review of World Energy (2022)

Although according to UNFCCC 2019, fossil fuel accounts for 58% in total global GHG emissions. Currently, fossil fuels (coal, oil, and gas) are the dominant source for energy production in Vietnam. This is the reason for energy production, and especially electricity generation, is a major factor within emissions in Vietnam.

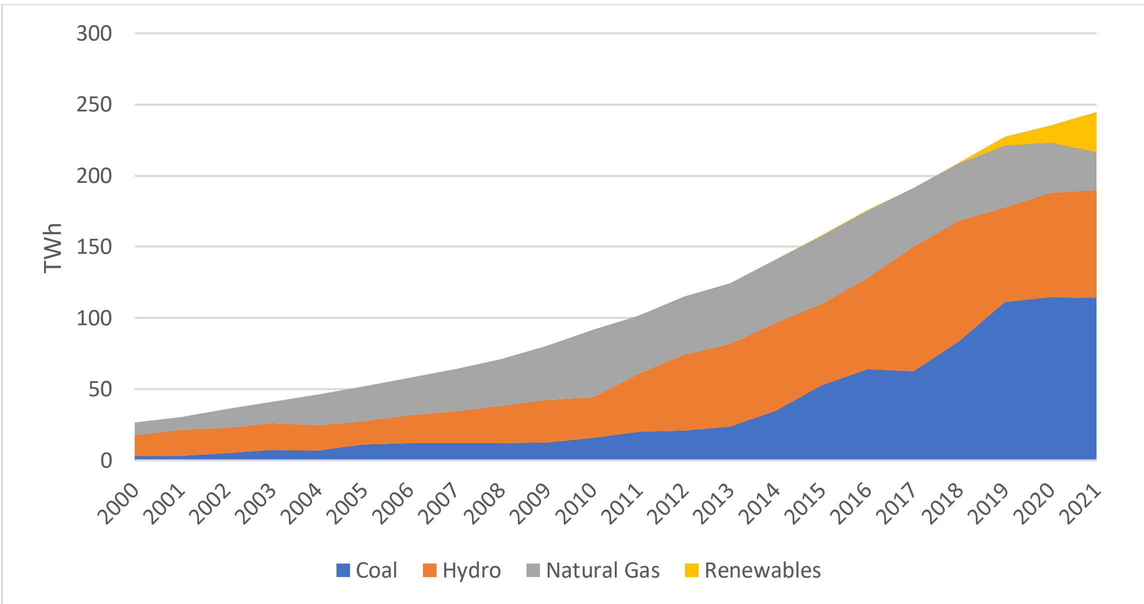


Figure 2.7. Electricity generation by source in Vietnam

Source: Our World in Data based on BP Statistical Review of World Energy (2022)

In Vietnam, the share of coal in electricity generation has increased substantially from 11.8% in 2000 to 46.6% in 2021. At the same time, the share of electricity produced from renewable sources (excluding hydro) has increased slightly from 0% in 2000 to 0.2% in 2015, remained very low until 2019, then increased to 11.6% in 2021. Hydropower plays an important role in electricity from renewable energy in the country, but the share of hydropower slightly decreases from 54.8% in 2000 to 31% in 2021 (Figure 2.7). It is noted that although the rate of renewable energy in electricity production has increased from 2019 to 2021, the electricity generation from renewable energy is unstable due to the lack of infrastructure such as transmission lines and storage systems.

2.3.2 Emissions reduction targets and efforts

Realizing the serious increase in GHG emissions and climate change risks, Vietnam has issued national action strategies to reduce GHG emissions. Recently, Vietnam's government has strong international commitments related to climate change, especially GHG emissions mitigation. In 2021, Vietnam's Prime Minister declared that Vietnam would reach net-zero GHG emissions by 2050. He also indicated “climate change response and the restoration of nature must become the highest priority in all development decisions”. These commitments surpass those mentioned before such as the targets in NDC.

Vietnam's targets in emissions mitigation have continued to be stringent. In Vietnam's NDC 2015, by 2030, Vietnam committed to reducing its GHG emissions by 8% in comparison with the BAU scenario with domestic resources. With international support, the commitment is by 25%. These figures were revised in NDC 2020 to 9% and 27% respectively. In the latest NDC updated in 2022, the figures are 15.8% and 43.5% respectively.

In addition, the targets of emissions mitigation and sustainable development are mentioned in national development strategies such as the Socio-Economic Development Strategy for the period of 2011-2020 and that for 2021 - 2030; the National Strategy for Climate

Change until 2050 (in 2011 and in 2022); The National Green Growth Strategy in 2012; The Target Program on Climate Change Response and Green Growth for the 2016-2020 period in 2017, and so on.

In the efforts to mitigate emissions and achieve the government commitments, Vietnam has issued many guidelines, policies, strategies, and plans, including: Orientations and strategies on socio-economic development associated with environmental protection that is the legal foundation for emissions reduction and response to climate change such as Resolution No. 24-NQ/TW on Proactive Response to Climate Change, Strengthening Natural Resource Management and Environmental Protection in 2013; Resolution No. 55-NQ/TW in 2020 on Strategic Orientations for Viet Nam's National Energy Development to 2030, with a vision to 2045; Resolution No.50/NQ-CP (2021) on Plan of the Government to Implement the Resolution of 13th Party Congress; Conclusion No. 56-KL/TW of the Politburo on Promoting Proactive Response to Climate Change, Strengthening Natural Resource Management and Environmental Protection (2019); The Socio-Economic Development Strategy for the period of 2021 - 2030, with which the government has already established a legal framework for green development with specific targets such as 9% emissions reduction, and 100% of enterprises meeting environmental standards; The National Strategy for Climate Change until 2050; The Vietnam Green Growth Strategy (2021); Orientations of Viet Nam's National Energy Development Strategy by 2030 with a vision to 2045 with a number of targets such as the rate of renewable energy sources around 15-20% by 2030, and 25-30% by 2045, the GHG emission from energy sectors reduction of 20% by 2045; Viet Nam Renewable Energy Development Strategy to 2030 with a vision to 2050.

The emissions mitigation-related laws and policies such as the Revised Environmental Protection Law (2020); the Forestry Law (2017); the Environmental Protection Tax; and the Law on Economical and Efficient Use of Energy (2011).

In addition, there are programs, plans and projects directly related to emissions reduction such as the Ministry of Foreign Affairs Climate Diplomacy Action Plan aiming to implement Viet Nam's commitments at COP26 in the period 2022-2025 (2022); Environmental Protection Plan for Industry and Trade in the period of 2025-2030 (2020); Action Program on Green Energy Transition and Reduction of Carbon and Methane Emissions of the Transportation Sector (2022); National Program on Economical and Efficient Use of Energy in the period of 2019-2030 (2019); Scheme on Sustainable Forest Management and Forest Certification (2018), and so on.

By revamping legal frameworks and strategies and implementing emissions reduction measures, Vietnam has a chance to achieve its emissions reduction targets. However, the existing instruments in Viet Nam are mainly regulations. There are some already market-based instruments such as environmental protection tax and environmental protection fees (regulated by the Law of Environment Protection Tax). The current environmental tax has considered the polluter pays principle, but it does not explicitly reflect the carbon price. Moreover, these policy measures have yet to be translated into significant changes. The GHG emission level in the country continues to increase dramatically. Therefore, more drastic measures need to be taken.

Carbon pricing was introduced formally in the Revised Environmental Protection Law in 2020, which is the first legislated step toward implementing carbon pricing in Vietnam. In 2022, Decision No. 01/2022/QD-TTg mandated a list of sectors and facilities that must conduct GHG inventories, including energy, transportation, construction, industrial processes, and agriculture-forestry sectors. Most recently, in Decree 06/2022/ND-CP on GHG reduction and Ozone Layer Protection, Vietnam targets to establish the Pilot ETS in 2025, officially launching the Emission Trading Scheme in 2028, and then connecting its carbon market with regional and international carbon markets. In this Decree, Vietnam also introduced general regulations related to carbon permits, auctions, transfers, borrowing, and payment of emission quotas. By 2025, Vietnam plans to establish an information and data system and develop guidelines for implementing the carbon market. Vietnam intends to allocate emission quotas through an auction although the details have not been stipulated.

In addition, a carbon tax is also considered along with ETS in implementing and adjusting the Revised Environmental Protection Law in 2020. As mentioned above, although Vietnam imposed the environmental tax following the Law of Environment Protection Tax, the implementation has limitations. Designing an appropriate carbon tax would assist Vietnam in achieving its emissions reduction targets. However, until now, implementing and designing a carbon tax is under consideration, and there are no specific guidance or detailed plans.

In summary, climate change, caused mainly by increasing emissions, has increasingly become serious in the world, which has a lot of negative impacts on human life and economic development. Vietnam is one of the countries heavily affected by climate change. In addition, after a long time with a purely economic development strategy, Vietnam is facing remarkably increased carbon emissions. Although Vietnam has introduced a lot of regulations on emission mitigation as well as changed its economic development strategy, these measures have not led to many changes in emissions. Carbon pricing was introduced and scheduled in the Law and Decrees. Vietnam expected these measures would be effective tools to support meeting its targets. However, until now, detailed plans for implementing carbon pricing have not been announced, and specific guidelines for implementing carbon pricing are still under consideration. Therefore, ex-ante impact assessments of carbon pricing in the country are necessary for assisting in designing and implementing carbon pricing in Vietnam.

Chapter 3: The Potential Impacts of a Carbon Tax in Vietnam

A carbon tax has been widely discussed and implemented in developed countries to mitigate carbon emissions, but this measure is still quite new in developing countries. Recently, the ambition of Vietnam's government in mitigating emissions has been mentioned in international commitments. To achieve these targets, the government is making efforts to seek and implement mitigation measures in the country. While carbon pricing was introduced in Vietnam, there is no study simulating the effects of a carbon tax in the country. This Chapter designs carbon tax scenarios for Vietnam based on the current carbon prices in literature and practice in different countries from the lowest to higher levels for matching with some countries with the same economic situation or the same region. The pure impacts of carbon tax are simulated by using a static CGE framework. A new flexible carbon tax mechanism is designed in this study to improve adequate coverage of emissions resources. The results show that the carbon tax would lead to a decrease in emissions, but it causes negative effects on the economy and welfare. With US\$1/tCO_2eq, US\$5/tCO_2eq, and US\$10/tCO_2eq, the country would be able to reduce its emission levels by 0.2% - 4.5% (0.47 - 9.90 MtCO_2eq) at the cost of GDP reduction of 0.11% - 2.32%. Moreover, fewer sectors covered by carbon tax would cause lighter economic and welfare loss but lower emissions reduction. At the sectoral level, the carbon tax would lead to a restructuring of the economy, with the production of mining and high carbon-intensive industries shrinking sharply while the outputs of other sectors slightly declining. Interestingly, the electricity generation sector, the exceptional carbon-intensive sector in Vietnam, would be the most affected and the main contributor to reducing emissions in Vietnam, accounting for 38.4% of total carbon emissions under the carbon tax policy.

3.1 Introduction

A carbon tax is an effective policy and has been implemented/scheduled in 30 countries around the world to mitigate emissions in nations such as Ireland, Australia, Chile, and Japan (World Bank, 2020). Although research on the carbon tax has been widely discussed in developed countries, this topic is still quite new in developing countries, especially Vietnam. In addition, previous studies tended to focus on carbon tax mechanisms for fossil fuels, which raises the concern of inadequate coverage of sectors. Recently, many countries have expanded the scope of carbon tax application not only to fossil fuels but also depending on the countries' context, sector coverages are also extended. Therefore, research on carbon taxes with a flexible mechanism of carbon tax coverage must be included to fill this gap.

In Vietnam, after a long period of pure economic growth policies, the country has achieved an impressive economic growth rate, with an annual average growth rate of 6.3% between 2000 and 2020. However, total GHG emissions in Vietnam have increased continuously from 50.3 $MtCO_2eq$ in 2000 to 321.9 $MtCO_2eq$ in 2020, with an annual average growth of 10%. Therefore, recently, the country has increasingly focused on environmental policies. The government has established ambitious targets which are enshrined in many recent international commitments. In 2022, in the updated NDC, Vietnam has identified GHG emissions mitigation targets, voluntarily committed to reducing GHG emissions by 15.8% through domestic financing and by 43.5% through international support by 2030 (compared to BAU[2]). In the 26^{th} session of the Conference of the Parties (COP26) to the UNFCCC in 2021, Vietnam pledged to reach its net-zero carbon emission target by 2050. Given these targets, Vietnam adopted the Revised Environmental Protection Law in 2020 and introduced carbon pricing in the country. A carbon tax has been considered under this Law. However, the specific structure and rules have not been established yet because there is a lack of research in this field.

Currently, the carbon tax has not yet been implemented in Vietnam, and thus any numerical data on the impact is not available, meaning an ex-post analysis is impossible to

[2] Business-As-Usual. Viet Nam's BAU scenario for GHG emissions was developed based on the assumption of economic growth in the absence of climate change policies.

conduct. Applying an ex-ante analysis to simulate the impact on the Vietnamese economy is possible and necessary for Vietnam in designing a carbon tax policy. This study will apply a static CGE model to examine the impact of a carbon tax on the economy and environment in Vietnam. Compared with previous models, the proposed model in this paper is a fairly standard CGE approach that tries to picture the economic system of Vietnam. In addition, a carbon tax on output will be modeled. This carbon tax mechanism is more flexible and direct when a carbon tax is based on direct emissions level by industry and the industry's carbon intensity. A carbon tax would not be applied solely to fossil fuels, with this model allowing policymakers to select industrial sectors that have to pay for their released emissions based on their carbon intensity. With this model, policymakers can create various simulations with different carbon prices and sector coverages. Such simulations would be useful for policymakers and government agents in Vietnam to be aware of the likely potential economywide impacts if the country followed such policies as well as relatively compare the impacts among policies. Based on such assessment, the government would adjust carbon prices, sector coverages and recycling policies in the next stages to achieve its targets. Thereby, the analysis in this Chapter supports to design and implement carbon tax policies in Vietnam. Moreover, this study also would contribute to the literature as an example of the adoption of the carbon tax in a developing country, serving as an example for countries with similar conditions.

Designing carbon tax scenarios at different carbon prices (US\$1/tCO_2eq, US\$5/tCO_2eq, US\$10/tCO_2eq) with different targeted industries, this study shows that higher carbon prices cause greater damage to GDP and welfare, but also better reductions in emissions. The country is able to reduce its emission levels by 0.2% - 4.5% (0.47 - 9.90 MtCO_2eq) at the cost of GDP reduction of 0.11% - 2.32%. In addition, a carbon tax only on the energy sectors results in milder economic and welfare damage but less emissions reduction than the case levying on all sectors. At the sectoral level, a carbon tax might cause sectoral restructuring: The production of mining and high carbon-intensive industries shrinks sharply while the outputs of other sectors slightly decline, even when a higher carbon tax is imposed on energy sectors and establishing revenue recycling policies. Interestingly, the electricity generation sector, the exceptional carbon-intensive sector in Vietnam, is the most affected and also is the main contributor to reducing emissions in Vietnam. Carbon emissions reduction in the electricity sector would decline by 4.9% (or 3.8 $MtCO_2$), accounting for 38.4% total carbon emissions reduction.

The rest of the Chapter is organized as follows. Section 3.2 shows a literature review of carbon tax studies. Section 3.3 details the model and data, this part also designs carbon tax scenarios. In section 3.4, the simulation results are discussed. The last section summarizes the results and discussions.

3.2 Literature Review

Initiatives to mitigate GHG emissions and climate change have received increasing attention in recent decades. Since the early 1990s, a carbon tax has been introduced and has become an important tool in reducing emissions in many countries. In recent years, research on impact assessments and carbon tax policy design has increased rapidly owing to the rising demand for implementing a carbon tax in many countries and subnational regions. CGE models dominate in research on simulating the effects of a carbon tax because of their advantages in describing the economy as well as assessing the economy-wide and sectoral impacts (World Bank, 2018).

Carbon tax effects on mitigating GHG emissions, reducing economic growth, and welfare are proved in many studies. The emissions reduction levels are different among countries, depending on economic characteristics and structures, tax rate, and tax base. For example, the emissions reduction level would be very small, from 0.11% to 0.27% in Japan with a carbon price of 3,000 yen/tCO_2eq (Kawase et al., 2003), whereas carbon emissions would decline sharply by around 12%-28% in Ireland, Australia, and Poland under the carbon tax policies (Wissema and Dellink, 2007; Meng et al., 2013; Antosiewicz et al., 2022). In China, Cao et al. (2021) compared carbon emissions reduction due to the carbon tax among models and found that carbon emission mitigation was shown in all cases. Wu et al. (2019) analyze the effects of carbon taxes ranging from RMB10 to RMB100/tCO_2eq (around US$1.6 to US$15.7/tCO_2eq) imposed on the use of fossil energy in China by employing a CGE model and found that a carbon tax rate of RMB70/tCO_2eq (around US$11/t$CO_2$eq) could lead to the Chinese reduction target achievement in 2020.

Regarding the adverse economic impacts of the carbon tax, the low carbon tax rate shows a modest negative effect on GDP, higher carbon tax causes more loss in GDP (e.g. Zhou et al., 2021; Meng et al., 2013; Cao et al., 2021; Wu et al., 2019; Li and Su, 2017). With carbon tax rates of RMB5-84-284/tCO_2 in 2020, 2030, and 2050, respectively, GDP would decrease about 0.2% to 0.8% in 2050, and with the double tax rate, GDP loss would be 0.5% to 1.8% (Cao et al., 2021). Wissema and Dellink (2007) indicated the slight negative effect of carbon tax on welfare measured by equivalent variation (EV). With the tax level of EUR 30/tCO_2eq, the welfare would decline by less than 1%. A strong decline (0.12-1.12%) in welfare due to carbon tax was found by Wu et al., 2019.

Carbon taxes vary widely from around US$1/t$CO_2$eq to US$130/tCO_2eq and tend to increase in many jurisdictions. While some countries adopted a fairly high carbon tax such as Switzerland (US$87/t$CO_2$eq), and Sweden (US$132/tCO_2eq), others have a fairly low carbon level such as Chile, India, Japan, and Portugal (a tax rate equivalent of around US$3 and US$6 per tCO_2eq) (World Bank, 2017). Some previous studies focus on looking at the possible impacts of different carbon prices such as Wissema and Dellink (2007) who examined the carbon energy tax of €10-15/tCO_2eq in Ireland; Antosiewicz et al. (2022) simulate impacts of carbon prices ranging from EUR 29.4 to 84.6/tCO_2eq in Poland; Wu et al. (2019) analyze the effects of carbon taxes ranging from RMB10 to RMB 100/tCO_2eq (around US$1.6 to US$15.7/tCO_2eq) imposed on the use of fossil energy in China. However, some studies only look at a specific carbon price as proposed by the government such as Meng et al. (2013) who focused on a carbon tax of A$23/t$CO_2$eq in Australia. Benavides et al. (2015) set up a carbon tax of 20 US$/t CO_2eq on the electricity generation sector in Chile; Nong (2020) shows the impacts of a carbon price of $9.15/t$CO_2$eq in South Africa; Li and Su (2017) analyzed the effects of a carbon tax of S$10/t$CO_2$eq (around US$7/tCO_2eq) in Singapore; Herbert (2017) analyzed the effects of a carbon tax of Rp. 100,000/tCO_2eq in Indonesia. As there is no agreement on the optimal carbon tax level in the literature, therefore, in ex-ante models carbon prices should be set at different levels, giving planners an idea of the different impacts that varied carbon prices would cause.

Identifying the sector coverage of a carbon tax can be based on the targeted sectors or subsectors, the types of GHG emissions, or the types of fuels. By far, most jurisdictions that have adopted a carbon tax have focused on the use of fossil fuels. Although a carbon tax tied to fossil fuels can be attractive from an administrative perspective and support cost-effectiveness, carbon taxes applied on direct emissions may be able to ensure broader coverage, especially where a large part of emissions are not fuel-based (World Bank, 2017). Most previous studies focus on carbon tax on fossil fuels (e.g. Wissema and Dellink, 2007; Wu et al., 2019; Guo et al., 2014). Even, global and national models mostly set up a mechanism to impose a carbon tax on fossil fuels (e.g. GTAP-E, GTAP-E-Power, C-GEM, ORANI-G, MONASH-Green, MMRF-Green). Some countries apply carbon tax based on their countries' context such as Chile, which focuses on a carbon tax on electricity; Australia applies the tax on electricity generation, industry, waste, and fugitive emissions; South Africa levies on all sectors involving fossil fuel combustion, industrial processes, product use, and fugitive emissions. Nong (2020) introduced new carbon mechanisms with the flexibility to select targeted sectors subject to a carbon tax in the global CGE model (GTAP-E-PowerS). In this model, the carbon tax on emissions would be tied to intermediate input consumptions, endowment factor usages, and output levels. However, the decomposition of the carbon tax on intermediate inputs, factor usages, and output levels can raise doubts about accuracy given that these coefficients are all quite complicated to estimate. A simpler way of determining a carbon tax is based on direct emissions level by industry and the industry's carbon intensity. By setting up in this way, the selection of the targeted industry remains flexible, while determining the tax rate for each industry is also more convenient to the government.

In Vietnam, carbon pricing is enshrined in the Revised Environmental Protection Law 2020. Prior to the new Law, there were only a few studies analyzing environmental policies such as ETS, and energy taxes in Vietnam. Nong et al. (2020) used GTAP_E model to consider the effects of the ETS in Vietnam, which is the first study about carbon pricing in Vietnam. The results show emissions from fossil fuels would decrease significantly under ETS. In addition, the negative effects of ETS on GDP, consumer price index (CPI), and welfare were also found. Coxhead et al. (2013) examined the effects of environmental taxes in Vietnam in 2012 and found that the tax would reduce GDP by 0.35%–0.63% under different assumptions, but the carbon emissions reduction could not be estimated in this paper. In 2018, when the increase of environmental tax rates was proposed, Nong (2018) indicated that the new taxes rates would lead the CPI to rise by 2.9% and real GDP to decline by 2.5%. However, these current environmental tax rates are not reflected the carbon price and are not strictly construed as taxes on carbon (Coxhead et al., 2013). UNDP et al. (2018) also confirmed that the current environmental taxation in Vietnam does not explicitly reflect the price of carbon although it has taken into account a “polluter pays” principle.

It can be seen that the carbon tax has been analyzed quite widely. However, previous studies have mainly been conducted for developed countries or in China, carbon tax studies in developing countries are limited. Other major concerns that remained controversial are the coverage of the targeted sectors in the countries. While previous studies mostly focus on carbon tax on fossil fuels, there is a lack of research on carbon tax levied on other industries. In Vietnam, despite the introduction of a carbon tax in the law, specific measures to enforce have not been enacted. Policymakers have no ex-ante analysis of such policy on the economy and environment because there are no studies simulating the impacts of the carbon tax on macro and sectoral levels at different carbon prices and different targeted sectors, which is a major obstacle to implementing a carbon tax in Vietnam. To fill this gap, this study will employ the static CGE model to simulate the pure and combined effects of the carbon tax on the economy and environment.

3.3 Methodology and Data

3.3.1 Methodology

There are some methodologies used in the carbon tax literature, but the CGE models dominate in analyzing all major issues related to carbon pricing. It is because of their advantage in reflecting the behavior of all economic agents in the model (World Bank, 2018). The CGE models integrate a number of accounts to provide a complete description of an economy including the income and expenditure accounts; a breakdown of industry by sector that reflects inter-sectoral input-output links; a production function for each sector that combines sector-specific inputs of capital, labour, and intermediate inputs; and a trade account that models the international linkages for each sector of the economy. Since the model connects every economic agent, it is capable of capturing changes in all variables representing the behavior of the economic agents when a variable is altered due to a new policy. In this study, a national static CGE model is employed. In addition, the environmental account with a carbon emissions indicator is also combined in the model. The appearance of the carbon tax will generate results of changing national account aggregates, industry output and prices, factor inputs and prices, trade flows as well as carbon emissions. The model consists of eighteen industries with four blocks of production, income & expenditure, environment, and market equilibrium. It is described in Figure 3.1.

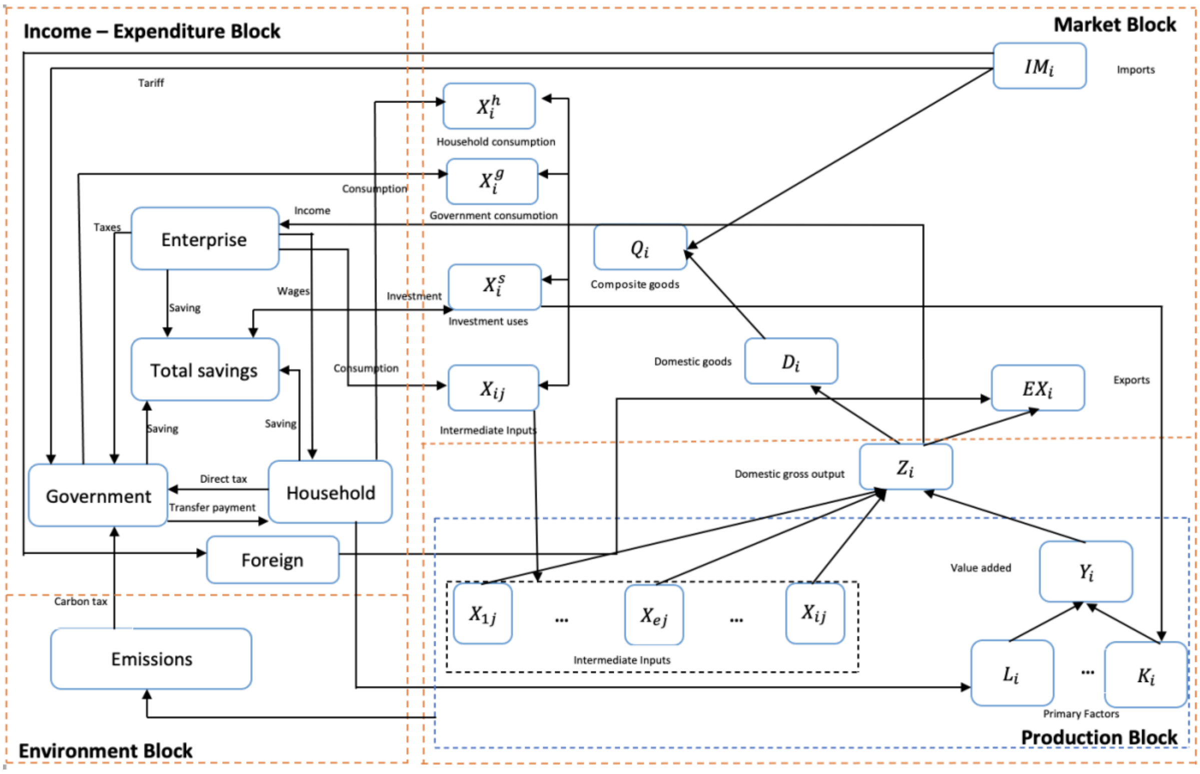


Figure 3.1. A National Static Computable General Equilibrium Model for Carbon Tax in Vietnam

Production block

In this block, multi-level nested production functions are adopted. In the first stage, each firm uses endowment factors (labor (L_i), capital ($K_{i,}$)) to produce its own composite goods and maximize its profit (π_i).

$$Max\ \pi_i = p_i^F F_i(K_{i,} L_i) - rK_i - wL_i$$

$$s.t. \qquad F_i(K_{i,} L_i) = K_i^{\beta_{K,i}} L_i^{\beta_{L,i}} \qquad i = 1, 2 \ldots n \qquad (1)$$

where F_i and p_i^F are the production of composite goods (i) and its price, respectively; $\beta_{K,i}$ and $\beta_{L,i}$ are share parameters in production function; n is the number of sectors in the model. In this model, the technology of endowment factor production is assumed to be a Cobb-Douglas production function, then $\beta_{K,i} + \beta_{L,i} = 1$. Under the zero-profit assumption, we have:

$$p_i^F F_i(K_{i,} L_i) = rK_i + wL_i \qquad (2)$$

where r and w are the rental cost and the wage rate of *i*, respectively.

In the second stage, intermediate inputs are combined with primary factors to produce domestic goods (Z_i). The profit maximization behavior is given by:

$$Max\ \pi_i = p_i^Z Z_i - (p_i^F F_i(K_{i,} L_i) + \sum_j p_j^X X_{i,j})$$

$$s.t. \qquad Z_i = \min(\frac{X_{i,j}}{ax_{i,j}}, \frac{F_i}{af_{i,j}}) \qquad i, j = 1, 2 \ldots n \qquad (3)$$

where Z_i and p_i^Z are domestic goods of i and its price; $X_{i,j}$ and p_j^X are intermediate goods of j used by firm i and its price; $ax_{i,j}$ is the intermediate input coefficients; and $af_{i,j}$ is composite good coefficients. The production function in equation (3) is the Leontief-type function. With the assumption of the zero-profit condition, we have:

$$p_i^Z Z_i = p_i^F F_i(K_{i,} L_i) + \sum_j p_j^X X_{i,j} \qquad (4)$$

In the third stage, the domestic goods (Z_i) is decomposed into exported goods (EX_i) and final domestic goods (D_i). The decomposition function of Z_i is assumed to follow the Cobb-Douglas technology. The profit-maximization problem of firms can be described as follows:

$$Max\ \pi_i = (p_i^{ex} EX_i + p_i^d D_i) - (1 + \pi_i^p) p_i^Z Z_i$$

$$s.t. \qquad Z_i = EX_i^{\kappa_i^{ex}} D_i^{\kappa_i^d} \qquad i = 1, 2 \ldots n \qquad (5)$$

where p_i^d and p_i^{ex} are the prices of final domestic goods and exported goods in terms of domestic currency, respectively; π_i^p is a tax rate imposed on the production of Z_i; κ_i^{ex} and κ_i^d are the ratios between exported goods and final domestic goods, $\kappa_i^{ex} + \kappa_i^d = 1$. By solving (5), we have:

$$EX_i = \frac{\kappa_i^{ex}(1+\pi_i^p) p_i^Z Z_i}{p_i^{ex}} \qquad (6a)$$

$$D_i = \frac{\kappa_i^d (1+\pi_i^p) p_i^Z Z_i}{p_i^d} \qquad i = 1, 2\ldots\text{n}. \qquad (6b)$$

In addition, each firm is assumed to use final domestic goods (D_i) and the imported goods (IM_i) to produce final consumption goods (Q_i). The profit maximization behavior is given by:

$$Max\ \pi_i = p_i^Q Q_i - (1+\pi_i^{im}) p_i^{im} IM_i - p_i^d D_i$$

$$s.t. \qquad Q_i = IM_i^{\gamma_i^{im}} D_i^{\gamma_i^d} \qquad i = 1,2\ldots\text{n} \qquad (7)$$

where γ_i^{im} and γ_i^d are the ratios between imported goods and final domestic goods ($\gamma_i^{im} + \gamma_i^d = 1$); $p_i^m$and p_i^d denote the prices of IM_i and D_i in domestic currency; π_i^{im} is import tax rates.

Demand functions are:

$$IM_i = \frac{\gamma_i^{im} p_i^Q Q_i}{(1+\pi_i^{im}) p_i^{im}} \qquad (8a)$$

$$D_i = \frac{\gamma_i^d p_i^Q Q_i}{p_i^d} \qquad (8b)$$

It is noted that all parameters in this model are calculated by using a SAM.

Income and expenditure block

Household

The income of households comes from provision of the labor and capital (also from government transfer payments). Households use their own income in consumption following the utility maximization principle. The household expenditure on goods/services (X_i) and income tax (T^f) and the rest is for savings (S^f). Their behavior is shown in the following equation:

$$Max\ U(X_i) = \prod_i X_i^{\alpha_i}$$

$$s.t.\ \sum_i p_i^Q X_i = F - T^f - S^f = (1-\pi^f)(\sum_i r_i K_i + \sum_i w_i L_i) - S^f \qquad (9)$$

where $U(X_i)$: household utility; α_i: share parameters in utility function, $\sum_i \alpha_i = 1$, the values of α_i are calculated from SAM ; F denotes household disposable income and is given by $F = \sum_i r_i K_i + \sum_i w_i L_i$; π^f is the income tax rate.

Government

The government is assumed to impose an income tax on households, a production tax on production, and an import tax on imports. The budget constraint of the government:

$$\sum_i p_i^Q X_i^g + S^g = T^f + T^p + T^{im} = \pi^f(r\bar{K} + w\bar{L}) + \sum_i \pi_i^p p_i^Z Z_i + \sum_i \pi_i^{im} p_i^{im} IM_i \qquad (10)$$

where X_i^g denotes government consumption of final goods i; T^f, T^p, T^{im} are the total amount of income tax, production tax, and import tax, respectively; S^g is government saving.

Environment block

In the environment account, the total emissions (EM_i) by sector are integrated. The carbon tax levies on emissions released from production. The carbon tax on emissions tied to output levels is calculated from the carbon price on emissions released by industry *i.* The total carbon tax revenue is:

$$T_i^{EM} = cpEM_i \qquad (11)$$

where T_i^{EM} is the carbon tax revenue from sector i; cp = carbon price. EM_i is total carbon emissions of sector *i*.

The carbon tax rate is:

$$\pi_i^{EM} = \frac{T_i^{EM}}{p_i^Z Z_i} \qquad (12)$$

where π_i^{EM} is tax rate imposed on the emissions released from sector *i*. Different from previous studies, this mechanism allows imposing a carbon tax on industries more flexibly instead of fixing carbon tax on fossil fuel commodities. The carbon tax rate also reflects more accurately the principle of higher taxation for carbon-intensive industries, and lower taxation for less carbon-intensive industries. In addition, taxing output will more fully capture the emissions released from the production processes of industries because emissions come not only from combusting fossil fuels but also from other activities such as emissions from using land in agricultural production, and emissions from using chemicals.

Market block

The market clearing condition of goods when demand meets supply in all markets is expressed by:

$$Q_i = X_i + X_i^g + X_i^S + \sum_j X_{i,j} \qquad (13)$$

Savings/ Investment

This model assumes that the investment equals the whole savings:

$$\sum_i p_i^Q X_i^S = S^f + S^g + S^{fr} \qquad (14)$$

where X_i^S is the investment in sector i.

Foreign sector

The foreign trade balance is given by:

$$\sum_i p_i^{w,ex} EX_i + S^{fr} = \sum_i p_i^{w,im} IM_i \qquad (15)$$

where $p_i^{w,ex}$ and $p_i^{w,im}$ are the prices of export goods and import goods in foreign currency (world prices), then we have:

$$p_i^{im} = \varepsilon p_i^{w,im} \qquad (16a)$$

$$p_i^{ex} = \varepsilon p_i^{w,ex} \qquad (16b)$$

S^{fr} is the foreign savings or deficits in the current account.

3.3.2 Data and Scenarios

Based on the latest Input – Output table of Vietnam in 2016, this paper constructs a SAM 2016 to describe the real Vietnamese economy. This study also aggregated 164 sectors into 18 sectors (Table 3.1). Regarding sector-level emissions, the data is collected from the EORA database for the year 2016. In this database, the GHG satellite accounts include GHG emissions data from three sources including Emission Database for Global Atmospheric Research

(EDGAR), Carbon Dioxide Information Analysis Center (CDIAC), and the PRIMAP. In this paper, GHG emissions measured in carbon dioxide equivalent from EDGAR are used due to the total emissions from this source being closer to emissions from the national GHG inventories of Vietnam in the Biennial Update Report (BUR) of Vietnam.

Table 3.1. Aggregate sectors

Aggregate Sector		
1. Agriculture (Agr)	7. Textile and leather (Texlea)	13. Machinery (Machn)
2. Coal mining (Coal)	8. Wood products (Wood)	14. Other manufacturing (Oth Manf)
3. Crude oil (CrO)	9. Petroleum products (Petr)	15. Electricity generation (Elec)
4. Natural gas ((NaG)	10. Chemicals (Chems)	16. Construction (Cons)
5. Other mining (Oth Min)	11. Mineral (Miner)	17. Transportation (Trans)
6. Food and tobacco (FoTo)	12. Metal (Metal)	18. Other services (Serv)

Note: Energy sectors include Coal mining, Crude oil, Natural gas, Other mining, Petroleum products, Electricity generation.

Currently, there is no agreement or regulation on the carbon price for each country. While carbon prices are set very high in some countries such as Sweden and Switzerland (\$130/tCO_2eq), other countries imposed low carbon price levels such as Poland, Japan, Chile (<= \$5/tCO_2eq) (World Bank, 2022). In addition, the targeted industries taxed are also different. Most countries levy carbon tax on fossil fuels, while others choose specific sectors with high carbon intensity (Table 3.2). In South Africa, the carbon tax was introduced in 2019 with the first phase of the tax rate of \$10/tCO_2eq on all sectors. Singapore is applying carbon tax of US\$4/tCO_2eq on all facilities with annual GHG emissions of 25,000 tCO_2eq or more. Chile levies carbon tax on electricity sector. Meanwhile, other countries such as Sweden, Switzerland, Ireland impose carbon tax on fossil fuels.

Table 3.2. Carbon Price and Sector Coverage in some Countries

Country	*Carbon Price*	*Sector Coverage*
Sweden	US\$130/tCO_2eq	Purchase and sale of fossil fuels for heating and transport. Full/partial exemptions for EU ETS installations and diesel for agricultural vehicles and vehicles used in mining.
Switzerland	US\$130/tCO_2eq	Electricity and heat production. Exemption: Energy-intensive companies subject to international competition, large companies that are covered by the Swiss ETS, SMEs that make emissions reduction commitments.
Ireland	US\$ 37- 45/tCO_2eq	Auto fuels and all other fuels. Exemption: EU ETS sectors, agriculture, heavy oil and LPG (partial), high-efficiency CHP (partial).
Japan	US\$2/tCO_2eq	Purchase and sale of fossil fuels. Major exemptions: Agriculture; forestry; air, rail, and maritime transport.
Chile	US\$5/tCO_2eq	Turbines with capacity equal to or greater than 50 MW. Exemption: Thermal power plants fueled by biomass; smaller installations.
South Africa	US\$10/tCO_2eq	All sectors involving fossil fuel combustion, industrial processes, product use, and fugitive emissions. Exemptions: International flights and ships.
Singapore	US\$4/tCO_2eq	All facilities with annual GHG emissions of 25,000 tCO_2eq or more.

Source: Author Adapt from World Bank, 2017 & 2022

In addition, previous studies on this topic considered various scenarios in other countries. In China, the carbon prices proposed vary among previous studies such as Wu et al. (2018) who analyzed carbon prices from RMB 10-100/tCO_2eq (about US\$1.58 - US\$15.8/tCO_2eq) on fossil fuel sectors; Lu et al. (2010) considered carbon prices from RMB50-300/tCO_2eq (around

\$7-43/tCO_2eq) in China. Li and Su (2017) adopted the carbon tax of S\$10/tCO_2eq (about \$7.37/tCO_2eq) on energy, manufacturing, land, transport sectors for their study in Singapore. Based on the situation of Vietnam and the carbon prices in previous studies, this research analyses carbon prices of US\$1, US\$5, and US\$10/tCO_2eq. In addition, different from previous studies, this study not only considers carbon tax on energy sectors but also examines the carbon tax on all sectors (Table 3.3).

Table 3.3. The carbon tax scenarios in this study

Scenario	Sub_scenario	Carbon price (US\$/tCO_2eq)	Sector coverage
Scenario 1	(a)	1	All sectors
	(b)	5	All sectors
	(c)	10	All sectors
Scenario 2	(a)	1	Energy sectors
	(b)	5	Energy sectors
	(c)	10	Energy sectors

3.4 Simulation analysis and Discussions

3.4.1 Macro-economic and environmental impacts

A carbon tax policy would result in an increase of tax revenue, then changes in government consumption and investment. Consequently, the effects of the carbon tax would be mixed with the effects of secondary activities such as expanding government expenditure or government savings/investment. In this chapter, to analyze the pure effects of the carbon tax, the government expenditure and government savings/investment are assumed unchanged. In other words, the new revenue from the carbon tax would not come to the economy in the second loop. The results show that compared with the benchmark scenario (no carbon tax), imposing the carbon tax hinders the economy, and all macroeconomic indicators decrease. The decline in GDP ranges from 0.11% to 1.05% when the carbon price increases from US$1/t$CO_2$eq to US$10/tCO_2eq in case of imposing the carbon tax on energy sectors and expanding from 0.25% to 2.32% when imposing the carbon tax on all sectors. A decrease in overall consumption and investment is also found. Household consumption drops significantly with the highest level of 4.77% and the lowest level of 0.23% while investment reduces slightly from 0.082% to 1.35%. Exports decline slightly by around 0.04% and 0.85% depending on the carbon prices and sector coverages. Similarly, imports also decrease by around 0.11% and 2.29% because of the decrease in domestic production and income levels.

Table 3.4. Macro-economic and environmental impacts of carbon tax

	Scenario_1			**Scenario_2**		
	(a)	*(b)*	*(c)*	*(a)*	*(b)*	*(c)*
Carbon price (US$/t$CO_2$eq)	*1*	*5*	*10*	*1*	*5*	*10*
ECONOMIC (% CHANGE)						
GDP	-0.252	-1.237	-2.323	-0.116	-0.571	-1.048
Household consumption	-0.510	-2.476	-4.772	-0.227	-1.098	-2.104
Investment	-0.144	-0.701	-1.353	-0.082	-0.400	-0.768
Exports	-0.092	-0.445	-0.852	-0.042	-0.204	-0.389
Imports	-0.240	-1.151	-2.285	-0.108	-0.517	-1.045
WELFARE						
EV (Trillion VND)	-14.021	-68.107	-131.246	-6.232	-30.212	-57.864
EV/GDP (%)	-0.305	-1.496	-2.915	-0.135	-0.659	-1.268
ENVIRONMENT						
Carbon Emissions Reduction (MtCO_2eq)	-1.057	-5.138	-9.903	-0.466	-2.260	-4.330
Carbon Emissions Reduction (%)	-0.484	-2.35	-4.53	-0.213	-1.034	-1.98
PRICE (% CHANGE)						
Average Commodity Price	0.096	0.468	0.909	0.066	0.381	0.676

In terms of welfare, the changes in welfare in currency form are measured by a Hicksian equivalent variation (EV) represented in VND values and the percentage of GDP. The results show that EV decreases in all cases, ranging from VND 6.23 trillion to VND 131.25 trillion, accounting for 0.14% to 2.92% GDP (Table 3.4). EV drops higher when more sectors are levied by the carbon tax. In addition, higher carbon prices also lead to higher EV decline.

In terms of average commodity price, in general, pricing carbon emissions through carbon tax leads to increased production costs. As a result, the commodity prices increase. Higher carbon prices lead to higher increases in average commodity prices. In detail, with a carbon price of US$10/t$CO_2$eq, the average commodity price increases by 0.91% and 0.68% in Scenario_1 (c) and Scenario_2 (c), respectively while with a lower price of US$5/t$CO_2$eq, it increases by 0.47% and 0.38%. Sector coverage also impacts price level changes. Imposing a carbon tax on all sectors causes higher prices than levying a carbon tax on energy sectors. At US$10/t$CO_2$eq, the average commodity price increases by 0.91% if the carbon tax is imposed on all sectors and the figure is 0.68% if the carbon tax is only for energy sectors.

In terms of environmental impacts, carbon emissions also decline from 0.2% to 4.5% (from 0.47 to 9.90 MtCO_2eq), depending on carbon prices and sector coverage. As expected, higher carbon prices lead to more emissions reduction, but the trade-off is a negative effect on GDP and welfare which is also larger. These results are similar to previous studies (e.g. Zhou et al., 2021; Meng et al., 2013; Cao et al., 2021; Wu et al., 2018; Li and Su, 2017). The reduction in carbon emissions is moderate, at 0.48% and 0.21%, when the carbon price of US$1/t$CO_2$ applies to all sectors and to the energy sectors, respectively. But the reduction is higher, at 4.53% when the carbon price increases to US$10/t$CO_2$eq in all sectors.

Imposing the carbon tax on energy sectors leads to lower carbon emissions reduction than levying the carbon tax on all sectors. However, since fewer targeted sectors are selected, the economy is less negatively affected compared to the case of imposing the carbon tax on all sectors. With the carbon price of US$10/t$CO_2$eq, the carbon emissions level reduces by 4.5%, and GDP drops by 2.3% when the carbon tax is levied on all sectors, but carbon emissions reductions decrease to 1.98%, and GDP declines to 1.05% when the carbon tax is applied on energy sectors (Table 3.4). Nong (2020) had similar results, a carbon price of US$9.15/t$CO_2$eq imposed on all sectors in South Africa would lead to higher carbon emission mitigation and stronger adverse impacts on the economy and welfare than that imposed on fewer targeted sectors.

In general, with a very low carbon price of US$1/t$CO_2$eq and fewer sector coverages, the emissions reduction effect is very modest. Compared with the mitigation targets mentioned in Vietnam's NDC, the carbon reductions under the carbon tax in this study do not meet the targets. Even with the highest carbon price proposed in this study (US$10/t$CO_2$eq), carbon emissions reduction of only 4.53% is achieved, whereas in Vietnam's NDC, the mitigation targets are 15.8% and 43.5% by 2030 depending on supporting conditions. To achieve these goals, the carbon tax must be higher than US$10/t$CO_2$eq if the government only uses the carbon tax policy. However, along with that, the cost to the economy is also potentially significantly higher.

3.4.2 Sectoral impacts of carbon tax

At the sectoral level, the drop in output occurs in all sectors because of the increased costs under the carbon tax policy (Table 3.5). In particular, the electricity generation sector’s output declines significantly by 7.33% in Scenario_1 (c) and 5.87% in Scenario_2 (c). In Vietnam, electricity is the main energy source in production. Production shrinking leads to a rapid decrease in electricity demand. In addition, a larger output decline in agriculture and service sectors is found in Scenario_1 while the output decline of these sectors is significantly reduced in Scenario_2, which is due to these sectors being excluded from carbon tax in Scenario_2, and then emissions costs are reduced. Although the percentage change in output of manufacturing sectors is lower than others, the absolute change is considerably higher. The decline in electricity production results in a decrease in demands for some fossil fuels such as coal mining, crude oil, natural gas, and other mining, resulting in a decrease in these outputs.

Table 3.5. Percentage changes in output levels by sector

Sector	Scenario_1			Scenario_2		
	(a)	*(b)*	*(c)*	*(a)*	*(b)*	*(c)*
Agriculture	-0.165	-0.804	-1.552	-0.067	-0.323	-0.620
Coal mining	-0.114	-0.552	-1.057	-0.073	-0.356	-0.682
Crude oil	-0.213	-1.035	-1.997	-0.109	-0.529	-1.021
Natural gas	-0.218	-1.061	-2.042	-0.117	-0.571	-1.099
Other mining	-0.173	-0.844	-1.629	-0.086	-0.418	-0.806
Food and tobacco	-0.053	-0.259	-0.499	-0.022	-0.106	-0.203
Textile and leather	-0.148	-0.720	-1.390	-0.047	-0.229	-0.440
Wood products	-0.061	-0.296	-0.572	-0.025	-0.120	-0.229
Petroleum products	-0.042	-0.203	-0.391	-0.019	-0.092	-0.177
Chemicals	-0.084	-0.408	-0.788	-0.033	-0.161	-0.309
Mineral	-0.083	-0.404	-0.781	-0.034	-0.164	-0.314
Metal	-0.078	-0.378	-0.729	-0.033	-0.159	-0.305
Machinery	-0.054	-0.265	-0.510	-0.024	-0.118	-0.227
Other manufacturing	-0.092	-0.447	-0.861	-0.040	-0.192	-0.368
Electricity generation	-0.809	-3.867	-7.326	-0.643	-3.089	-5.878
Construction	-0.057	-0.277	-0.537	-0.024	-0.116	-0.222
Transportation	-0.141	-0.686	-1.323	-0.060	-0.293	-0.561
Other services	-0.207	-1.005	-1.939	-0.086	-0.418	-0.801

Electricity generation is also the main source of emissions because it still largely depends on fossil fuels. The share of electricity generated from renewable energy is minor. In detail, electricity generation from coal accounts for 36.4%, gas is 26.9% and renewables only 0.2%. Therefore, the decline of electricity output is the main driver of carbon emissions reduction. This sector significantly drops its emissions by 4.9% (or 3.8 $MtCO_2eq$), accounting for 38.4% total carbon emissions reduction in Scenario_1 (c) due to the decline in its output. It is noted that by levying a carbon tax on only energy industries (Scenario_2), the percentage change in emissions reduction of the coal mining sector is highest (3.73% in Scenario_2 (c)) (Table 3.6). It might be due to lower demand for high carbon-intensive energy sources when the electricity industry's production shrinks.

Table 3.6. Percentage changes in carbon emissions levels by sector

Sector	Scenario_1			Scenario_2		
	(a)	*(b)*	*(c)*	*(a)*	*(b)*	*(c)*
Agriculture	-0.507	-2.467	-4.758	-0.211	-1.023	-1.960
Coal mining	-0.669	-3.235	-6.190	-0.404	-1.955	-3.731
Crude oil	-0.482	-2.346	-4.522	-0.220	-1.072	-2.055
Natural gas	-0.565	-2.742	-5.276	-0.289	-1.405	-2.696
Other mining	-0.491	-2.392	-4.613	-0.224	-1.093	-2.096
Food and tobacco	-0.509	-2.477	-4.777	-0.215	-1.043	-1.999
Textile and leather	-0.610	-2.971	-5.736	-0.207	-1.005	-1.925
Wood products	-0.488	-2.372	-4.576	-0.201	-0.978	-1.874
Petroleum products	-0.505	-2.455	-4.732	-0.229	-1.113	-2.134
Chemicals	-0.498	-2.425	-4.681	-0.200	-0.972	-1.863
Mineral	-0.398	-1.938	-3.743	-0.167	-0.810	-1.553
Metal	-0.449	-2.184	-4.217	-0.196	-0.951	-1.824
Machinery	-0.390	-1.896	-3.655	-0.183	-0.889	-1.704
Other manufacturing	-0.477	-2.318	-4.466	-0.214	-1.037	-1.986
Electricity generation	-0.524	-2.545	-4.901	-0.241	-1.168	-2.236
Construction	-0.200	-0.971	-1.872	-0.103	-0.499	-0.958
Transportation	-0.490	-2.384	-4.598	-0.211	-1.024	-1.963
Other services	-0.441	-2.144	-4.134	-0.191	-0.927	-1.776

In general, when levying carbon tax on output, the carbon-intensive sectors such as the energy sectors would be burdened by relatively higher tax rates than other sectors. Their outputs also vary more drastically than other industries, resulting in more reduction in their carbon emissions. In addition, outputs of these sectors are an indispensable input for other industries. When the production of other industries declines, the demand for energy also decreases, leading to a sharper decline in the production of these industries as well as promoting larger carbon emissions reduction. Electricity generation has a huge contribution in mitigating carbon emissions, with around 38% in Scenario_1 and 40% in Scenario_2 of total emissions reductions. The result implies that the electricity generation sector can be a key in emissions mitigation policy. However, the electricity generation sector has economic wide effect, the higher carbon price on this sector would lead to a decrease in its outputs as well as other sector outputs. Therefore, instead of increasing carbon price on this sector, the government can focus on reducing the carbon intensity of this sector by improving its technology or developing electricity generation by renewable energy sources.

Table 3.7. Percentage changes in commodity price

	Scenario_1			Scenario_2		
Sector	*(a)*	*(b)*	*(c)*	*(a)*	*(b)*	*(c)*
Agriculture	0.131	0.637	1.225	0.059	0.288	0.552
Coal mining	0.041	0.189	0.335	0.009	0.979	0.472
Crude oil	0.040	0.188	0.346	0.055	0.328	0.808
Natural gas	0.195	0.942	1.805	0.090	0.436	0.828
Other mining	0.114	0.551	1.054	0.038	0.180	0.334
Food and tobacco	0.023	0.110	0.207	0.016	0.075	0.144
Textile and leather	0.104	0.502	0.960	0.045	0.219	0.419
Wood products	0.042	0.204	0.390	0.021	0.102	0.196
Petroleum products	0.021	0.102	0.196	0.009	0.044	0.084
Chemicals	0.049	0.237	0.455	0.022	0.108	0.207
Mineral	0.047	0.226	0.432	0.024	0.117	0.225
Metal	0.042	0.201	0.383	0.024	0.114	0.219
Machinery	0.017	0.078	0.145	0.016	0.077	0.147
Other manufacturing	0.074	0.358	0.684	0.040	0.195	0.373
Electricity generation	0.503	2.534	5.116	0.576	2.888	5.801
Construction	0.013	0.056	0.096	0.024	0.117	0.225
Transportation	0.108	0.523	1.009	0.047	0.230	0.440
Other services	0.163	0.790	1.519	0.075	0.364	0.698

In terms of price, the carbon tax leads to increased prices in all commodities (Table 3.7). The impact of the carbon tax on electricity prices is greatest. It can be explained due to its exceptional carbon intensity, electricity generation sector faces higher production costs when the carbon tax is introduced, and then firms transfer this additional cost into the product price. Comparing sector coverage scenarios, in general, the carbon tax on all sectors results in higher prices in all sectors, except electricity generation sector. Since demand for electricity in the case of imposing the carbon tax on the energy sectors declines less than in the case of carbon tax levying on all sectors. The reduction of outputs in the carbon tax on energy sectors is lower than that in the carbon tax on all sectors, which means that the demand for electricity is higher because electricity is the essential input for production.

3.5 Conclusions

The results show that carbon emission mitigation is promoted by the carbon tax, higher carbon prices lead to more emissions reduction. However, this policy also causes negative effects on GDP and welfare. The carbon emissions levels reduce by 0.2% - 4.5% (0.47 - 9.90 $MtCO_2eq$) while GDP drops by 0.11% - 2.31%. However, compared with the mitigation targets mentioned in Vietnam's NDC, these carbon emissions reduction levels are much lower. Imposing the carbon tax on all sectors is more effective in terms of reducing carbon emissions. However, the economy would face more drawbacks, compared to the case of imposing the carbon tax on energy sectors. By sector, the carbon tax results in shrinking production in mining and other high carbon-intensity manufacturing sectors. Especially, the electricity generation sector is the main source of carbon emissions change in Vietnam. In all scenarios, the change in electricity emissions significantly contributes (around 38-40%) to the total carbon emissions reduction.

Chapter 4: The Potential Impacts of a Carbon Emission Trading Scheme in Vietnam

The Chapter 3 examined the impacts of a carbon tax with different carbon prices and sector coverages and showed that it is hard for Vietnam to achieve its GHG emissions reduction targets in NDC with those carbon prices and coverages. This Chapter will be based on Vietnam's GHG emissions reduction targets in NDC and the emissions reduction level identified in Chapter 3 to design ETS scenarios and analyze the pure impacts of ETS on the environment and economy in Vietnam. By using a national static CGE model, the simulation results show that to achieve Vietnam's GHG emissions reduction targets of 9% and 15.8% in NDC, carbon prices are estimated at US$23.278/t$CO_2$eq and US$56.608/tCO_2eq respectively. With a target of 15.8% emissions reduction, the ETS considerably impacts the economy with a decrease in GDP of 3.694%. The country experiences much smaller impacts with a lower target of 9%. Compared with a carbon tax at the same emissions reduction of 4.5%, the impacts of ETS on GDP and welfare are less than that of the carbon tax. In all ETS scenarios, the electricity generation sector is the main factor in reducing carbon emissions, but its output is highly adversely affected. Compared with carbon tax, the sectoral effects of ETS are much more concentrated. This study suggests that a lower target at the first stage of ETS implementation is appropriate in Vietnam, which assists firms in restructuring their business to adapt to the new policy.

4.1 Introduction

Climate change caused by the increase in GHG emissions has been an attractive topic in recent years. One of the most effective tools in mitigation policies is carbon pricing. While a carbon tax results in an uncertain carbon emissions target, ETS comes up with certainty in the total amount of emissions reduction. Therefore, governments have been more interested in the

ETS to support their carbon emissions targets. By 2022, there were 34 countries/regions implementing ETSs worldwide (World Bank, 2022).

Vietnam is one of the countries with great ambition in carbon emissions mitigation. In COP26 to UNFCCC in 2021, Vietnam pledged to reach its net-zero carbon emission target by 2050. In addition, its targets in Vietnam's NDC are increasing significantly. In Vietnam's NDC updated 2020, Vietnam committed to reducing its carbon emissions by 9% by 2030 (compared to BAU) with domestic resources and by 27% by 2030 with international financial support. In NDC updated 2022, these targets were heightened to 15.8% and 43.5%, respectively. To achieve these targets, Vietnam is focusing its effort into finding an effective mitigation tool. In 2020, carbon pricing was formally introduced in Vietnam’s Revised Environmental Protection Law and the country planned to launch a pilot ETS in 2026 before a full ETS in 2028. However, research on ETS in Vietnam is still limited. Thus, this study will simulate the ETS impacts in Vietnam by employing a national static CGE model and provide a better understanding of ETS for supporting policymakers in properly designing an ETS in the country to achieve its targets in NDC. Secondly, by setting a scenario with the same emission target identified in the carbon tax scenario in Chapter 3, this chapter provides some comparison between ETS and carbon tax policies. In addition, although previous studies on ETS in developed countries such as the EU, Australia, South Korea, and major emitters like China have confirmed the role of ETS in reducing emissions as well as some adverse impacts on the economy and welfare (e.g. Tang et al., 2016; Lin & Jia, 2020; Meng et al., 2018; Nong et al., 2017; Kat et al., 2018; and Choi et al., 2017), research on ETS in developing countries has not been clear. This study will contribute an example of ETS in developing countries to the literature and assist ETS adoption in countries with similar situations.

Focusing on examining the impacts of ETS on the economy and environment in the case of achieving latest Vietnam’s NDC emissions reduction targets of 9% and 15.8% respectively, with the assumption of all sectors participating in the ETS market, the results show that carbon prices increase from US$23.278/t$CO_2$eq to US$56.608/tCO_2eq when the emissions target increases. Higher emissions reduction targets have more adverse impacts on the economy and welfare. With the emissions target of 15.8%, the economy is substantially affected by the ETS with a drop in GDP by 3.694%. These impacts are much lower when the emissions reduction target drops to 9%. In addition, compared with a carbon tax at the same emissions reduction of 4.5%, the impacts of ETS on GDP and welfare are less than that of the carbon tax. In terms of sectoral effects, the ETS policy would lead to a change in sectoral production, shifting from the high-carbon intensity sectors to the low-carbon intensity sectors. The electricity generation sector is the main driver in total carbon emissions reduction. However, its output declines at significant rates, which could cause obstacles in economic development. Compared with a carbon tax, the sectoral effects of ETS are much more concentrated. Therefore, the electricity output under the ETS policy is more negatively affected than in the case of the carbon tax.

The rest of the Chapter is structured as follows. Section 4.2 provides a literature review of ETS studies and a comparison between ETS and carbon tax. Section 4.3 describes the model and data; this part also designs ETS scenarios. In the next section, the simulation results are discussed. The last section summarizes the results and discussions.

4.2 Literature Review

Global climate change has been driving the research on carbon emissions mitigation. Carbon pricing is one of the most popular tools and has been used to mitigate carbon emissions in many countries/regions in the world. While the carbon tax is applied and scheduled in nations such as Ireland (Wissema & Dellink, 2007), Japan (Takeda and Toshi (2021), Australia (Meng et al., 2013; Nong et al., 2017), China (Zhou et al., 2021; Lu et al., 2010; Cao et al., 2021), and Chile (Benavente, 2016), an ETS has been also implemented in many countries and regions such as in the EU, China, South Korea, some provinces/states in Canada and the US

(World Bank, 2022), because of their advantages in establishing a carbon price through the market and linking carbon markets across national borders (Nong et al., 2020). Moreover, studies show that the linked ETS can raise the efficiency of international carbon emissions mitigation (Akin-Olçum et al., 2022; Alexeeva and Anger, 2016; Böhringer et al., 2021; Fujimori et al., 2016; Nong and Siriwardana, 2018).

In the context of increasing international cooperation, the ETS is likely to be introduced in more countries and regions, leading to studies on this topic widening rapidly. Previous literature mostly focused on major emitters or developed countries/regions such as the EU, China, and Australia (Babatunde et al., 2017; Nong et al., 2020). To examine the economy-wide effects of ETS on specific countries/regions, CGE models are mainly employed (An et al., 2023; Tang and Bao, 2016). CGE models could be the most appropriate method in analyzing impacts of carbon pricing policies because of their advantage in linking all agents in an economy and reflecting their behavior based on economic theory (Dixon and Jorgenson, 2013). When an ETS is introduced, the price of carbon emission will change. Consequently, it will disturb the current equilibrium and the economy will move to a new one in the CGE model. Then, all variables such as GDP, welfare, and emissions level in the model will change corresponding to new carbon prices and reflect the gains and losses under this policy.

Some authors tried to design a hypothetical global carbon market (Babiker et al. (2002), Fujimori et al. (2017), Qi et al. (2016)) while others paid special attention to the bilateral and multiregional ETS linkages such as a series of studies analyzing the EU Emissions Trading System (EU-ETS) (Creti et al., 2012; Aatola et al., 2013; Koch et al., 2014; Dellink et al., 2014; Brink et al., 2016); while Li et al. (2019) focused on China and the EU; Nong and Siriwardana (2015) focused on a linked ETS among the EU, Norway, Switzerland, New Zealand, South Korea, and Kazakhstan, and suggested a more effective linked ETS adding China, USA, and India. Nong and Siriwardana (2015) focused on a joint ETS between the EU and other countries such as Norway, New Zealand, China, USA. They found that the international ETS could lead to lower costs. Zhang et al. (2017) simulated the impacts of an ETS connection among developed countries/regions such as the EU, Australia, Japan, and China. They concluded that this connection would bring benefits to the countries that import carbon permits. Designing an international/regional ETS market requires highly coordinated individual ETS market coordination among nations.

For countries scheduling ETS, studies focused on designing national ETS and examining different effects of ETS in the country attract more attention from policymakers. Recently, many studies have been conducted on China's ETS because of the ETS's high potential for carbon emission mitigation. For example, Lin & Jia (2017), Lin & Jia (2019), Lin & Jia (2020), Jia & Lin (2020), and Li & Jia (2016) simulated different ETS scenarios for China considering fines, quotas, sector coverages, prices, and recycling policies. They also concluded that ETS is an effective tool in reducing carbon emissions, but different designs would lead to various results. Tang et al., (2016) studied the implementation of an ETS with various designs by employing a CGE model. They showed that the ETS is a cost-effective mitigation tool. With the carbon price around RMB36.82–39.61/MtCO_2eq (around US$5.12 – US$5.50/MtCO_2eq), China can achieve China's Copenhagen commitment although the authors also suggested that to avoid significant economic loss, ETS sub-policies should be implemented carefully. Weng et al. (2018) concluded that China's ETS needs a progressive carbon price floor of US$4 to US$12/CO_2eq to achieve its climate pledges with a 90% chance. For other countries, Meng et al. (2018) simulated the impacts of an ETS in Australia and found that such a policy would lead to a small decrease in GDP and consumption. Nong et al. (2017) developed a national dynamic CGE model to study the ETS impacts in Australia and showed that the carbon permit price must increase from A$4.1/t$CO_2$ to A$41.3/t$CO_2$ in 2030 to accomplish the country's target. Kat et al. (2018) employed a dynamic CGE model and analyzed ETS's impacts in Turkey. They showed that ETS would lead to the disappearance of the generation of coal-fired power by 2030. Choi et al. (2017) analyzed South Korea's ETS and indicated that although ETS is a relatively powerful tool for reducing emissions, it causes slightly unfavorable impacts on the economy.

In addition, research on the comparison between carbon tax and ETS is conducted. Barragán-Beaud et al. (2018) and Hu et al. (2020) analyzed ETS and carbon tax in terms of political feasibility and concluded that ETS is the most preferred tool in Mexico and China. Jia and Lin (2020) compared the mitigation effects of the carbon tax and ETS by setting the same economic level and found that the carbon tax is slightly greater than ETS in the long run. Bi et al. (2019) found that the ETS policy would lead to lower GDP reduction in the short term than carbon tax. Li and Jia (2017) also found that the adverse impact of carbon tax on GDP is greater than that of ETS. Although previous studies compared these two policies, there remains controversy about which is better.

Existing studies consistently confirm that ETSs play an important role in reducing carbon emissions but their emissions reduction cost and incentive effects vary considerably in reality. Therefore, the main foci are the estimation of carbon prices and ETS impacts on the economy to achieve the country's goals as well as propose effective ETS mechanisms for the targeted country. In addition, comparisons between ETS and a carbon tax are also considered when designing carbon pricing in the country.

Although the ETS has been widely discussed, studies focusing on developing countries that are considering/scheduling implementation of an ETS are quite limited. For example, in ASEAN, the ETS is being considered by the governments of Indonesia, Malaysia, Thailand, and Vietnam, but only a few studies analyzed the ETS in these countries. Nguyen et al. (2023) used a global CGE model to analyze the impacts of a regional ETS in ASEAN. They indicated that the regional market results in smaller costs for permit-buyers (Indonesia), but not for permit-seller (such as Vietnam and Thailand), compared to their national ETSs.

In Vietnam, carbon pricing was introduced in the Revised Environmental Protection Law in 2020. In 2022, in Decree No. 06/2022/ND-CP on Mitigation of GHG Emissions and Protection of Ozone Layer, Vietnam outlines a roadmap for ETS implementation with a pilot ETS in 2026 before launching a full ETS in 2028 and set the provisions for developing a national ETS corresponding to Vietnam's NDC. Although the ETS is scheduled in Vietnam, the lack of studies on ETS in Vietnam causes difficulties in specifying ETS in the country. Until now, there is only one study examining the impacts of ETS in Vietnam. Nong et al. (2020) employed a global energy CGE model and showed that with a relatively high carbon price of \$109.32/tCO_2eq and a decrease of 4.57% in real GDP, Vietnam can achieve its target of reducing 8% emissions in the energy and transportation sectors and 20% in the agriculture sector in 2020 if only these sectors join in ETS market. The price and emissions reduction costs would be reduced significantly if all sectors participate in the market. However, the emissions reduction targets set in this research are quite far from Vietnam's current NDC. In Vietnam's NDC updated 2020 and 2022, the unconditional emissions targets are adjusted to 9% and 15.8% while conditional emissions targets are 27% and 43.5%.

In this context, this study aims to fill a gap in the literature by simulating ETS impacts with the target of achieving Vietnam's latest NDC. In addition, a comparison between ETS and carbon tax is also considered. Moreover, although a global CGE model has advantages in linking Vietnam with other economies, the national CGE model is fairly standard in describing the economic situation of Vietnam. Therefore, this study aims to show domestic policymakers more realistic and meaningful insights about the likely impacts on the economy of ETS, compared with a carbon tax in the country by developing a national CGE model for Vietnam. In terms of literature, this study is expected to enrich the literature on the ETS in developing countries where the ETS impacts have not been well understood.

4.3 Methodology and Data

4.3.1 Methodology

CGE models are ideally suited for analyzing the impact of new policies and have been widely used in analyzing ETS impacts. This model provides a complete picture of an economy with all economic agents. Therefore, when a variable is changed due to a new policy, other variables would be changed to reflect the economic agents' behaviors. This study develops a national static CGE model to examine the ETS impacts in Vietnam. The model consists of eighteen industries with four blocks of production, income & expenditure, environment, and market equilibrium, which are illustrated in Fig. 4.1.

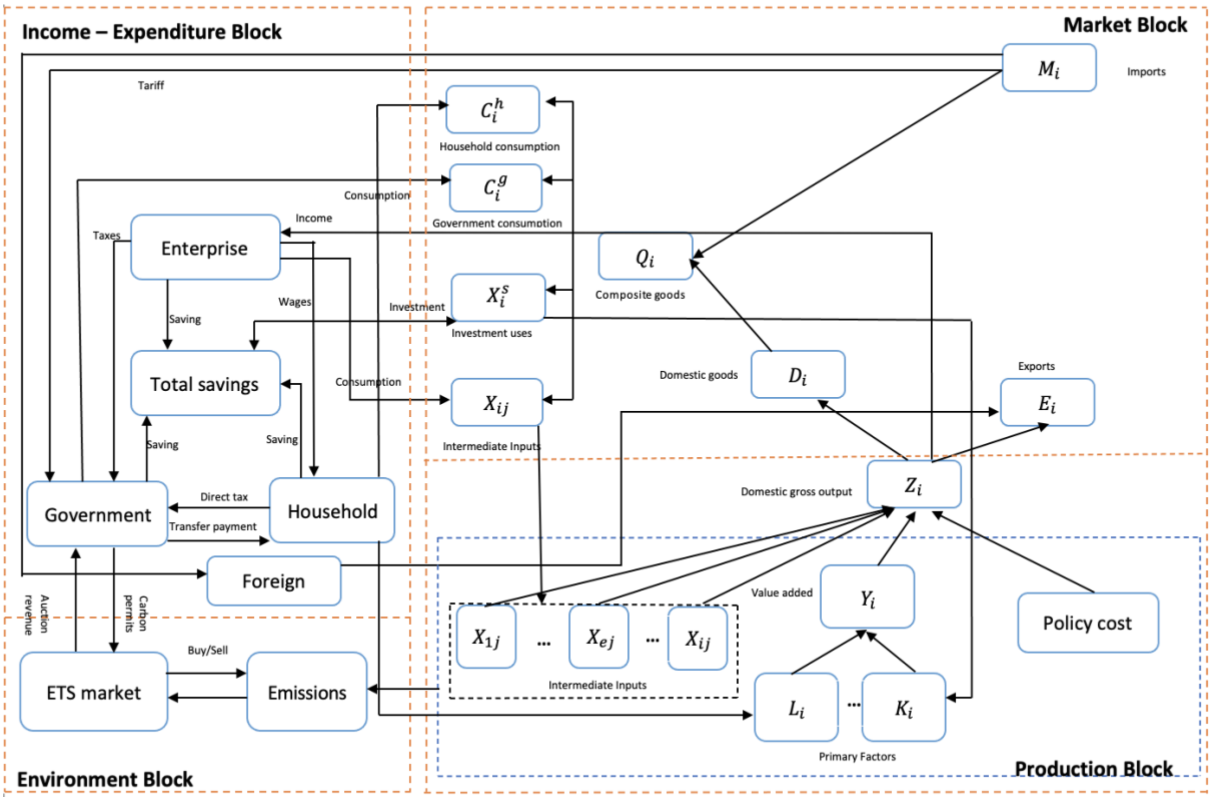


Figure 4.1. A National Static Computable General Equilibrium Model for ETS in Vietnam

Production block

This paper makes the model simple and easy to understand by using standard assumptions. In the production block, the enterprises use primary factors (labor (L) and capital (K)), intermediate input (X), and carbon emissions expense when introducing ETS following a Leontief function. The multi-level nested production functions are adopted.

In the first layer, firms use primary factors to produce their own composite goods and maximize their profit.

$$Max\ \pi_i = p_i^F Y_i(K_{i,} L_i) - rK_i - wL_i$$

$$s.t. \qquad Y_i(K_{i,} L_i) = K_i^{\beta_{K,i}} L_i^{\beta_{L,i}} \qquad i = 1, 2 \ldots n \qquad (1)$$

where Y_i and p_i^Y are the production of composite goods (i) and its price (i), respectively; *n* is the number of sectors in the model. The primary factor production function is assumed to be a Cobb-Douglas production function, then $\beta_{K,i} + \beta_{L,i} = 1$. And, under the zero-profit assumption:

$$p_i^F Y_i(K_{i,} L_i) = rK_i + wL_i \qquad (2)$$

where *r* and *w* are the rental cost and the wage rate of i, respectively.

In the next level, domestic output (Z_i) is constituted by a Leontief function of its own good (Y_i), and intermediate input, and policy cost (carbon expense). The optimal behavior can be described such that:

$$Max\ \pi_i = p_i^Z Z_i - p_i^F Y_i(K_{i,} L_i) - \sum_j p_j^X X_{i,j} - PLC_i$$

$$s.t. \qquad Z_i = \min(\frac{X_{i,j}}{ax_{i,j}}, \frac{y_i}{ay_{i,j}}) \qquad i, j = 1, 2 \ldots n \qquad (3)$$

where Z_i and p_i^Z are domestic goods of i and its price; $X_{i,j}$ and p_j^X are intermediate goods of j used by firm (*i*) and its price (i), respectively; $ax_{i,j}$ is the amount of intermediate good *j* used for producing one unit of a final domestic consumption good produced by firm *i*; and $ay_{i,j}$ is composite good coefficients; PLC_i is the carbon expense or policy cost. The production function in equation (3) is the Leontief-type function. With the assumption of the zero-profit condition, we have:

$$p_i^Z Z_i = p_i^F Y_i(K_{i,} L_i) + \sum_j p_j^X X_{i,j} + PLC_i \qquad i, j = 1, 2 \ldots n \qquad (4)$$

In the third stage, the domestic goods (Z_i) are decomposed into exported goods (E_i) and final domestic goods (D_i). The decomposition function of Z_i is assumed to follow the Cobb-Douglas function:

$$Max\ \pi_i = (p_i^e E_i + p_i^d D_i) - (1 + \pi_i^p) p_i^Z Z_i$$

$$s.t. \qquad Z_i = E_i^{\kappa_i^e} D_i^{\kappa_i^d} \qquad i = 1, 2 \ldots n \qquad (5)$$

where p_i^d and p_i^e are the prices of final domestic goods and exported goods in domestic currency, respectively; π_i^p is a tax rate imposed on the production of Z_i; κ_i^e and κ_i^d are the ratios between exported goods and final domestic goods, $\kappa_i^e + \kappa_i^d = 1$. Then, we have:

$$E_i = \frac{\kappa_i^e (1+\pi_i^p) p_i^Z Z_i}{p_i^e} \qquad (6a)$$

$$D_i = \frac{\kappa_i^d (1+\pi_i^p) p_i^Z Z_i}{p_i^d} \qquad i = 1, 2 \ldots n. \qquad (6b)$$

In addition, final consumption goods (Q_i) is assumed to be combined by final domestic goods (D_i) and the imported goods (M_i). The profit maximization behavior is given by:

$$Max\ \pi_i = p_i^Q Q_i - (1 + \pi_i^m) p_i^m M_i - p_i^d D_i$$

$$s.t. \qquad Q_i = M_i^{\gamma_i^m} D_i^{\gamma_i^d} \qquad i = 1,2 \ldots n \qquad (7)$$

where γ_i^m and γ_i^d are the ratios between imported goods and final domestic goods ($\gamma_i^m + \gamma_i^d = 1$); $p_i^m$and p_i^d denote the prices of M_i and D_i in domestic currency; π_i^m is import tax rates. By solving (7), we have:

$$M_i = \frac{\gamma_i^m p_i^Q Q_i}{(1+\pi_i^m) p_i^m} \qquad (8a)$$

$$D_i = \frac{\gamma_i^d p_i^Q Q_i}{p_i^d} \qquad (8b)$$

All parameters in this model are estimated based on a SAM.

Income and expenditure block

Household

The income of households comes from remunerations from enterprises and transfer payments by the government. Households use their own income in consumption following the utility maximization principle. The household expenditure on goods/services (C_i) and income tax (T^h) and the rest is for savings (S^h). Their behavior is shown in the following equation:

$$Max\ U(C_i) = \prod_i C_i^{\alpha_i}$$

$$s.t. \sum_i p_i^Q C_i = Y - T^h - S^h = (1 - \pi^h)(\sum_i r_i K_i + \sum_i w_i L_i\ ) - S^h \qquad (9)$$

where $U(C_i)$: household utility; α_i: share parameters, $\sum_i \alpha_i = 1$, the values of α_i are calculated from SAM ; Y denotes household disposable income and is given by $Y = \sum_i r_i K_i + \sum_i w_i L_i$; $\pi^y$is the income tax rate.

Government

The government acquires revenues via direct tax, indirect tax, and tariff. These revenues are then used for consumption and saving:

$$\sum_i p_i^Q C_i^g + S^g = T^h + T^p + T^m = \pi^y(r\bar{K} + w\bar{L}) + \sum_i \pi_i^p p_i^Z Z_i + \sum_i \pi_i^m p_i^m M_i \qquad (10)$$

where C_i^g denotes government consumption of final goods i; T^h, T^p, T^m are the total amount of income tax, production tax, and import tax, respectively; S^g is government saving.

Environment block

In the environment account, the total carbon emissions (EMI_i) is assumed to be associated with production of Z_i and given by:

$$EMI_i = \gamma_i p_i^Z Z_i \qquad (11)$$

where γ_i is the carbon emission coefficient or carbon intensity of sector i. It is noted that different from previous studies, the carbon emissions released from the production processes of industries are calculated based on the output and carbon intensity by sector. Thus, it captures fully emissions generated by the sector because carbon emissions come not only from combusting fossil fuels but also from other activities such as emissions from using land in agricultural production, and emissions from using chemicals.

As long as sector i is covered by the ETS, the sector has carbon rights or carbon allowances, denoted by CR_i, set by the government. The government determines CR_i and sells them to sector *i*. The carbon allowances can be free of charge or auctioned to the firms. Denote the amount of free emission allowances to sector *i* by FA_i.

In this paper, the ETS market is assumed as a perfectly competitive market; thus, the carbon auction price is the same as the trading price of carbon emissions in the equilibrium state, denoted by p^t. If the sectors generate emissions more than their allowances, they can purchase additional carbon emission permits from other firms and vice versa. In other words, sectors under ETS can sell (buy) the emissions gap ($|EMI_i - CR_i|$) at the equilibrium in the ETS market, thus p^t is determined to satisfy the equilibrium condition of the ETS market such that:

$$\sum_i (EMI_i - CR_i) = 0 \qquad (12)$$

Where the equilibrium price is also assumed to satisfy:

$$0 < p^t < \infty \qquad (13)$$

Thus, the total cost to be covered in the ETS for sector *i* denoted by PLC_i is given by:

$$PLC_i = p^t(CR_i - FA_i) + p^t(EMI_i - CR_i) \qquad (14)$$

The revenue of the government from ETS is given by:

$$TT = \sum_i p^t(CR_i - FA_i) \qquad (15).$$

Market equilibrium block

The market clearing condition of goods is expressed by:

$$Q_i = C_i + C_i^g + X_i^S + \sum_j X_{i,j} \qquad (16)$$

Savings/ Investment

This model assumes that the investment equals the whole savings:

$$\sum_i p_i^Q X_i^S = S^h + S^g + S^f \qquad (17)$$

where X_i^S is the investment in sector i; S^f is the foreign savings or deficits in the current account.

Foreign sector

The foreign trade balance is given by:

$$\sum_i p_i^{w,e} E_i + S^f = \sum_i p_i^{w,m} M_i \qquad (18)$$

where $p_i^{w,e}$ and $p_i^{w,m}$ are the prices of export goods and import goods in foreign currency (world prices), then we have:

$$p_i^m = \varepsilon p_i^{w,m} \qquad (19a)$$

$$p_i^e = \varepsilon p_i^{w,e} \qquad (19b).$$

4.3.2 Data and Scenarios

SAM 2016 is constructed based on the latest Vietnam Input – Output table 2016. This study also aggregated 164 sectors into 18 sectors (see Table 3.1). The sector-level carbon emissions data is collected from the EORA database for the year 2016 (as described in Chapter 3).

In the outline of ETS implementation, Vietnam's government expects to allocate emission quotas through an auction. Therefore, in this paper, it is assumed that all emission allowances are auctioned and thus no free payment allocations. All sectors are assumed to participate in the ETS market. In addition, to examine the pure impacts of ETS, it is assumed that the ETS is implemented without any revenue recycling policies. It is because those recycling policies can impact the ETS results. It means that all revenue collected from the ETS is transferred to the government revenue, which might only be used for keeping government activity as in the baseline and generating a state budget surplus. As such, the impacts on the Vietnamese economy from the ETS only are estimated.

Table 4.1. The ETS scenarios in this study

Scenarios	Emissions reduction targets	Sector coverages	Auction allowances (%)	Free allowance rate (%)
Scenario_1	4.5%	All sectors	100	0
Scenario_2	9%	All sectors	100	0
Scenario_3	15.8%	All sectors	100	0

In Vietnam's NDC updated 2020, Vietnam targeted reducing its carbon emission by 9% by 2030 (compared to the BAU) with domestic resources and by 27% by 2030 with international financial support. In NDC updated 2022, these targets increased to 15.8% and 43.5% respectively. Based on these targets, this study suggests two ETS scenarios for Vietnam with 9% and 15.8% respectively of carbon emissions reductions. Because this paper develops a national static CGE model and therefore, the scope of this paper is not to study international financial support, it focuses on the targets with domestic resources. In addition, a target of 4.5% emissions reduction is also used for analysis in this Chapter. It helps to compare between ETS and carbon tax in Vietnam. All sectors are set to reduce their carbon emissions by 4.5%, 9% and 15.8% from baseline emissions in Scenario_1, Scenario_2 and Scenario_3 respectively. It means that the allowances (carbon rights) are 95.5%, 91% and 84.2% of the baseline for all sectors in Scenario_1, Scenario_2, and Scenario_3, respectively. The scenarios are described in Table 4.1.

4.4 Simulation analysis and Discussions

4.4.1 Macro-economic and environmental impacts of the ETS

Table 4.2 shows the impacts of the ETS on the environment, economy, welfare, and price under different emissions reduction options. To achieve an emissions reduction of 9%, the carbon permit price is estimated to be at US$23.278/t$CO_2$eq, and this permit price increases significantly, with the permit price of US$56.608/t$CO_2$eq if the emissions reduction target is heightened to 15.8%. Compared with the carbon price at the first stage of other countries[3], these prices in Vietnam are quite high. If Vietnam targets 4.5% emissions reduction (around 9.9MtCO_2eq), the carbon price is US$8.9/t$CO_2$eq. Compared with carbon tax at the same emissions reduction[4], the carbon price under ETS is lower.

Table 4.2. Macro-economic and environmental impacts of the ETS

	Scenario_1	**Scenario_2**	**Scenario_3**
Emissions reduction target (%)	*4.5*	*9.0*	*15.8*
ECONOMIC (% CHANGE)			
GDP	-0.822	-1.606	-3.694
Household consumption	-1.039	-2.029	-4.666
Investment	-0.604	-1.206	-3.254
Exports	-0.113	0.012	-0.431
Imports	-0.130	-0.020	-0.667
ENVIRONMENT			
Carbon price (US$/t$CO_2$eq)	8.924	23.278	56.608
Carbon Emissions Reduction (MtCO_2eq)	-9.904	-19.677	34.544
PRICE			
Average Commodity Price (%)	1.299	3.677	9.349

In terms of the economy, the ETS leads to a decrease in GDP of 0.82% in Scenario_1, 1.606% in Scenario_2 and 3.694% in Scenario_3. It is clear that the ETS impacts are much higher when the emissions reduction target increases. In detail, this can be explained due to the increase in carbon price and production cost that lead to shrinking of the economy. From the demand perspective, because of increased commodity prices as well as shrinking of production, household income decreases and then household consumption decreases by 1.039%, 2.029%, and 4.666% in Scenario_1, Scenario_2, and Scenario_3 respectively. Similarly, investment also falls by 0.604%, 1.206%, and 3.254%. Exports increase slightly by 0.012% in Scenario_2,

[3] For example, Carbon prices in New Zealand ETS, South Korea ETS were around US$15–20/t$CO_2$eq in 2017; Carbon price in China ETS (based on 7 ETS pilot cities.) was US$2–9/t$CO_2$eq in 2017.
[4] In Chapter 3, at the same carbon emissions reduction, the carbon price is US$10/t$CO_2$eq.

mainly due to firms adding production costs, leading to an increase in the product price. However, when prices increase, it also negatively affects the country's competitiveness, and then causing a decrease in exports. In Scenario_1 and Scenario_3, exports decrease by 0.113% and 0.431%, respectively. Imports decline by 0.13%, 0.02%, and 0.667% in Scenario_1, Scenario_2, and Scennario_3 respectively because the decrease in production and income leads to a drop in domestic and international product demand. It is noted that, in all scenarios, it is assumed that all revenue collected from the ETS might only be used for keeping government activity as in the baseline and generate a budget surplus, hence government consumption and public investment are unchanged in both scenarios.

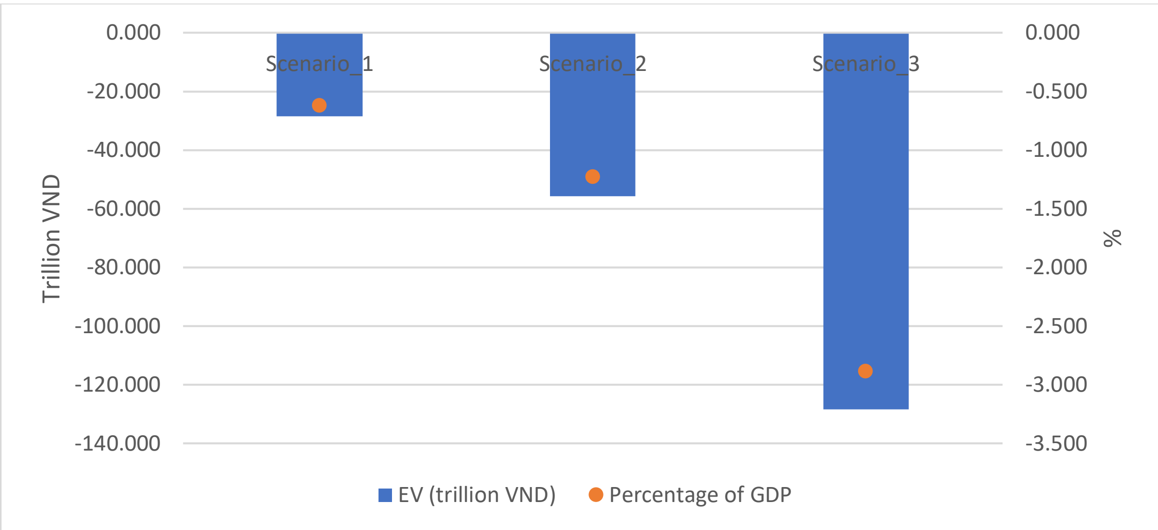


Figure 4.2. Welfare changes

The rising production costs caused by imposing a price on emissions causes a climb in the price index. In detail, the average commodity price increases by 1.299%, 3.677% and 9.349% under Scenario_1, Scenario_2 and Scenario_3 respectively (Figure 4.2). It contributes to changes in welfare. In this study, the changes in social welfare in currency form are measured by a Hicksian equivalent variation (EV) represented in VND values and the percentage of GDP. The results show that welfare is materially affected. Welfare declines by VND 28.57 trillion in Scenario_1, which accounts for 0.63% of GDP. When the emissions reduction target increases (in Scenario_2 and Scenario_3), the effect on welfare is higher, and welfare falls by VND 55.80 trillion and VND 128.34 trillion, accounting for 1.23% and 2.89% of GDP (Figure 4.2). These effects are caused by the increase in prices and the decrease in household income and consumption.

Compared with carbon tax, with the same emission target of 4.5%, the ETS presents lower costs in terms of GDP and welfare. Specifically, the carbon tax leads to a drop of 2.32% in GDP and VND 131.25 trillion in welfare[5] while ETS causes a decrease of 0.82% in GDP and VND 28.57 trillion in welfare. The results are consistent with the results provided Bi et al. (2019) and Li & Jia (2017). It can be explained that the carbon tax imposition will squeeze the profit space of enterprises due to fixing the tax rate on sectors and then firms decide to reduce their output or improve their production efficiency while ETS brings a flexible mechanism for firms where they can choose to reduce or expand their production by trading emission permits with other sectors.

In general, the results show that with the latest emissions reduction target of 15.8% in NDC, if it is achieved with ETS, the Vietnamese economy will experience a dramatic loss in economy and welfare due to the increase in production costs and subsequent narrowing of production and increase in product prices. With the lower target of 9% and 4.5%, these negative impacts will be lightened. In addition, the ETS has lighter negative effects on GDP and welfare than the carbon tax. Therefore, in Vietnam, ETS could be a better tool than carbon tax. However, in the early stages of ETS implementation, a lower target level would be more appropriate for the Vietnamese economy.

4.4.2 Sectoral impacts of the ETS

The ETS leads to a decrease in emissions in all sectors (Table 4.3). Of which, the emissions reduction of electricity generation sectors is the highest, with the emissions reduction

[5] These results are from Chapter 3.

of 9.03 $MtCO_2eq$ (or 11.64%) in Scenario_1, 17.946 $MtCO_2eq$ (or 23.13%) in Scenario_2 and 28.90 $MtCO_2eq$ (or 37.24%) in Scenario_3, accounting for over 80% of total carbon emissions reduction target, followed by coal mining, construction, other energy and high-emissions intensity industries such as textile and leather, machinery. This is because the high emissions intensity sectors face higher costs when ETS is implemented, leading to a drop in their production. In addition, their production is also affected by the decrease in demand when the economy shrinks.

Table 4.3. Carbon emissions reduction by sector

	Scenario_1		**Scenario_2**		**Scenario_3**	
Sector	*% change*	*Volume change ($MtCO_2eq$)*	*% change*	*Volume change ($MtCO_2eq$)*	*% change*	*Volume change ($MtCO_2eq$)*
Agriculture	-0.310	-0.049	-0.700	-0.110	-1.872	-0.294
Coal mining	-1.426	-0.059	-3.558	-0.148	-7.886	-0.327
Crude oil	-1.064	-0.113	-2.531	-0.269	-5.975	-0.634
Natural gas	-0.447	-0.011	-1.148	-0.029	-2.748	-0.069
Other mining	-0.611	-0.007	-1.562	-0.019	-3.593	-0.043
Food and tobacco	-0.353	-0.045	-0.830	-0.106	-2.121	-0.272
Textile and leather	-0.696	-0.148	-1.706	-0.364	-4.087	-0.871
Wood products	-0.210	-0.004	-0.528	-0.009	-1.272	-0.021
Petroleum products	-0.019	0.000	-0.049	0.000	-0.081	0.000
Chemicals	-0.128	-0.003	-0.392	-0.008	-0.823	-0.016
Mineral	-0.239	-0.009	-0.662	-0.025	-1.501	-0.057
Metal	-0.247	-0.013	-0.743	-0.039	-1.590	-0.083
Machinery	-0.852	-0.109	-1.094	-0.140	-4.697	-0.602
Other manufacturing	-0.477	-0.023	-0.937	-0.045	-2.671	-0.128
Electricity generation	-11.638	-9.031	-23.128	-17.946	-37.241	-28.899
Construction	-2.317	-0.389	-2.128	-0.357	-10.931	-1.835
Transportation	-0.074	-0.001	-0.142	-0.001	-0.434	-0.003
Other services	-0.257	-0.063	-0.638	-0.157	-1.571	-0.388

In the ETS policy, carbon permits are bought by firms from the government. Emitters producing more emissions than their carbon rights should purchase their deficient carbon emissions from others, and vice versa. Firms can choose to reduce their outputs to achieve their carbon rights or have more redundant emissions for selling, while others choose to buy more carbon permits to expand their production. Table 4.4 presents emissions trading volumes in the ETS market by industry. Positive numbers represent carbon permit sellers, whereas negative numbers represent purchasers. In the ETS market, total buying emissions are equal to the total selling emissions hence, the total emissions trading volume is equal to zero.

Table 4.4. Carbon emissions trading by sector

Sector	Scenario_1		Scenario_2		Scenario_3	
	Volume ($MtCO_2eq$)	*Value (million US$)*	*Volume ($MtCO_2eq$)*	*Value (million US$)*	*Volume ($MtCO_2eq$)*	*Value (million US$)*
Agriculture	-0.674	-6.017	-1.304	-30.364	-2.189	-123.912
Coal mining	-0.132	-1.175	-0.226	-5.254	-0.328	-18.581
Crude oil	-0.375	-3.348	-0.686	-15.977	-1.043	-59.015
Natural gas	-0.104	-0.925	-0.196	-4.563	-0.326	-18.444
Other mining	-0.048	-0.428	-0.089	-2.080	-0.147	-8.300
Food and tobacco	-0.544	-4.855	-1.047	-24.365	-1.752	-99.199
Textile and leather	-0.832	-7.424	-1.554	-36.178	-2.496	-141.282
Wood products	-0.073	-0.653	-0.141	-3.285	-0.242	-13.700
Petroleum products	-0.011	-0.094	-0.021	-0.482	-0.036	-2.057
Chemicals	-0.088	-0.788	-0.170	-3.954	-0.296	-16.732
Mineral	-0.166	-1.484	-0.318	-7.400	-0.545	-30.860
Metal	-0.228	-2.035	-0.433	-10.070	-0.744	-42.142
Machinery	-0.480	-4.286	-1.013	-23.585	-1.423	-80.544
Other manufacturing	-0.197	-1.757	-0.385	-8.965	-0.627	-35.501
Electricity generation	5.461	48.735	10.868	252.986	16.640	941.955
Construction	-0.383	-3.420	-1.154	-26.852	-0.817	-46.262
Transportation	-0.034	-0.307	-0.067	-1.568	-0.117	-6.613
Other services	-1.072	-9.566	-2.064	-48.043	-3.512	-198.812

It is clear that different sectors will act differently in the ETS market. While only the electricity sector becomes a seller, others are buyers. The electricity generation sector chooses to reduce its output more than the output reduction needed to achieve its carbon rights.

Therefore, they have redundant emissions for selling. In Scenario_1, the emissions reduction target of electricity is 4.5% (or 3.57MtCO_2eq), but the final emissions reduction is 9.03 MtCO_2eq, thus additional emissions reduction of 5.46MtCO_2eq is sold to other industries and the electricity generation sector achieves emission turnover of US$ 48.7 million. In scenario_2, the electricity generation sector is targeted to cut its emissions by 9% (or 6.98MtCO_2eq), but under the ETS market, this sector reduces additional carbon emissions by 10.87 MtCO_2eq, which are sold to other industries. Its turnover is nearly US$ 253 million. In Scenario_3, its trading volumes and its turnover from selling its carbon permit even increase significantly, and this sector is able to cut its additional carbon emissions by 16.64MtCO_2eq. This result indicates the high potential for carbon emissions reduction in the electricity generation sector. Other sectors release low carbon emissions levels and hence they have low potential emission trading volumes.

The ETS sets up the mechanism such that, polluting firms, both carbon permit sellers and purchasers, have to take responsibility for their produced emissions. Consequently, this policy causes higher production costs, affecting the firms' outputs. The results in Table 4.5 illustrate that all sectors experience a drop in their outputs. Obviously, high-carbon-intensity sectors face higher emissions costs, resulting in higher production costs and then a relatively higher increase in the price of these products. Thus, both firms and consumers would attempt to find ways to cut their production as well as consumption of these products. The electricity generation sector with the highest carbon emissions intensity suffers the highest output reduction rate of 15.06% (VND 29.02 trillion), 28.8% (VND 55.55 trillion) and 44.4% (VND 85.6 trillion) in Scenario_1, Scenario_2 and Scenario_3 respectively, followed by coal mining with 1.68%, 4.2% and 9.2% and construction with 3.01%, 2.8% and 13.8% in Scenario_1, Scenario_2 and Scenario_3 respectively. Other sectors with low carbon intensity decline slightly. It seems that the ETS would lead to a sectoral restructuring, shifting from high emissions-intensive sectors to low emissions-intensive sectors. In addition, for the coal mining sector, it is not only because of high production costs but also due to a decrease in demand. When the electricity sector output declines, demand for coal also falls since it is the main input for electricity generation in Vietnam. The decrease in construction output is explained by the economy shrinking, the demand for construction, and production reduction of all sectors.

Table 4.5. Output change by sector

Sector	Scenario_1		Scenario_2		Scenario_3	
	% change	*Value (trillion VND)*	*% change*	*Value (trillion VND)*	*% change*	*Value (trillion VND)*
Agriculture	-0.43	-9.22	-0.97	-20.80	-2.59	-55.38
Coal mining	-1.68	-1.95	-4.19	-4.84	-9.20	-10.65
Crude oil	-1.28	-5.59	-3.04	-13.26	-7.13	-31.07
Natural gas	-0.72	-1.22	-1.83	-3.13	-4.35	-7.42
Other mining	-0.85	-0.57	-2.17	-1.44	-4.96	-3.28
Food and tobacco	-0.38	-7.22	-0.89	-16.97	-2.28	-43.35
Textile and leather	-0.89	-11.03	-2.17	-26.96	-5.17	-64.17
Wood products	-0.23	-0.88	-0.59	-2.20	-1.42	-5.29
Petroleum products	-0.02	-0.12	-0.05	-0.30	-0.09	-0.50
Chemicals	-0.14	-0.83	-0.44	-2.55	-0.92	-5.34
Mineral	-0.28	-1.78	-0.77	-4.93	-1.75	-11.18
Metal	-0.28	-2.27	-0.84	-6.81	-1.80	-14.55
Machinery	-0.93	-13.14	-1.20	-16.87	-5.12	-72.19
Other manufacturing	-0.59	-3.13	-1.15	-6.14	-3.27	-17.42
Electricity generation	-15.06	-29.02	-28.83	-55.55	-44.41	-85.57
Construction	-3.01	-24.75	-2.76	-22.74	-13.83	-113.76
Transportation	-0.10	-0.53	-0.18	-1.02	-0.56	-3.11
Other services	-0.42	-12.64	-1.05	-31.30	-2.56	-76.61

However, it is noted that although the potential emissions reduction in the electricity generation sector is large, the sharp decrease in its output could raise concern about electricity security for economic development. It is because electricity is the essential input for production. This result also indicates that, in the first phase of ETS implementation, a lower emissions reduction target is needed for firms to adapt to the new policy. The rapid reduction in output will lead to many adverse consequences, while the gradual implementation of ETS will encourage businesses to seek for improvement of technology and reducing carbon intensity.

Table 4.6. Commodity price changes

(Unit: %)

Commodity	Scenario_1	Scenario_2	Scenario_3
Agriculture	0.253	0.705	1.660
Coal mining	1.554	4.413	12.492
Crude oil	1.047	2.917	7.885
Natural gas	0.453	1.195	2.946
Other mining	0.626	1.672	4.268
Food and tobacco	0.321	0.850	2.094
Textile and leather	0.688	1.894	5.013
Wood products	0.204	0.535	1.307
Petroleum products	0.019	0.049	0.122
Chemicals	0.155	0.399	0.987
Mineral	0.261	0.679	1.685
Metal	0.297	0.765	1.901
Machinery	0.366	1.067	2.597
Other manufacturing	0.340	0.967	2.335
Electricity generation	16.171	45.193	115.656
Construction	0.345	2.097	3.424
Transportation	0.049	0.142	0.321
Other services	0.241	0.652	1.593

The results in Table 4.6 indicate the percentage changes in the prices of commodities due to the ETS policy. In all scenarios, the prices of all commodities rise at different rates; of which the price of electricity soars highest in all scenarios. In detail, it is 16.2% in Scenario_1 and then continues to dramatically increase to 45.2 in Scenario_2 and 115.7% in Scennario_3. It is because the electricity sector itself has the highest carbon intensity, thus facing higher emission costs. In Vietnam, electricity generation is mainly from coal, accounting for over 32% (BP, 2022). Moreover, as a highly carbon-intensive source of electricity generation in Vietnam, coal is also seriously influenced by the ETS policy. Hence, the price of coal increases significantly by about 1.55%, 4.4% and 12.5% in Scenario_1, Scenario_2 and Scenario_3. These factors cause a rise in electricity production costs, and remarkable high electricity prices. Meanwhile, increases in the prices of other commodities are relatively modest.

Compared with carbon tax at the same emission target of 4.5%, the sectoral effects of ETS are much more concentrated (see Appendices 4.1, 4.2 and 4.3). In detail, with the carbon tax policy, emissions reduction of electricity generation sector accounts for 34% of total emissions reduction while the figure for the ETS scenario is 80%. Similarly, the output reduction of electricity in the case of imposing the carbon tax is 7.3% while it is 15.1% in the case of implementing ETS. The ETS also leads to a dramatic increase in the electricity price (16.2%) compared with the carbon tax (5.1%). In general, although carbon tax leads to a lower reduction in GDP and welfare, the sectoral effect of ETS is more concentrated than that of carbon tax. Especially, the ETS effects on electricity are much higher than that in the case of implementing the carbon tax, which would lead to the electricity generation sector suffering substantially. The negative shock on electricity output and the dramatic increase in the electricity price would lead to the lack of essential input and be a challenge to economic development. Therefore, supporting policies for ensuring electricity supply and minimizing electricity emissions such as renewable electricity development should be added along with the ETS policy.

4.5 Conclusions

This study carries out simulations with different emissions reduction targets of 9% and 15.8% based on Vietnam's NDC as well as reduction target of 4.5% based on the carbon emissions reduction identified in Chapter 3. The results show that to achieve Vietnam’s NDC targets, carbon permit prices would be at US$23.278/t$CO_2$eq and US$56.608/tCO_2eq respectively, which are relatively high compared with other countries in the first stage of ETS implementation. With the carbon emissions target of 15.8%, the economy experiences a significant loss with a drop of 3.694% in GDP and a decrease of VND128.34 trillion in welfare. The loss would be smaller with the lower targets. At the sectoral level, the ETS would lead to sectoral restructuring when low-carbon-intensity industries reduce their outputs less than that of high-carbon-intensity industries. Electricity generation is the key to emissions reduction in the country, but the drop in its output could raise concerns about ensuring electricity security in the economy. Compared with carbon tax policy, the ETS leads to smaller GDP and welfare reduction but the sectoral effects of ETS are much more concentrated, especially, the ETS leads the electricity generation sector to suffer substantially. This study suggests that a modest target at the initial stage of ETS implementation would be appropriate in Vietnam, which assists firms in transferring their business to adapt to the new policy. In addition, if the ETS is applied, supplemental policies to support electricity generation sector development such as the use of renewable energy source for electricity generation needs to be implemented to minimize emissions as well as ensuring electricity supply for production.

Chapter 5: Carbon Pricing with Revenue Redistribution Policies

In previous Chapters, the pure impacts of carbon pricing were examined. The results showed that carbon pricing has positive impacts on emission mitigation. However, the results also showed that carbon pricing has negative impacts on GDP and welfare. In this chapter, carbon pricing combined with the redistribution of revenue from carbon pricing is analyzed. By using national static CGE models, this paper simulates the potential impacts of the carbon pricing with different revenue recycling options. The results indicate that the revenue recycling policies would lighten the negative impacts of carbon pricing on GDP and welfare. While the revenue transferring to government activities leads to an increase in GDP, reducing income tax policy results in welfare and GDP improvement. At the sectoral level, the revenue redistribution for government activities could improve outputs for the construction and some heavy industries while the recycling policy for households creates improvements for light industries and service sectors. In addition, carbon tax revenue recycling policies could lead to higher GDP growth and welfare than the ETS revenue recycling policies, but carbon tax revenue recycling policies could reduce the impacts of the carbon tax on mitigating emissions, even distorting the original goal of the carbon tax policy with a sign of rebound emissions.

5.1 Introduction

The increase in industrial activities in countries leads to an increase in economic growth, but the production process generates carbon emissions and causes environmental degradation. Recently, carbon pricing has been widely applied in curbing carbon emissions because of their flexible emission mitigation mechanism. Until 2022, carbon pricing has been implemented/scheduled in 71 jurisdictions around the world (including 37 carbon taxes and 34 ETSs) to mitigate emissions such as Ireland, Australia, Chile, and Japan (World Bank, 2022). In addition, carbon pricing would potentially raise revenue significantly through tax collection or a carbon permit auction. The IMF (2019) showed that a carbon price of US$70/t$CO_2$ would generate revenues equivalent to around 1–3% of GDP by 2030 in most countries analyzed. Fay et al. (2015) also showed that carbon pricing revenue has accounted for around 1-3% of the government budget in British Columbia and in Sweden. These revenues would play an important role in many countries (World Bank, 2019). Furthermore, as the revenue from the carbon pricing policy grows, research on revenue redistribution is an important part of designing carbon pricing in the countries.

Previous studies have confirmed the positive impact of carbon pricing in emissions mitigation, however, they also pointed to the negative economic and welfare effects that carbon pricing can cause (e.g. Mardones and Ortege (2021); Tang and Bao (2016); Meng et al. (2018); Choi et al. (2017); Nong et al. (2020); Lin and Jia (2017); Lin and Jia (2018); Wissema and Dellink (2007); Meng et al. (2013); Antosiewicz et al. (2022)). Using revenue from the carbon pricing policy would lead to a 'double dividend' by lightening the negative effects of such a policy (e.g. Rausch et al. (2011); Lin and Jia (2020); Tran et al. (2019); Li and Su (2017); Liu et al. (2021)). Although designing carbon pricing attracts a lot of attention from policymakers, currently, policies are mainly about designing carbon pricing mechanisms (e.g. Babiker et al. (2002), Qi and Weng (2016); Brink et al. (2016); Lin and Jia (2017)), estimating carbon prices (e.g. Tang et al. (2016); Weng et al. (2018); Wissema and Dellink (2007); Antosiewicz et al. (2022)), and economic losses (e.g. Mardones and Ortege (2021); Tang et al. (2016); Meng et al. (2018)). Policies associated with revenue recycling are still being pushing aside.

Although carbon pricing was established and operated formally in the EU in 2008 and became popular in many countries/regions in the world, this instrument was introduced officially in Vietnam in the Revised Environmental Protection Law 2020. Unfortunately, the lack of studies on carbon pricing in Vietnam causes difficulties in specifying carbon pricing in the country. Nong et al. (2020) employed a global energy CGE model and showed that with a relatively high carbon price of US$109.32/t$CO_2$eq and a decrease of 4.57% in real GDP, Vietnam can achieve its target of reducing 8% emissions in the energy and transportation sectors and 20% in the agriculture sector in 2020 if only these sectors join in ETS market. The price and emissions reduction costs would be reduced significantly if all sectors participate in the market. However, in this research, the focus was on ETS policy with different coverage sectors. There is no research on using new revenue from carbon pricing policy in the country. Therefore, this research will fill in the gap by using a CGE model to analyze the effects of carbon pricing when it is combined with recycling policies.

The results show that revenue redistribution policies could lighten the negative impacts of carbon pricing. Specifically, the new revenue transfers to government activities could lead to increasing GDP with a boost to the GDP growth rate of 0.6% and 0.25% under the carbon tax scheme and ETS scheme respectively. On the other hand, the revenue transferred to households by cutting income tax would result in improving welfare with an increase by VND 32.4 trillion and VND 29.34 trillion under the carbon tax scheme and ETS scheme respectively. At the sector level, the revenue redistribution for government activities could improve outputs for the construction and some heavy industries while the recycling policy for households creates improvements for light industries and service sectors. In addition, the combination of the carbon tax and the revenue recycling policies could lead to higher GDP growth and welfare than the combination of the ETS and revenue recycling policies, but carbon tax revenue recycling policies could reduce the impacts of the carbon tax on mitigating emissions more than the ETS revenue recycling policies.

The rest of the Chapter is organized as follows. The next section delivers a literature review of carbon pricing and carbon pricing revenue redistribution issues. Section 5.3 specifies the model and data as well as designing scenarios. The results are discussed in Section 5.4 and the conclusion is presented in the last Section.

5.2 Literature Review

As an effective tool in reducing emissions with the advantage of flexible emission mitigation mechanism, carbon pricing has become popular in the carbon mitigation strategy of many countries/regions. Currently, many countries schedule carbon pricing implementation to achieve their emission targets in their NDCs to the Paris Agreement. Following that, studies on carbon pricing have been increasing in the literature.

Previous studies mainly used CGE models and focused on designing carbon pricing at the national and regional levels and comparing the carbon pricing impacts with different designs. They confirmed the effects of carbon pricing in mitigation emissions. For example, Mardones and Ortege (2021) showed that to reach Chile's emissions reduction goal of 30%, the carbon price in the ETS market would be around US\$36.5/tCO_2eq. Tang et al. (2016) indicated that with the tight carbon cap and reduction rate of 2.8% each year, the carbon price in China's ETS market would be RMB36.82/MtCO_2 in 2016 and up to RMB39.61/MtCO_2eq in 2020. Meng et al. (2018) found that to reach the emission mitigation goal of 12% in Australia, the carbon price in the market would be about A\$25/tCO_2eq. Wissema and Dellink (2007) found that with a carbon energy tax of EUR 10-15/tCO_2eq, emissions in Ireland would fall by 28% compared to 1998. Existing studies consistently agree that carbon pricing is an effective tool for cutting carbon emissions. However, carbon pricing also negatively impacts GDP and welfare at various levels because firms face with higher production costs under this policy. For example, Tang et al., (2016) showed that under ETS, China could experience a decline in GDP from 1.65% to 2.79% depending on the ETS mechanism. Mardones and Ortege (2021) concluded that the increase in emissions reduction targets results in a higher GDP decline. Cao et al. (2021) indicated that the carbon tax rates of RMB 5-84-284/tCO_2eq in 2020, 2030, and 2050, respectively, GDP would decrease by 0.2% to 0.8% in 2050, respectively. In terms of welfare, Tran et al. (2019) showed that the ETS policy in Australia would lead to reducing welfare by A$1,255 million. In addition, Jia (2023) introduces the process of using the CGE model in simulating the effects of ETS in China to assist policymakers in finding the effects of ETS on enterprises and residents. Zhang et al. (2023) examine the income distribution effects of a carbon tax and ETS. They suggest that a combination of a carbon tax and ETS could be a superior plan to accomplish the carbon peak targets of China. Wissema and Dellink (2007) indicated the slight negative effect of the carbon tax on welfare in Ireland. A strong decline (0.12-1.12%) in welfare in China due to carbon tax was found by Wu et al. (2019).

Furthermore, the carbon pricing policy can raise substantial revenue for the government through a carbon permit auction and/or a tax collection. The recycling policies from new revenues can be used for lightening the negative impacts of carbon pricing on the economy and welfare and resulting in a "double dividend". Therefore, the effectiveness of the carbon pricing policy also depends on how the government utilizes the revenue from this policy. Rausch et al. (2011) by using a simulation model showed that redistribution of revenues raised from carbon pricing could affect the efficiency and equity of carbon pricing policy. They also concluded that focusing solely on carbon pricing could cause seriously misleading outcomes. Lin and Jia (2020) found that revenue transfers to households could lead to an increase in social welfare while GDP loss will be less if revenue is used for consumption and investment of the government. Tran et al. (2019) focused on different measures of using ETS revenue for households in Australia and found that recycling policies are likely to improve macroeconomic indicators but the effects on different household groups vary depending on their income levels. Liu et al. (2021) analyzed the carbon tax recycling policies based on the principle of tax neutrality such as reducing residents' personal income tax, the enterprise income tax rate, and the enterprise indirect tax rate. They found that these policies can reduce the drawbacks of the carbon tax on economic development and welfare. A lump-sum transfer to the household would offset the burden of the carbon tax on the household, but it also causes smaller emissions reduction. With tax revenue recycled to firms, producers will get a refund from carbon tax revenue, which reduces the distortion of the carbon tax on selected sectors and subsidy for other sectors that are not under the carbon tax. However, in all scenarios, reallocation of carbon tax revenue leads to improved economic indicators but reduces the effects on climate change mitigation (Li and Su, 2017).

In Vietnam, although carbon pricing was introduced formally as a policy measure used for achieving Vietnam's NDC targets, the country has also highlighted how to implement and the roadmap to apply carbon pricing, studies on carbon pricing are still very limited. Nong et al. (2020) analyzed the effects of ETS on the economy with different sector coverages. They concluded that narrowing sectors participating in ETS could lead to an extremely high carbon price and then significantly harm GDP and welfare. However, in this research, they have not focused on using new revenue in mitigating the negative effects of ETS.

Research solely focused on carbon pricing is quite popular and has shown positive effects of carbon pricing on emissions reductions, increased government revenue, as well as negative effects on the economy and welfare, but only a few studies using new revenue from carbon pricing policy have been undertaken. Previous studies have indicated that revenue redistribution can reduce the negative impact of carbon pricing on the economy and welfare. Therefore, to design a realistic carbon pricing policy, studying revenue redistribution is very important. In Vietnam, there is only a study on ETS, however, the study has not focused on the aspect of revenue recycling. Therefore, this study will analyze the impacts of carbon pricing when accompanied by different revenue recycling policies in Vietnam, thereby providing some analysis and suggestions on the combinations of carbon pricing policy with recycling policies. In addition, this research compares the harmony of the carbon tax and ETS policies when combined with recycling policies. In terms of literature, this study will also contribute to the literature an analysis of carbon pricing revenue redistribution in developing countries to serve as a reference for countries planning to implement carbon pricing.

5.3 Methodology and Data

5.3.1 Methodology

The CGE models are dominant for simulating the impacts of new policies and have been widely developed for analyzing the effects of climate change policies including carbon pricing and other combinations of carbon pricing. CGE has advantages in describing the economy with all agents in the model (World Bank, 2018). Therefore, when new policies are introduced, the model would show changes in all variables. In this study, the national static CGE models are used for Vietnam. In addition to standard economic accounts, the environmental account is also integrated into the model. Therefore, environmental policies can be modeled, then the environmental impact and economic impact can be explored easily. As a carbon pricing is introduced, all variables such as national account aggregates, outputs, prices, and trade flows would be changed, representing the effects of carbon pricing on the environment and economy. The model includes five blocks: production, income and expenditure, trade, environmental policy, and market equilibrium block.

Production block

In this block, the production consists of a two-level nested production function. At the lowest nest, the production function is a Leontief function of endowment factors (labor, capital). The endowment factor function is given by:

$$p_i^Y Y_i = rCAP_i + wLAB_i \qquad i = 1, 2 \ldots n \qquad (1)$$

where Y_i and p_i^Y are the composite goods (i) and its price, respectively; n is the number of sectors; CAP_i and LAB_i are capital and labor used by firm i in the first stage; r and w are prices of capital and labor.

Following profit maximization behavior, the factor demand functions are identified:

$$CAP_i = \frac{\beta_{CAP,i}}{r} p_i^Y Y \qquad (2)$$

$$LAB_i = \frac{\beta_{LAB,i}}{w} p_i^Y Y \qquad (3)$$

where $\beta_{CAP,i}$ and $\beta_{LAB,i}$ are share parameters in the composite factor function.

At the top level, intermediate inputs are nested with primary factors to produce domestic outputs. Under the zero-profit assumption, we have:

$$p_i^Z Z_i = p_i^Y Y_i + \sum_j p_j^X X_{i,j} \qquad i = 1, 2 \ldots n \qquad (4)$$

where Z_i and p_i^Z are domestic output of firm *i* and its price; $X_{i,j}$ and p_j^X are intermediate goods of *j* used by firm *i* and its price.

Trade block

Domestic output (Z_i) is transformed into exports and domestic goods. The transformation assumptions follow a constant elasticity of transformation (CET) function, then we have:

$$Z_i = \left(\kappa_i^e E_i^{\sigma_i} + \kappa_i^d D_i^{\sigma_i}{}_i\right)^{\frac{1}{\sigma_i}} \qquad i = 1, 2 \ldots n \qquad (5)$$

and, supply functions for exports and domestic goods are identified by:

$$E_i = \left(\frac{\kappa_i^e (1+\tau_i^p) p_i^Z}{p_i^e}\right)^{\frac{1}{1-\sigma_i}} Z_i \qquad (6)$$

$$D_i = \frac{\kappa_i^d (1+\tau_i^p) p_i^Z \, Z_i}{p_i^d} \qquad (7)$$

where E_i and p_i^e are the exported goods and its price; D_i and p_i^d τ_i^p is production tax on domestic good i; κ_i^e and κ_i^d are share parameters in the transformation function; σ_i is transformation elasticity parameter.

Final consumption goods include domestic goods and imports. The Armington function is given by the constant elasticity of substitution (CES) function:

$$Q_i = \left(\varepsilon_i^m M_i^{\theta_i} + \varepsilon_i^d D_i^{\theta_i}{}_i\right)^{\frac{1}{\theta_i}} \qquad i = 1, 2 \ldots n \qquad (8)$$

and, demand functions for imports and domestic goods are:

$$M_i = \left(\frac{\varepsilon_i^m p_i^Q}{(1+\tau_i^m)p_i^m}\right)^{\frac{1}{1-\theta_i}} Q_i \qquad (9)$$

$$D_i = \left(\frac{\varepsilon_i^d p_i^Q}{p_i^d}\right)^{\frac{1}{1-\theta_i}} Q_i \qquad (10)$$

where Q_i and p_i^Q are final consumption goods and its price; M_i and p_i^m are imports and its price; τ_i^m is tariff rate; ε_i^m and ε_i^d are share parameters in the Arminngton function; $\theta_i$is the substitution elasticity parameter.

Income and expenditure block

Household

Households use their income from provision of the labor and capital (also from government transfer payments) in paying income tax and consuming goods/services following the utility maximization principle and the rest for savings. The household demand function is shown in the following equation:

$$XP_i = \frac{\alpha_i}{P_i^Q}\left(\sum_i (rCAP_i + wLAB_i) - XSP - TI\right) \qquad (11)$$

The household saving is:

$$XSP = s^p \sum_i (rCAP_i + wLAB_i) \qquad (12)$$

The income tax is:

$$TI = \tau^d \sum_i (rCAP_i + wLAB_i) \qquad (13)$$

where α_i is share parameter in utility function; $\sum_i (rCAP_i + wLAB_i)$ is household income; *XSP* is household saving; $s^p$is the household saving rate; *TI* is income tax; $\tau^d$is the income tax rate.

Government

The government acquires its revenue through income tax, production tax, and an imported tax. Then, the revenue is used for its consumption and saving as well as transfer payments. The government consumption function is:

$$XG_i = \frac{\delta_i}{P_i^Q}(TD + \sum_i TP_i + \sum_i TM_i - XSG) \quad (14)$$

$$XSG = s^g(TD + \sum_i TP_i + \sum_i TM_i) \quad (15)$$

where XG_i denotes government consumption of goods i; TD, TP, TM are the total amount of income tax, production tax, and import tax, respectively; XSG is government saving; s^g is government saving rate.

When ETS is introduced, government revenue would increase due to new revenue from the carbon permit auction.

Environment block

In the environment account, the total carbon emissions (EMI_i) are assumed to be associated with domestic production and given by:

$$EMI_i = \gamma_i p_i^Z Z_i \quad (16)$$

where γ_i is the carbon emission coefficient or carbon intensity of sector *i*.

Under a carbon tax scheme, the total carbon tax revenue is:

$$TT^{CT} = \sum_i cpEMI_i \quad (17)$$

where TT^{CT} is the total carbon tax revenue; *cp* = carbon price.

The carbon tax rate is:

$$\pi_i^{EM} = \frac{cpEMI_i}{p_i^Z Z_i} \quad (18)$$

Under the ETS, as long as sector *i* is covered by the ETS, the sector has carbon rights or carbon allowances, denoted by CR_i, set by the government. The government determines CR_i and sells them to sector *i*. The carbon allowances can be free of charge or auctioned to the firms. Denote the amount of free emission allowances to sector *i* by FA_i.

In this paper, the ETS market is assumed as a perfectly competitive market; thus, the carbon auction price is the same as the trading price of carbon emissions in the equilibrium state, denoted by p^t. If the sectors generate more than their allowances, they can purchase additional carbon emission permits from other firms and vice versa. In other words, sectors under ETS can sell (buy) the emissions gap ($|EMI_i - CR_i|$) at the equilibrium in the ETS market, thus p^t is determined to satisfy the equilibrium condition of the ETS market such that:

$$\sum_i (EMI_i - CR_i) = 0 \qquad (19)$$

Where the equilibrium price is also assumed to satisfy:

$$0 < p^t < \infty \qquad (20)$$

Thus, the total cost to be covered in the ETS for sector *i* denoted by PLC_i is given by:

$$PLC_i = p^t(CR_i - FA_i) + p^t(EMI_i - CR_i) \qquad (21)$$

The ETS revenue is given by:

$$TT^{ETS} = \sum_i p^t (CR_i - FA_i) \qquad (22).$$

In this paper, the new revenue from the ETS and carbon tax policy will be used for recycling policies and will be detailed in the Scenario design part.

Equilibrium block

The market clearing conditions are expressed by:

$$Q_i = XP_i + XG_i + XS_i + \sum_j X_{i,j} \qquad (23)$$

Investment function is:

$$XS_i = \frac{\eta_i}{P_i^Q}(XSP + XSG + SF) \qquad (24)$$

where XS_i is the investment in sector i; η_i is investment demand share; SF is the foreign savings or deficits in the current account.

The foreign trade balance is given by:

$$\sum_i p_i^{w,e} E_i + SF = \sum_i p_i^{w,m} M_i \qquad (25)$$

where $p_i^{w,e}$ and $p_i^{w,m}$ are the prices of export goods and import goods in world prices and:

$$p_i^m = \varepsilon p_i^{w,m} \qquad (26)$$

$$p_i^e = \varepsilon p_i^{w,e} \qquad (27).$$

5.3.2 Data and Scenarios

The basic data for the Vietnam CGE model is Vietnam SAM2016. In this research, the 164 sectors in SAM2016 are reclassified into 18 sectors as in previous Chapters. Carbon emissions by sector are taken from the EORA database for the year 2016.

In this Chapter, two popular recycling policies will be examined including use for government activities as normal and transfers to households via reduction of the income tax. The results of pure impacts scenarios are the same as Chapter 3 and Chapter 4 and are used for comparing pure impacts of carbon pricing and impacts of carbon pricing combined with recycling policies.

In Scenario (a), under the assumption of implementing carbon pricing and keeping expenditure and investment of government unchanged, pure effects of carbon pricing will be identified. In this case, new revenue would not be transferred and might create a budget surplus. These scenario results are the same as in Chapter 3 and Chapter 4.

In Scenario (b), the new revenue would be used for consumption and investment by the government. This scenario examines the double dividends of environmental policy referring to GDP growth and emissions reduction.

Scenario (c) assumes the new revenue would be transferred to households by reducing income tax while expenditure and investment of government are kept unchanged. This scenario focuses on the double dividends of environmental policy referring to welfare and emissions reduction.

To compare ETS and carbon tax impacts under recycling schemes, the paper assumes the same carbon emissions reduction level (4.5%) in the ETS scenarios and the same carbon price (US$10/t$CO_2$eq) in the carbon tax scenarios. Under the ETS, all carbon permits are auctioned and thus no free payment allocations. All sectors are assumed to participate in the ETS market. Under the carbon tax, it is also assumed that the carbon tax is imposed on all sectors.

Table 5.1. The carbon pricing and recycling policy scenarios in this study

Scenarios	Carbon pricing	Sub-scenarios	Recycling policy
Scenario_1	Carbon tax	(a)	No
		(b)	Transfer to expenditure and investment of government
		(c)	Transfer to households by reducing income tax
Scennario_2	ETS	(a)	No
		(b)	Transfer to expenditure and investment of government
		(c)	Transfer to households by reducing income tax

By comparing the scenarios above, this paper expects to examine the existence of double dividends of the combinations between carbon pricing and other recycling policies. In addition, the research expects to compare the harmony of ETS and carbon tax with other recycling policies. The summary of the the scenarios is shown in Table 5.1.

5.4 Simulation analysis and Discussions

5.4.1 Impacts of revenue redistributions under the carbon tax policy

Reallocating new tax revenue scenarios is introduced to explore whether the negative impacts caused by a carbon tax policy might be diminished through appropriate recycling policies. Such recycling policies redistribute new tax revenue into the economy and are expected to stimulate production and consumption again, thereby reducing the impact of carbon tax policies on the economy and welfare. However, these redistributions could also lead to a reduction in the environmental effects of the carbon tax.

The results show that, without redistributing new revenue, a carbon tax of US$10/t$CO_2$eq leads to a significant decrease in GDP and welfare. Specifically, GDP decreases by 2.32%, household consumption drops by 4.77%, investment decreases by 1.35%, exports and imports decrease by 0.85% and 2.28% respectively. Meanwhile, welfare drops by VND 131.25 trillion in Scenario_1 (a) (Table 5.2). In terms of revenue, carbon tax leads to the raising of VND 46.92

trillion, accounting for 1.02% of GDP.

When the carbon tax is redistributed to government activities as usual, this leads to an increase in government consumption and government savings/investment. With this distribution, GDP increases by 0.596% in Scenario_1 (b). In detail, government consumption increases significantly by 4.83%, investment increases by 3.32%, and exports and imports increase by 0.16% and 0.59% respectively. The increase in GDP is mainly due to an increase in investment and consumption of the government. Meanwhile, although EV is improved, it remains negative (VND 7.28 trillion) due to a decrease in household consumption and private investment. The overwhelming of the public sector when the revenue increases from the carbon tax, government activities are expanded results in GDP growth but not go with substantial improvement in welfare. More resources are used by the government but smaller resources by the household. The expansion of government spending and investment also drives a rebound in carbon emissions. In this case, the effect of the carbon tax on mitigating emissions is lower than the case of not using the new revenue with a decrease of 0.012% in carbon emissions (Table 5.2). In terms of revenue, this policy combination leads to increasing revenue due to the higher levels of output and emissions. Compared with carbon tax policies analyzed in previous studies in other countries, with the same assumption of redistributing carbon tax in government's activities, such a carbon tax policy in Vietnam leads to relatively small emissions reductions. Wu et al. (2019) showed that if a carbon price of RMB60/tCO_2eq (around US$9.43/t$CO_2$eq) is imposed, it would lead to a decrease in carbon emissions by -15.32% in China. Meng et al. (2013) also indicated that the carbon emission in Australia would drop by 12% when the government applies a carbon price of US$16.6/t$CO_2$eq. Although the previous studies could not find any increase in GDP, it seems that the growth of government expenditure and government investment in Vietnam has a huge effect on expanding production and then emissions but still has not improved welfare.

Table 5.2. The macro – economic and environmental impacts of carbon tax policy options

	Scenario_1		
	(a)	*(b)*	*(c)*
ECONOMIC (% CHANGE)			
GDP	-2.32	0.60	0.59
Government consumption	0.00	4.83	0.00
Household consumption	-4.77	-0.26	1.18
Investment	-1.35	3.32	0.52
Exports	-0.85	0.16	0.21
Imports	-2.28	0.59	0.59
WELFARE			
EV (Trillion VND)	-131.25	-7.28	32.40
EV/GDP (%)	-2.91	-0.16	0.70
ENVIRONMENT			
Emissions Reduction ($MtCO_2eq$)	-9.90	-0.03	0.14
Carbon Tax Revenue (Trillion VND)	46.92	47.71	47.74

In Scenario_1 (c), the new revenue is transferred to households by reducing income tax, and as expected, the decline in income tax relieves the negative impacts of the carbon tax on the economy and welfare, and even overwhelms the carbon tax effects. All macroeconomic indicators rise in all scenarios. Household consumption, investment, and exports increase to 1.18%, 0.52%, and 0.21% in Scenario_1 (c), respectively, which leads to the GDP increase of 0.59% in this scenario. In addition, the combination of carbon tax and income tax reduction policy leads to an increase of welfare, EV is positive with VND 32.4 trillion. The revenue also increases to VND 47.74 trillion in this case due to the increase of emissions and output. However, carbon emissions in this reallocation policy increase by about 0.14 $MtCO_2eq$ (0.069%), which might be due to the expansion of production and consumption when the income tax is relaxed. All things considered, the incorporated income tax reduction policy brings improvement to the economy and welfare, but it also causes a negative impact on the emissions reduction. The increase in carbon emissions indicates that this recycling policy has distorted the initial goals of the carbon tax.

Table 5.3. Output change by sector under the carbon tax policy options

Unit: %

Sector	Scenario_1		
	(a)	*(b)*	*(c)*
Agriculture	-1.552	-0.130	0.132
Coal mining	-1.057	-0.379	-0.417
Crude oil	-1.997	-0.209	-0.180
Natural gas	-2.042	-0.405	-0.211
Other mining	-1.629	-0.151	-0.279
Food and tobacco	-0.499	-0.042	0.062
Textile and leather	-1.390	-0.375	-0.234
Wood products	-0.572	-0.019	0.002
Petroleum products	-0.391	-0.019	0.004
Chemicals	-0.788	-0.040	-0.004
Mineral	-0.781	0.138	-0.028
Metal	-0.729	0.030	-0.058
Machinery	-0.510	0.095	-0.004
Other manufacturing	-0.861	-0.025	0.018
Electricity generation	-7.326	-4.882	-4.712
Construction	-0.537	0.537	0.015
Transportation	-1.323	-0.033	0.119
Other services	-1.939	0.103	0.171

Regarding sectoral production, while revenue redistribution to government would lead to increasing outputs of heavy industries and construction, the redistribution to household would lead to increasing outputs of the agriculture, services, and light industries. When increased revenue from the carbon tax is used for expanding public investment, the demand for construction would be increased because Vietnam is a developing country and the country has high demand for construction, thereby leading to strong growth of the construction industry.

In contrast, when revenue is transferred to households, the demand for consumer goods becomes higher, leading to the expansion of production in the above mentioned sectors (Table 5.3). The outputs of electricity generation, mining, and some manufacturing industries still decline, but at lower levels than in the case of solely carbon tax policy.

Table 5.4. Carbon emissions reduction by sector under the carbon tax policy options

Unit: %

Sector	Scenario_1		
	(a)	*(b)*	*(c)*
Agriculture	-4.758	-0.251	0.578
Coal mining	-6.190	-1.741	-1.995
Crude oil	-4.522	-0.001	0.073
Natural gas	-5.276	-0.797	-0.266
Other mining	-4.613	-0.093	-0.485
Food and tobacco	-4.777	-0.270	0.762
Textile and leather	-5.736	-1.277	-0.657
Wood products	-4.576	-0.061	0.116
Petroleum products	-4.732	-0.222	0.056
Chemicals	-4.681	-0.170	0.049
Mineral	-3.743	0.814	-0.011
Metal	-4.217	0.318	-0.205
Machinery	-3.655	0.906	0.155
Other manufacturing	-4.466	0.056	0.287
Electricity generation	-4.901	-0.402	-0.088
Construction	-1.872	2.773	0.516
Transportation	-4.598	-0.084	0.446
Other services	-4.134	0.403	0.553

The changes in sectoral outputs drive the changes in sectoral emissions (Table 5.4). Emissions of construction and heavy industries increase in Scenario_1 (b) while emissions of agriculture, light industries and services industries increase in Scenario_1 (c). For other sectors, their emissions decrease but with lower levels when there is no redistribution policy. Generally, revenue relocation arising from carbon tax policy would reduce the effects of the carbon tax on the environment in all redistribution scenarios, and the reductions in sectoral carbon emissions are thus smaller, even reversal in some sectors.

The results from the two recycling policy scenarios show that, in economic terms, it is more beneficial to use revenue from carbon tax for income tax reduction. Under this scheme, there is a similar increase in GDP but a higher increase in social welfare, compared to shifting tax revenue to government consumption. However, in terms of environmental impact, recycling to income tax reduction causes a carbon rebound effect. Under both recycling policies, the carbon reduction levels are very low, or even increase. At the sectoral level, the revenue redistribution on government activities leads to improvement mainly in construction and heavy industries while the redistribution in households results in improvement of light industries and service sectors.

5.4.2 Impacts of revenue redistributions under the ETS policy

The impacts of the revenue redistribution policy under ETS are shown in Table 5.5. To achieve an emissions reduction of 4.5%, the carbon permit price is estimated to be around US$8.91/t$CO_2$eq when only ETS is implemented (Scenario_2 (a)). The carbon price grows slightly when recycling policies are added, with the price of US$9.43/t$CO_2$eq in Scenario_2 (b) and US$9.51/t$CO_2$eq in Scenario_2 (c). Compared to other Scenarios, the price in Scenario_2 (c) is much higher than others because it seems that new revenue transferred to households results in a higher demand for goods and services as well as higher investment in production. Therefore, demand for carbon emissions from firms might be higher, and consequently the carbon price goes up. The carbon price in Scenario_2 (b) increases but at a lower level, it is supposedly that the policy of transferring to the government would not stimulate production much as transferring new revenue to households. In terms of revenue, the auction revenue in Scenario_2 (c) is highest at VND 44.06 trillion, accounting for 0.95% of GDP, due to the highest increase in carbon price.

Table 5.5. Macro-economic and environmental impacts of the ETS policy options

	Scenario_2		
	(a)	*(b)*	*(c)*
ECONOMIC (% CHANGE)			
GDP	-0.822	0.253	0.236
Government consumption	0.000	4.017	0.000
Household consumption	-1.039	-0.737	0.298
Investment	-0.604	1.888	-0.101
Exports	-0.113	0.091	0.145
Imports	-0.130	0.071	0.072
WELFARE			
EV (Trillion VND)	-28.572	-20.259	29.394
EV/GDP (%)	-0.625	-0.438	0.636
ENVIRONMENT			
Carbon price (US$/tCO2eq)	8.924	9.432	9.507
ETS Revenue (Trillion VND)	41.335	43.738	44.056

Regarding economic impacts, the ETS policy in isolation leads to a drop in GDP of 0.82%. However, when recycling policies are combined, the GDP is improved with a growth rate of 0.25% in Scenario_2 (b) and 0.24% in Scenario_2 (c). In detail, household consumption decreases to 1.04% in Scenario_2 (a) and slightly improves with the reduction rate of 0.74% in Scenario_2 (b) and increases by 0.3% in Scenario_2 (c). The investment is much better in Scenario_2 (b) with the growth rate of 1.89%, it is mainly due to the increase in investment of government. In Scenario_2 (c), the investment reduces by 0.1%. Exports and imports are down by 0.11% and 0.13%, respectively in Scenario_2 (a) because of the demand for consumption and intermediate inputs for production decrease. However, when demand and production are improved, exports and imports are also enhanced in Scenario_2 (b) and Scenario_2 (c). It is clear that all economic indicators improve when new revenue from implementing the ETS policy is used.

In terms of welfare, the results reveal that welfare is materially affected in Scenario_2 (a) when there are no compensation policies. In detail, welfare declines by VND 28.57 trillion in Scenario_2 (a), which accounts for 0.63% of GDP. When the revenue is transferred to government activities (Scenario_2 (b)), the negative effect on welfare is lower with a decline of VND 20.26 trillion, accounting for 0.44% of GDP. These effects are caused by the increase in prices and the decrease in household income and consumption. However, when the revenue is used for households by reducing income tax (Scenario_2 (c)), welfare becomes positive. It means that the income tax cut is sufficient to offset the negative effects caused by the ETS on welfare even though the increase is very light at VND 29.4 trillion (0.64% of GDP) (Table 5.5).

The results confirm that recycling policies could lighten the negative impacts of ETS and result in a “double dividend” when the revenue is used in the right way. It is clear that transferring new revenue for consumption and investment of government could lead to improve GDP growth while using the new revenue for households via income tax cut could lead to an increase in welfare.

Compared with redistribution policies under the ETS scheme, the redistributed revenue under the carbon tax scheme is slightly better in terms of economic effects, with higher improvement in GDP and welfare. It can be explained that under the carbon tax, the carbon reduction level is not controlled, firms can choose to expand their production and then emit more emissions when they have more resources while under ETS, the controlled emission level, it is harder to expand their production even when they have more resources. However, in terms of environmental effects, the revenue redistribution policies under ETS are more effective because of the control of emission targets whereas these policies under carbon tax might cause a rebound in emissions.

Table 5.6. Carbon emissions reduction by sector under the ETS policy options

Unit: %

Sector	Scenario_2		
	(a)	*(b)*	*(c)*
Agriculture	-0.310	-0.270	-0.159
Coal mining	-1.426	-1.505	-1.476
Crude oil	-1.064	-1.029	-1.122
Natural gas	-0.447	-0.468	-0.323
Other mining	-0.611	-0.647	-0.626
Food and tobacco	-0.353	-0.332	0.003
Textile and leather	-0.696	-0.701	-0.634
Wood products	-0.210	-0.226	-0.189
Petroleum products	-0.019	-0.024	0.029
Chemicals	-0.128	-0.161	-0.110
Mineral	-0.239	-0.263	-0.231
Metal	-0.247	-0.312	-0.282
Machinery	-0.852	-0.263	-0.512
Other manufacturing	-0.477	-0.337	-0.228
Electricity generation	-11.638	-11.978	-11.938
Construction	-2.317	-0.295	-1.522
Transportation	-0.074	-0.065	0.169
Other services	-0.257	0.008	-0.005

Regarding sectoral impacts, Table 5.6 shows that carbon emissions reduce in all sectors with different levels. The carbon emissions decrease due to the production shrinks when facing higher costs from the ETS policy and the decline in demand. Specifically, in Scenario_2 (a), the electricity generation sector is the main contributor in mitigating carbon emissions with a reduction rate of 11.63% (9.03 $MtCO_2eq$), accounting for 89.6% of total carbon emissions, followed by construction and coal with a rate of 2.32% (3.86 $MtCO_2eq$) and 1.48% (0.59$MtCO_2eq$) respectively. With recycling policies in Scenario_2 (b) and Scenario_2 (c), the electricity generation sector still mainly contributes to the total emissions reduction. The trend of reducing carbon emissions remains the same, but the level changes are different between the two recycling options. If the revenue is used for government activities, the emissions from construction and heavy industry such as machinery will be less than in Scenario_2 (a). On the other hand, if the revenue is transferred to households through an income tax cut, the emissions from electricity and light industries such as food and tobacco are lower than in Scenario_2 (a). This is because the output reductions of industries are different when the revenue is transferred to different objects (Table 5.7).

Table 5.7. Output change by sector under the ETS policy options

Unit: %

Sector	**Scenario_2**		
	(a)	***(b)***	***(c)***
Agriculture	-0.431	-0.376	-0.222
Coal mining	-1.683	-1.777	-1.742
Crude oil	-1.284	-1.242	-1.354
Natural gas	-0.717	-0.751	-0.519
Other mining	-0.854	-0.903	-0.875
Food and tobacco	-0.380	-0.358	0.003
Textile and leather	-0.888	-0.895	-0.809
Wood products	-0.235	-0.253	-0.211
Petroleum products	-0.020	-0.025	0.031
Chemicals	-0.144	-0.181	-0.123
Mineral	-0.279	-0.308	-0.270
Metal	-0.281	-0.355	-0.321
Machinery	-0.932	-0.288	-0.560
Other manufacturing	-0.587	-0.415	-0.280
Electricity generation	-15.060	-15.482	-15.433
Construction	-3.008	-0.386	-1.981
Transportation	-0.096	-0.083	0.218
Other services	-0.422	0.013	-0.008

Obviously, without recycling policies, all sectors witness a drop in their outputs because of increasing production costs when ETS is implemented (Table 5.7). The electricity sector with the highest carbon intensity faces higher costs. Consequently, its output seriously suffers from the new policy, with the highest output reduction rate of 15.06% (VND 29.02 trillion) in Scenario_2 (a). In addition, from the demand side, when all sectors decline their output, the demand for electricity also drops because electricity is one of the main input factors for production. The coal sector is the upstream sector of electricity since it is the main input for electricity generation in Vietnam. When the electricity sector output declines, demand for coal also falls. Therefore, coal output decreases strongly with a reduction rate of 1.68% (VND 1.95 trillion). It is noted that construction output also experiences a significant decrease of 3.0% (VND 24.75 trillion), which means that the economy shrinks, and then the demand for construction and expanding production falls.

Reuse of the revenue leads to the changes in outputs of all sectors. Compared with the sole ETS policy in Scenario_2 (a), when the revenue finances government activities in Scenario_2 (b), the outputs of heavy industries such as machinery and construction increase. It is because, in Vietnam, public investment is mainly for construction to improve the infrastructure. When the government budget is financed, the demand for construction would increase and then its output would increase. In addition, the public sector also owns large businesses in heavy industry, therefore, when the revenue from ETS policy is transferred to the government, the outputs of these sectors would be improved.

On the other side, compared with Scenario_2 (a), when the revenue is used for households via cutting income tax in Scenario_2 (c), the outputs of many industries increase, especially construction, light industries, and services. It seems that reducing income tax leads to an increase in household demand for consumer goods, construction, and services. It is noted that in both redistribution scenarios, outputs of agriculture, construction, transportation, and services improve (Table 5.7). However, electricity, coal, and other mining outputs decrease when the revenue is used. It is due to the increase in carbon price, the electricity generation sector decides to reduce its outputs and sell its carbon permits, which also leads to reduction of fossil fuel demand and production.

In general, recycling policies could lead to an improvement in the outputs of some sectors depending on what is the objective of recycling policies. Due to the difference in demand and investment between the public and private sectors, the changes among sectors vary. In all three scenarios, the electricity output reduction is extremely high, which may cause concerns about ensuring electricity security for production and consumption. Compared with redistribution policies under the carbon tax scheme, the redistribution policies under the ETS lead to a lower improvement in output levels of all sectors. Consequently, the emissions reduction levels of all sectors under ETS are higher than under the carbon tax.

5.5 Conclusions

This Chapter uses the CGE model to analyze the impact of revenue redistribution options under the carbon pricing schemes on the economy, welfare, and environment in Vietnam.

First of all, this study confirms that recycling policies would generate better impacts on GDP and welfare. Under the carbon tax scheme, recycling policies could lead to higher GDP growth and welfare than under the ETS. However, revenue redistribution under the carbon tax could reduce the impacts of the carbon tax on mitigating emissions, even distorting the original goal of the carbon tax policy with a sign of rebound emissions.

Secondly, the results show the possibility of generating a "double dividend" effect of recycling policies under the ETS scheme. The new revenue transferred to households could lead to improving GDP and welfare while the carbon emission level is controlled. However, recycling policies can cause an increase in the carbon permit price due to an increase in demand for emissions and then cause more reduction in the electricity output. It is noted that the electricity output significantly suffers under ETS and warning risks for electricity security in economic development. Therefore, additional support policies for the electricity generation sector are considered in this case even when a "double dividend" effect is found.

Thirdly, carbon pricing revenue reused for government activities leads to improvement in GDP better than the revenue redistribution to households, but the redistribution to households generates better effects on welfare. In addition, due to the different demands and investments between the public and private sectors, the reuse revenue for government activities produces improved outputs for the construction industry and some heavy industries while the recycling policy for the households creates improvements for the light industries and service sectors.

This study shows that recycling policies can affect the effectiveness of carbon pricing policies, different recycling policies will cause different impacts on production, consumption, etc. Therefore, this study suggests that the government should consider the costs and benefits of recycling policy options as well as priorities in each phase to select appropriate redistribution options. To improve the effectiveness of the carbon pricing policies, recycling policies should be considered in parallel with the carbon pricing policy. Although research has attempted to consider some recycling policies to limit the negative impacts of carbon pricing, further research is needed to provide a more complete picture of redistributing carbon pricing revenues.

Chapter 6: Discussions and Conclusions

6.1 Review of research

To mitigate GHG emissions, the Vietnamese government introduced carbon pricing in the Revised Environmental Protection Law in 2020. This dissertation studied the impacts of carbon pricing implementation in Vietnam by using static CGE models.

Chapter 2 presented an overview of climate change and the increase in GHG emissions in the world and Vietnam. In this chapter, mitigation policies were also introduced and analyzed. In Vietnam, although the Vietnamese government has introduced a lot of regulations on emissions reduction as well as changed its economic development strategy, these measures have not led to significant emissions reduction. To achieve Vietnam's NDC targets, carbon pricing was introduced in the Law with the expectation that this measure would be an effective tool to support meeting its targets.

Chapter 3 developed a national static CGE model to analyze the potential impact of a carbon tax in Vietnam. Based on the literature review and references from other countries that have implemented a carbon tax, this chapter designed carbon tax scenarios for Vietnam and analyzed different impacts of carbon tax under various scenarios. It investigated the changes in GDP growth, price, welfare, and emissions levels since the policy implementation. By comparing different carbon prices, it examined the differential effects manifested in the economy at the macro level and sectoral level. Besides the impacts on GDP and welfare, other characteristics such as revenue, and sectoral output changes were also reviewed. In addition, as a contribution to the design of carbon pricing, the study extended the sector coverage of carbon tax to all sectors with a flexible carbon tax mechanism, which more fully captures of the emissions released from the economic activities. This enabled policymakers flexibility in choosing the levels of carbon price as well as sectors covered by tax in each stage throughout its implementation. In summary, this chapter developed a national static CGE model with a flexible carbon tax mechanism and showed the potential impacts of the carbon tax on the economy and environment in Vietnam.

In Chapter 4, based on the emissions reduction targets in Vietnam's NDC, the study designed ETS scenarios and analyzed the impacts of ETS in Vietnam with these targets. Different from Chapter 3, this chapter focuses on the trade-off to achieve Vietnam's NDC targets by implementing ETS. By using a national static CGE model, this chapter examined the loss in GDP, and welfare when ETS is implemented to achieve Vietnam's NDC targets. This chapter also examined the corresponding carbon prices to achieve respective NDC targets. The changes in average price, revenue, sectoral output, sectoral emission levels, and emission trading among sectors since the ETS implementation are also considered in this chapter. Furthermore, by setting the same emissions reduction level and same sector coverage as Chapter 3, this chapter compared the impacts of ETS and carbon tax on the economy and environment.

Throughout the analyses in Chapter 3 and Chapter 4, carbon pricing showed its negative impact on GDP and welfare. Carbon pricing also raised revenue from tax collection or carbon permit auctions. Therefore, in Chapter 5, reuse of carbon pricing revenue was analyzed with the expectation of reducing the negative impacts of carbon pricing on GDP and welfare. By considering revenue redistribution to households and government activities, this study showed that revenue redistribution impacts the effectiveness of carbon pricing. These recycling policies contributed to changing the economic and environmental impacts of carbon pricing. In addition, by comparing carbon tax revenue recycling and ETS revenue recycling, this chapter showed the harmony levels of carbon pricing mechanisms with revenue redistribution policies.

6.2 Main findings and Further discussions

This study shows that carbon pricing has an impact on mitigating emissions in Vietnam, however, such a policy also has negative economic and welfare impacts. First, the study indicates that applying a carbon tax with too low carbon prices at US$1/t$CO_2$eq would create a negligible emissions reduction at 0.48% when the carbon tax is imposed on all sectors and 0.21% when the carbon tax is levied on energy sectors. Therefore, an appropriately higher carbon price is necessary for Vietnam. However, with a higher carbon price corresponding to other countries in the region as well as the same conditions at US$10/t$CO_2$eq for all industries, the emissions reduction level only reaches 4.5%, lower than the expected emissions reduction level of countries in the region as well as much lower than the emissions reduction target in the latest Vietnam's NDC. This carbon price level also causes a strong negative impact on the economy and welfare with a reduction of 2.3% in GDP and VND 131.2 trillion in welfare. This shows that if Vietnam only applies a carbon tax, it will be quite difficult to achieve its goal in NDC as well as cause strong negative impacts on growth and welfare.

Second, to achieve the emissions reduction targets in Vietnam's NDC through the ETS mechanism only, the carbon prices are also quite high, much higher than countries with the same conditions at early stages of implementing carbon pricing. With the latest emissions reduction target of 15.8% in Vietnam's NDC, the carbon price under ETS is US$56.6/t$CO_2$eq. To achieve this target, the loss of GDP and welfare is also quite high, with a drop of 3.69% in GDP and VND 128.34 trillion in welfare. With the emissions reduction target of 9%, the carbon price is US$ 23.3/tCO_2eq and ETS leads to a GDP reduction of 1.6%, and a welfare decline of VND 55.8 trillion. Besides, the ETS has a strong sectoral concentration impact, with a significant output drop in the electricity sector, which can cause risks in ensuring electricity security for production. Achieving the targets in the NDC through solely ETS mechanism also causes a great disadvantage to the economy. Therefore, a lower emissions reduction target at early stages of ETS implementation in Vietnam is necessary for the economy to gradually adapt to the new policy.

Third, with the same emissions reduction level, the carbon tax has a more negative impact on GDP and welfare than ETS. In detail, with emissions reduction of 4.5%, the carbon tax leads to the decrease of 2.3% in GDP and VND 131.2 trillion in welfare while the figures for ETS are 0.8% in GDP and VND 28.6 trillion in welfare. However, the carbon tax impact on industries is more dispersed than the ETS impact. Particularly, under ETS, the electricity sector output drops at the reduction rate of 15.06%, and other sectors slightly decrease, whereas, under the carbon tax, the electricity output decreases by 7.3%, and other sectors moderately decrease. Therefore, ETS has a better overall impact, but ETS would cause significant unbalance at the sectoral level and consequently, ETS would lead to the lack of necessary input for production in some cases such as the ability to provide electricity to react promptly to sudden changes in the supply-demand balance or the lack of electricity in peak periods.

Fourth, both carbon tax and ETS have an impact on industry restructuring, the industries with high carbon intensity all shrink their production stronger than other industries, specifically electricity, other energy sectors, construction, and some manufacturing industries such as textile and leather, and machinery reduce their output drastically while the production contraction in other industries is insignificant. It can be explained that a price on carbon results in increased emission costs and then production costs, consequently, the sectors with higher carbon intensity face higher emissions costs, then these sectors are affected by carbon pricing policy more than others. This finding also implies that carbon pricing has an impact on leading the economy toward a greener economic structure. However, it should be noted that the electricity generation in Vietnam is mainly from coal, its carbon intensity is exceptionally higher than others, causing this industry most suffer from the carbon pricing policy, but this sector provides essential input for the production of other sectors. Therefore, a significant decline in the electricity output also raises concerns of ensuring electricity security for economic development.

Fifth, this study shows that the reuse of carbon pricing revenue could lighten the negative impacts of carbon pricing on economic growth and welfare. While carbon pricing revenue reused for government activities leads to better improvement in GDP, the revenue transferring to households generates better effects on welfare. In addition, the reuse revenue for government activities would improve outputs for the construction industry and some heavy industries because the public investment is mainly for infrastructure and heavy industries in Vietnam. In contrast, the recycling policy for households would create improvements for the light industries and service sectors due to the higher demand for consumer goods.

Sixth, the carbon tax revenue reuse could improve GDP and welfare better than the ETS revenue reuse. However, under the carbon tax scheme, the revenue reuse could lead to emissions rebound effect. Meanwhile, a “double dividend” effect of recycling policies under the ETS scheme is found. The ETS revenue used for households could lead to improving GDP and welfare while the carbon emission level is controlled. However, under the ETS scheme, recycling policies cause more reduction in the electricity output. It is noted that the electricity output is significantly suffered under pure ETS policy so if this output decreases more, it is a warning of risks in ensuring electricity security in economic development.

6.3 Conclusion and Policy implications

Climate change caused by increasing GHG emissions has become a major challenge to the world. Carbon pricing is a market-based tool to tackle this global environmental issue. Studies in this dissertation show the impacts of carbon pricing in Vietnam. Based on the findings of the study, the following conclusions could be drawn:

Carbon pricing is an effective way to curb GHG emissions in Vietnam. In general, carbon pricing leads to an increase in production costs, then the businesses would change their business strategies to reduce their emission costs. Both carbon tax and ETS would lead to emissions reduction, but the reduction levels are different depending on carbon pricing mechanisms, carbon price, and sector coverages as well as revenue redistribution policy. Therefore, while carbon pricing is a necessary tool in emission mitigation strategy in Vietnam, designing carbon pricing and revenue redistribution policies should be considered carefully.

This study also shows that carbon taxes with a carbon price similar to that of countries in the region and the same conditions would reduce emissions at a fairly low level. Under the carbon tax scheme, the carbon prices of $1-10/tCO_2eq are not enough to achieve the emissions reduction goals in Vietnam's NDC, even if the carbon tax covers all sectors. Meanwhile, the carbon tax has negative impacts on GDP and welfare. Reusing carbon tax revenue for governments and households would reduce these negative impacts but cause worse environmental effects. Thus, the goals in the NDC are even more difficult to achieve if these revenue redistribution options are applied. To achieve the targets in NDC, carbon taxes should be applied with other environmental policies such as the carbon tax revenue can be used for improving technology toward low-carbon intensity technology or promoting the use of renewable sources.

Researching emission targets in Vietnam's NDC through the ETS mechanism, it can be seen that the carbon price to achieve the targets in the NDC is quite high. It is much higher than the carbon price applied at the early stages of ETS implementation in other countries. In addition, to achieve NDC targets, the loss of GDP and welfare are also quite high. The policy of using ETS revenue would create double dividends. However, the ETS policy options have a strong concentrated impact on the electricity sector. Therefore, if ETS is applied, additional policies related to the electricity generation industry need to be considered to ensure electricity supply. In addition, other environmental policies should also be done together with ETS to enhance the possibility of achieving the country's targets in NDC.

Moreover, as discussed above, to achieve the carbon emissions reduction target in Vietnam's NDC, the loss of GDP and welfare is quite severe. Therefore, carbon pricing in

Vietnam needs to be strengthened step by step so that businesses can gradually change their business strategies and production processes to meet new conditions. A low carbon price or lower emissions reduction target at early stages of carbon pricing implementation should be set, which assists businesses in adapting the new policy. The carbon price level or emissions reduction targets could be increased at subsequent stages to ensure the achievement of the goals of the NDC.

The comparison between ETS and carbon tax presents that although ETS seems to be more effective in terms of macro indicators, the ETS' concentrated impact on the electricity sector could cause a huge shock to the economy. This result implies that when the country chooses carbon pricing mechanisms, not only the macro impact should be considered, but the impact on each industry should also be analyzed. Both carbon tax and ETS tend to change industry structure, from carbon-intensive industries to less carbon-intensive industries. However, each economic sector has its position and role in other sectors. A serious decline in some sectors, especially important input sectors such as electricity generation sector, could cause a shock to the economy. Therefore, the policy assessment at both the macro level as well as the industry level at each stage is necessary to adjust goals as well as design appropriate mechanisms at subsequent stages.

Electricity generation sector is the main contributor to reducing emissions in all carbon pricing options. However, its output also declines drastically and causes concern of electricity security for economic development. Therefore, this study suggests that electricity should be the main point of environmental policy in Vietnam. In order to ensure electricity supply for production and consumption, the policies to control and support the electricity sector at the first stage should be done. However, in the long term, Vietnam needs to consider technology improvement as well as transfer to renewable energy toward reducing the carbon intensity of this sector.

Finally, it can be seen that the design of carbon pricing has a strong impact on the effectiveness of carbon pricing policy. Although carbon pricing is quite popular and has proven its effectiveness in reducing emissions in developed countries such as the EU countries, Canada, and Australia, these policies are still quite new, and their effectiveness has not been observed in developing countries. Therefore, the assessments of the impacts of carbon pricing are necessary to adjust policies to suit national conditions. This study is an example of the possible foreseen impacts of carbon pricing in a developing country and a reference for countries with similar conditions.

6.4 Limitations and Further research

Although the study attempts to examine the impacts of carbon pricing in Vietnam, there are some uncertainties and limitations.

A static CGE model has inherent limitations. A static CGE model only analyzes the impacts of carbon pricing in the short run. Therefore, the change in production technologies and innovation are not considered. In addition, due to the lack of data, the research does not consider the transition from fossil fuels to renewable energy. Although these factors could affect the results, the transition process from fossil fuels to renewable energy and technology improvement needs time, especially for developing countries such as Vietnam. In the short term, this study provides specific evidence to compare the economy without and with carbon pricing as well as compare the economy with different carbon pricing scenarios for a single period. However, further studies on incorporating innovation and transitions into the model and simulating the long-run effects of carbon pricing should be done to support carbon pricing implementation at subsequent stages. These points can be solved by developing a dynamic model or updating the SAM table for the static model. The static model can be used for at subsequent stages by updating SAM data and it can be done when Vietnam publishes new SAM tables. Meanwhile, further research on developing dynamic models should also be considered for simulating the long-run impacts of carbon pricing. A dynamic CGE model allows tracing each variable over time, thus reflecting the changes in the economy. In addition, the dynamic model allows for examining long-term effects and thus supports for designing and adjusting policy in the long term.

In this dissertation, macroeconomic and sectoral impacts of carbon pricing have been considered, however, studies on more specific impacts can support policy implementation. For example, this study showed that carbon pricing would assist in mitigating emissions in the country, but to achieve Vietnam's NDC targets, the loss in GDP and welfare are quite high. This study suggests some revenue redistribution policies to lighten these impacts. However, this study also showed that those policy options still result in negative impacts on some aspects. Other additional policies along with the carbon pricing policy should be analyzed to minimize and offset adverse impacts and enhance positive impacts. This research only considered the reuse of carbon pricing revenue for the purpose of lightening its negative impacts on the economy while carbon pricing revenue could be used for other environment-related purposes such as investing in low carbon emissions technologies and allocating to specific projects (e.g. implementation of renewable energy activities). In addition, this study also showed the electricity sector is the main contributor to emissions mitigation, but its production adversely suffers from carbon pricing policy. Therefore, further studies on the electricity sector such as research on disaggregating the electricity generation sector into various electricity-generated categories (e.g. coal, oil, gas, and renewable energy) to improve the accuracy of the carbon emission intensity of each electricity generation type; research on substitution between electricity generated from different energy sources to analyze the effect of carbon pricing on energy transition in electricity generation should be considered for supplementing carbon pricing implementation. Other topics should also be considered such as the distributional and welfare impacts of carbon pricing by income groups and other measures for transferring carbon pricing revenue to households; the combination of ETS and carbon tax. Finally, this study only simulates the economic and environmental impacts of carbon pricing while other impacts or costs of implementing carbon pricing such as administration costs or institutional or political issues are not considered. Thus, research assessing the costs and benefits of the policy would provide more accurate views for policymakers in implementing carbon pricing in Vietnam.

References

Aatola, P., Ollikainen, M., & Toppinen, A. (2013). Price determination in the EU ETS market: Theory and econometric analysis with market fundamentals. *Energy Economics*, *36*, 380–395. https://doi.org/https://doi.org/10.1016/j.eneco.2012.09.009

Akin-Olçum, G., Ghosh, M., Gilmore, E., Johnston, P., Khabbazan, M. M., Lubowski, R., Mccallister, M., Macaluso, N., Peterson, S., Winkler, M., Duan, M., Li, M., Parrado, R., & Rausch, S. (2022). A Model Intercomparison of the Welfare Effects of Regional Coalitions for Ambitious Climate Mitigation Targets. *Climate Change Economics*, 14(2). https://doi.org/10.1142/S2010007823500094

Alexeeva, V., N. Anger. (2016). The globalization of the carbon market: Welfare and competitiveness effects of linking emissions trading schemes. *Mitig. Adapt. Strateg. Glob. Chang.*, 21 (2016), pp. 905-930. 10.1007/s11027-014-9631-y

An, K., Zhang, S., Zhou, J., & Wang, C. (2023). How can computable general equilibrium models serve low-carbon policy? A systematic review. *Environmental Research Letters*, *18*(3). https://doi.org/10.1088/1748-9326/acbbe2

Antosiewicz, M., Fuentes, J. R., Lewandowski, P., & Witajewski-Baltvilks, J. (2022). Distributional effects of emission pricing in a carbon-intensive economy: The case of Poland. *Energy Policy*, *160*, 112678. https://doi.org/https://doi.org/10.1016/j.enpol.2021.112678

Babatunde, K.A., Begum, R.A., Said, F.F., (2017). Application of computable general equilibrium (CGE) to climate change mitigation policy: a systematic review. *Renew. Sustain. Energy Rev.* 78, 61–71.

Babiker, M. H., Jacoby, H. D., Reilly, J. M., & Reiner, D. M. (2002). The evolution of a climate regime: Kyoto to Marrakech and beyond. *Environmental Science and Policy*, *5*(3), 195–206. https://doi.org/10.1016/S1462-9011(02)00035-7

Barragán-Beaud, C., Pizarro-Alonso, A., Xylia, M., Syri, S., Silveira, S., 2018. Carbon tax or emissions trading? An analysis of economic and political feasibility of policy mechanisms for greenhouse gas emissions reduction in the Mexican power sector. *Energy Policy* 122, 287–299. https://doi.org/10.1016/j.enpol.2018.07.010.

Benavides, C., Gonzales, L., Diaz, M., Fuentes, R., García, G., Palma-Behnke, R., & Ravizza, C. (2015). The Impact of a Carbon Tax on the Chilean Electricity Generation Sector. *Energies*, 8(4), 2674–2700. https://doi.org/10.3390/en8042674

Bi, H., Xiao, H., Sun, K., 2019. The impact of carbon market and carbon tax on green growth pathway in China: a dynamic CGE model approach. *Emerging Markets Financ. Trade* 55 (6), 1312–1325.

Böhringer C., S. Peterson, T.F. Rutherford, J. Schneider, M. Winkler. (2021). Climate Policies after Paris: Pledge, Trade and Recycle: Insights from the 36th Energy Modeling Forum Study (EMF36). *Energy Econ.*, 103 (2021), p. 105471. 10.1016/j.eneco.2021.105471.

BP. (2022). BP Statistical Review of World Energy 2022 (71st edition). In *Bp*. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2022-full-report.pdf

Brink, C., Vollebergh, H. R. J., & van der Werf, E. (2016). Carbon pricing in the EU: Evaluation of different EU ETS reform options. *Energy Policy*, 97, 603–617. https://doi.org/https://doi.org/10.1016/j.enpol.2016.07.023

Cao, Jing, Hancheng Dai, Shantong Li, Chaoyi Guo, Mun Ho, Wenjia Cai, Jianwu He, et al. (2021). The General Equilibrium Impacts of Carbon Tax Policy in China: A Multi-Model Comparison. *Energy Economics* 99: 105284. https://doi.org/10.1016/j.eneco.2021.105284.

Carl, J., and Fedor, D. (2016). Tracking Global Carbon Revenues: A Survey of Carbon Taxes versus Cap-And-Trade in the Real World. *Energy Policy* 96, 50–77. doi:10.1016/j.enpol.2016.05.023

Choi Y, Liu Y, Lee H. (2017). The economy impacts of Korean ETS with an emphasis on sectoral coverage based on a CGE approach. *Energy Policy* 109:835–44. https://doi.org/10.1016/j.enpol.2017.06.039.

Coxhead, Ian, Anan Wattanakuljarus, and Chan V. Nguyen. 2013. Are Carbon Taxes Good for the Poor? A General Equilibrium Analysis for Vietnam. *World Development* 51: 119–31.

Creti, A., Jouvet, P.-A., & Mignon, V. (2012). Carbon price drivers: Phase I versus Phase II equilibrium? *Energy Economics*, *34*(1), 327–334. https://doi.org/https://doi.org/10.1016/j.eneco.2011.11.001

Dellink R, Jamet S, Chateau J, Duval RA. (2014). Towards global carbon pricing: direct and indirect linking of carbon markets. *Econ Stud*;2013(1):209–34. https://doi.org/10.1787/eco_studies-2013-5k421kk9j3vb

Dixon, P.B., Jorgenson, D., (2013). *Handbook of Computable General Equilibrium Modeling* SET, 1A, and 1B. Newnes.

Fay, M., Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Narloch, U., & Kerr, T. (2015). *Decarbonizing Development: Three Steps to a Zero-Carbon Future.* (Issue 1). https://openknowledge.worldbank.org/entities/publication/31452b7e-bc43-5ce8-a7f7-4a9b814d5324

Fujimori, S., Hasegawa, T., Masui, T., Takahashi, K., Herran, D. S., Dai, H., Hijioka, Y., & Kainuma, M. (2017). SSP3: AIM implementation of Shared Socioeconomic Pathways. *Global Environmental Change*, *42*, 268–283. https://doi.org/10.1016/j.gloenvcha.2016.06.009

Fujimori, S., Kubota, I., Dai, H., Takahashi, K., Hasegawa, T., Liu, J.-Y., Hijioka, Y., Masui, T., & Takimi, M. (2016). Will international emissions trading help achieve the objectives of the Paris Agreement? *Environmental Research Letters*, *11*(10), 104001. https://doi.org/10.1088/1748-9326/11/10/104001

Guo, Zhengquan, Xingping Zhang, Yuhua Zheng, and Rao Rao. (2014). Exploring the Impacts of a Carbon Tax on the Chinese Economy Using a CGE Model with a Detailed Disaggregation of Energy Sectors. *Energy Economics* 45 (2014): 455–62. https://doi.org/10.1016/j.eneco.2014.08.016.

Herbert, Wibert Hasudungan Victor. (2017). The Impacts of Impleminting the Carbon Tax on Fossil Fuels: A Hybrid CFE Analysis for Indonesia. *Scientific Contributions Oil and Gas* 40 (2): 91–105.

Hu, H., Dong, W., & Zhou, Q. (2021). A comparative study on the environmental and economic effects of a resource tax and carbon tax in China: Analysis based on the computable general equilibrium model. *Energy Policy*, 156, 112460. https://doi.org/https://doi.org/10.1016/j.enpol.2021.112460

Hutfilter, U. F., Parra, P. Y., Zimmer, A., Ancygier, A., Saeed, F., Brecha, R., Hare, B., Granadillos, J., Aboumahboub, T., Ganti, G., Kelischek, I., & Schaeffe, R. V. C.-F. S. M. (2019). COUNTRY PROFILE VIETNAM: DECARBONISING SOUTH ANND SOUTHEAST ASIA (Issue May).

Ian Parry, Simon Black, and K. Z. (2022). Carbon Taxes or Emissions Trading Systems? Instrument Choice and Design. In *IMF Staff Climate Note 2022/006*. International Monetary Fund, Washington, DC.

IMF. (2019). *Fiscal Policies for Paris Climate Strategies —From Principle to Practice* (Policy Paper No. 19/136; Issue May). https://www.imf.org/en/Publications/Policy-Papers/Issues/2019/05/01/Fiscal-Policies-for-Paris-Climate-Strategies-from-Principle-to-Practice-46826

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, Geneva, Switzerland, 151 pp.

IPCC. (2023). *Syntheis Report of the IPCC Sixth Assessment Report (AR6) Summanry*. IPCC, Geneva, Switzerland.

Jia, Z. (2023). What kind of enterprises and residents bear more responsibilities in carbon trading? A step-by-step analysis based on the CGE model. *Environmental Impact Assessment Review*, *98*, 106950. https://doi.org/https://doi.org/10.1016/j.eiar.2022.106950

Jia, Z., & Lin, B. (2020). Rethinking the choice of carbon tax and carbon trading in China. *Technological Forecasting and Social Change*, *159*(December 2019), 120187. https://doi.org/10.1016/j.techfore.2020.120187

Jiang, M., Zhu, B., Chevallier, J., and Xie, R. (2018). Allocating Provincial CO2 Quotas for the Chinese National Carbon Program. *Aust. J. Agric. Resour. Econ.* 62, 457–479. doi:10.1111/1467-8489.12261

Kat B, Paltsev S, Yuan M. (2018). Turkish energy sector development and the Paris Agreement goals: A CGE model assessment. Energy Policy 122:84–96. https://doi.org/10.1016/j.enpol.2018.07.030.

Kawase, A., Y. Kitaura, and K. Hashimoto. (2003). Environmental tax and the double dividend: a computational general equilibrium analysis. *Public Choice Studies (Kokyo Sentaku No Kenkyu)*41 (2003): 5-23.

Koch, N., Fuss, S., Grosjean, G., & Edenhofer, O. (2014). Causes of the EU ETS price drop: Recession, CDM, renewable policies or a bit of everything? New evidence. *Energy Policy*, *73*, 676–685. https://doi.org/https://doi.org/10.1016/j.enpol.2014.06.024

Li W., Jia Z. (2016). The impact of emission trading scheme and the ratio of free quota: A dynamic recursive CGE model in China. *Appl Energy* 174:1–14. https://doi.org/10.1016/j.apenergy.2016.04.086

Li, W., Jia, Z. (2017). Carbon tax, emission trading, or the mixed policy: which is the most effective strategy for climate change mitigation in China? *Mitigation and Adaptation Strategies for Global Change*, 22(6), 973–992. https://doi.org/10.1007/s11027-016-9710-3

Li, M., Weng, Y., & Duan, M. (2019). Emissions, energy and economic impacts of linking China's national ETS with the EU ETS. *Applied Energy*, *235*(November 2018), 1235–1244. https://doi.org/10.1016/j.apenergy.2018.11.047

Li, Yingzhu, and Bin Su. (2017). The Impacts of Carbon Pricing on Coastal Megacities: A CGE Analysis of Singapore. *Journal of Cleaner Production* 165: 1239–48. https://doi.org/10.1016/j.jclepro.2017.07.206.

Lin B, Jia Z. (2019). Energy, economic and environmental impact of government fines in China's carbon trading scheme. *Sci Total Environ* 667:658–70. https://doi.org/10.1016/j.scitotenv.2019.02.405.

Lin B, Jia Z. (2020). Is emission trading scheme an opportunity for renewable energy in China? A perspective of ETS revenue redistributions. *Appl Energy* 263:114605. https://doi.org/10.1016/j.apenergy.2020.114605.

Lin, B., & Jia, Z. (2017). The impact of Emission Trading Scheme (ETS) and the choice of coverage industry in ETS: A case study in China. *Applied Energy*, *205*(March), 1512–1527. https://doi.org/10.1016/j.apenergy.2017.08.098

Lin, B., & Jia, Z. (2018). Impact of quota decline scheme of emission trading in China: A dynamic recursive CGE model. *Energy*, *149*(2018), 190–203. https://doi.org/10.1016/j.energy.2018.02.039

Liu, Weijiang, Yangyang Li, Tingting Liu, Min Liu, and Hai Wei. (2021). How to Promote Low-Carbon Economic Development? A Comprehensive Assessment of Carbon Tax Policy in China. *International Journal of Environmental Research and Public Health* 18 (20). https://doi.org/10.3390/ijerph182010699.

Lu, Chuanyi, Qing Tong, and Xuemei Liu. (2010). The Impacts of Carbon Tax and Complementary Policies on Chinese Economy. *Energy Policy* 38 (11): 7278–85.

https://doi.org/https://doi.org/10.1016/j.enpol.2010.07.055.

Managi, S., & Kuriyama, K. (2017). *Environmental Economics*. Routledge, Taylor & Francis Group.

Mardones, C., & Ortega, J. (2021). Are the emissions trading systems' simulations generated with a computable general equilibrium model sensitive to the nested production structure? *Applied Energy*, 298(1191303). https://doi.org/10.1016/j.apenergy.2021.117222

Meng S, Siriwardana M, McNeill J, Nelson T. (2018). The impact of an ETS on the Australian energy sector: An integrated CGE and electricity modelling approach. *Energy Econ* 69:213–24. https://doi.org/10.1016/j.eneco.2017.11.017.

Meng, S., Siriwardana, M., & McNeill, J. (2013). The Environmental and Economic Impact of the Carbon Tax in Australia. *Environ Resource Econ* 54, 313–332 (2013). https://doi.org/10.1007/s10640-012-9600-4

Metcalf, G. E. (2021). Carbon taxes in theory and practice. *Annual Review of Resource Economics*, *13*, 245–265. https://doi.org/10.1146/annurev-resource-102519-113630

Nguyen, D. B., Nong, D., Siriwardana, M., & Pham, H. T. (2023). Insights from ASEAN-wide emissions trading schemes (ETSs): A general equilibrium assessment. *Energy Policy*, 178, 113583. https://doi.org/https://doi.org/10.1016/j.enpol.2023.113583

Nong D, Siriwardana M. (2015). Environmental impacts from a joint emissions trading at Country Level. *UNE Business School*. http://veam.org/wpcontent/uploads/2016/08/2015_14_Duy_Nong_Evironmental_impacts_from_a_joint_carbon_market.pdf

Nong, D., M. Siriwardana. (2018). The most advantageous partners for Australia to bilaterally link its emissions trading scheme. *Int. J. Glob. Warm.*, 15 (2018), pp. 371-391. 10.1504/IJGW.2018.093745

Nong, D., Meng, S., & Siriwardana, M. (2017). An assessment of a proposed ETS in Australia by using the MONASH-Green model. *Energy Policy*, *108*, 281–291. https://doi.org/https://doi.org/10.1016/j.enpol.2017.06.004

Nong, D., Nguyen, T. H., Wang, C., & Van Khuc, Q. (2020). The environmental and economic impact of the emissions trading scheme (ETS) in Vietnam. *Energy Policy*, *140*(January), 111362. https://doi.org/10.1016/j.enpol.2020.111362

Nong, Duy. (2018). General Equilibrium Economy-Wide Impacts of the Increased Energy Taxes in Vietnam. *Energy Policy* 123 (September): 471–81. https://doi.org/10.1016/j.enpol.2018.09.023.

Nong, Duy. (2020). Development of the Electricity-Environmental Policy CGE Model (GTAP-E-PowerS): A Case of the Carbon Tax in South Africa. *Energy Policy* 140 (March): 111375. https://doi.org/10.1016/j.enpol.2020.111375.

Pizer, W. A. (1997). Prices vs. Quantities Revisited: The Case of Climate Change. In *Resources for the Future: Vol. Discussion* (Issue October).

Qi, T., & Weng, Y. (2016). Economic impacts of an international carbon market in achieving the INDC targets. *Energy*, *109*(2016), 886–893. https://doi.org/10.1016/j.energy.2016.05.081

Rausch, S., Metcalf, G. E., & Reilly, J. M. (2011). Distributional impacts of carbon pricing: A general equilibrium approach with micro-data for households. *Energy Economics*, *33*(SUPPL. 1), S20–S33. https://doi.org/10.1016/j.eneco.2011.07.023

Stiglitz, J. E., & Rosengard, J. K. (2015). *Economics of the public sector* (Fourth edi). W. W. Nor ton & Company.

Tang L, Shi J, Bao Q. (2016). Designing an emissions trading scheme for China with a dynamic computable general equilibrium model. *Energy Policy*. 97:507–20. https://doi.org/10.1016/j.enpol.2016.07.039.

Thang N. Do. 2021. "Adding substance to Vietnam's climate commitments". Retrieved from https://www.eastasiaforum.org/2021/12/03/adding-substance-to-vietnams-climate-commitments/

Tran, Quang Minh. 2019. Projection of Fossil Fuel Demands in Vietnam to 2050 and Climate Change Implications. *Asia and the Pacific Policy Studies* 60 (1): 1–13. https://doi.org/10.1002/app5.274.

Tran, T. M., Siriwardana, M., Meng, S., & Nong, D. (2019). Impact of an emissions trading scheme on Australian households: A computable general equilibrium analysis. *Journal of Cleaner Production*, 221(2019), 439–456. https://doi.org/10.1016/j.jclepro.2019.02.273

UNDP, MPI, MOF, and USAID. 2018. *Opportunities for Carbon pricing in Vietnam*. Hanoi: UNDP.

United Nations. (1992). United Nations Framework Convention on Climate Change. Available online at: www.unfccc.int. Accessed on 06 April 2023.

United Nations. (1998). Kyoto Protocol to the United Nations Framework Convention on Climate Change. Available online at: www.unfccc.int. Accessed on 06 April 2023.

United Nations. (2016). Report of the Conference of the Parties on its twenty-first session. In *Framework Convention on Climate Change: Vol. 29 January*.

United Nations. (n.d.). About Carbon Pricing. https://unfccc.int/about-us/regional-collaboration-centres/the-ciaca/about-carbon-pricing?gclid=Cj0KCQjw27mhBhC9ARIsAIFsETEBzFdEnknk6bVg97TUv9ve13-ZzTArGPp01ieLNWcV3mVrPf3iLDMaAsNQEALw_wcB#What-does-the-Paris-Agreement-say-on-carbon-pricin. Accessed on 06 April 2023

Wang, Y. L., Xia, X. Q., and Zhang, Y. (2021). Research on Differential Countermeasures of Carbon Emission Reduction and Low Carbon Publicity in Supply Chain under Carbon Trading Policy. *Chin. J. Manag. Sci.* 30 (04), 155–166. doi:10.16381/j.cnki.issn1003-207x.2021.0165

Weng Yuyan, Da Zhang, Lanlan Lu & Xiliang Zhang. (2018). A general equilibrium analysis of floor prices for China's national carbon emissions trading system. *Climate Policy*. 18:sup1, 60-70, DOI: 10.1080/14693062.2018.1464895

Wissema, Wiepke, and Rob Dellink. (2007). AGE Analysis of the Impact of a Carbon Energy Tax on the Irish Economy. *Ecological Economics* 61 (4): 671–83. https://doi.org/https://doi.org/10.1016/j.ecolecon.2006.07.03

World Bank. (2017). Carbon Tax Guide: A Handbook for Policy Makers. World Bank Group. http://documents.worldbank.org/curated/en/728421535605566659/Carbon-Tax-Guide-A-Handbook-for-Policy-Makers

World Bank. (2019). Using Carbon Revenues (No. 16; TECHNICAL NOTE, Issue August). http://hdl.handle.net/10986/32247

World Bank. (2020). *State and Trends of Carbon Pricing 2020*. Washington, DC: World Bank.

World Bank. (2022). *State and Trends of Carbon Pricing 2022*. Washington, DC: World Bank Group, 2022. https://doi.org/10.1596/978-1-4648-1895-0.

World Bank. (2022). Vietnam Country Climate and Development Report. https://doi.org/10.1596/38252

World Bank. (2017). *Carbon Tax Guide: A Handbook for Policy Makers*. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/728421535605566659/Carbon-Tax-Guide-A-Handbook-for-Policy-Makers.

World Bank. (2018). Where Is the Carbon Tax after Thirty Years of Research? In *Policy Research Working Paper* (WPS8493).

Wu, Qunli, Chunxiang Li, Hongjie Zhang, and Jinyu Tian. (2019). Macro and Structural Effects of Carbon Tax in China Based on the ECGE Model. *Polish Journal of Environmental Studies* 28 (4): 2449–63. https://doi.org/10.15244/pjoes/90788.

Zhang X, Qi T, Ou X, Zhang X. (2017). The role of multi-region integrated emissions trading scheme: a computable general equilibrium analysis. *Appl Energy* 185:1860–8. https://doi.org/10.1016/j.apenergy.2015.11.092.

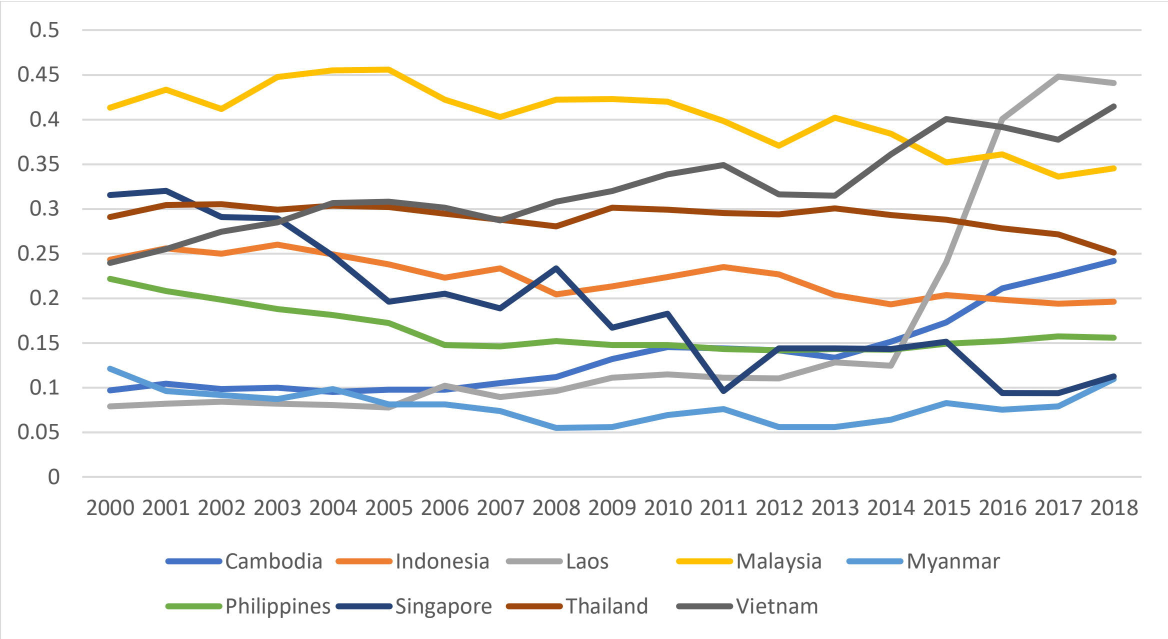
Zhang, Y., Jiang, S., Lin, X., Qi, L., & Sharp, B. (2023). Income distribution effect of carbon pricing mechanism under China's carbon peak target: CGE-based assessments. *Environmental Impact Assessment Review*, *101*, 107149. https://doi.org/https://doi.org/10.1016/j.eiar.2023.107149

Zhou, Jin-Feng, Dan Wu, and Wei Chen. (2021). Cap and Trade Versus Carbon Tax: An Analysis Based on a CGE Model. *Computational Economics*. https://doi.org/10.1007/s10614-021-10104-x.

Zhu, B., Ye, S., Jiang, M., Wang, P., Wu, Z., Xie, R., et al. (2019). Achieving the carbon intensity target of China: A least squares support vector machine with mixture Kernel function approach. *Applied Energy* 233–234, 196–207. doi:10.1016/j.apenergy.2018.10.048

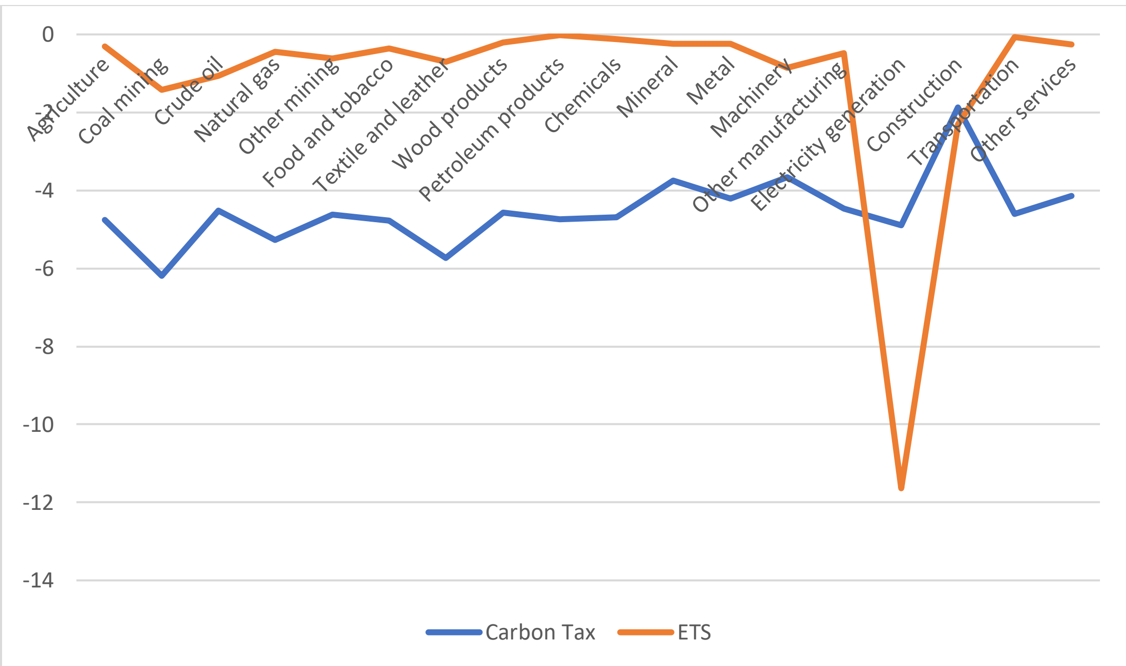
Appendices

Appendix 2.1. Emissions per dollar of GDP in ASEAN countries

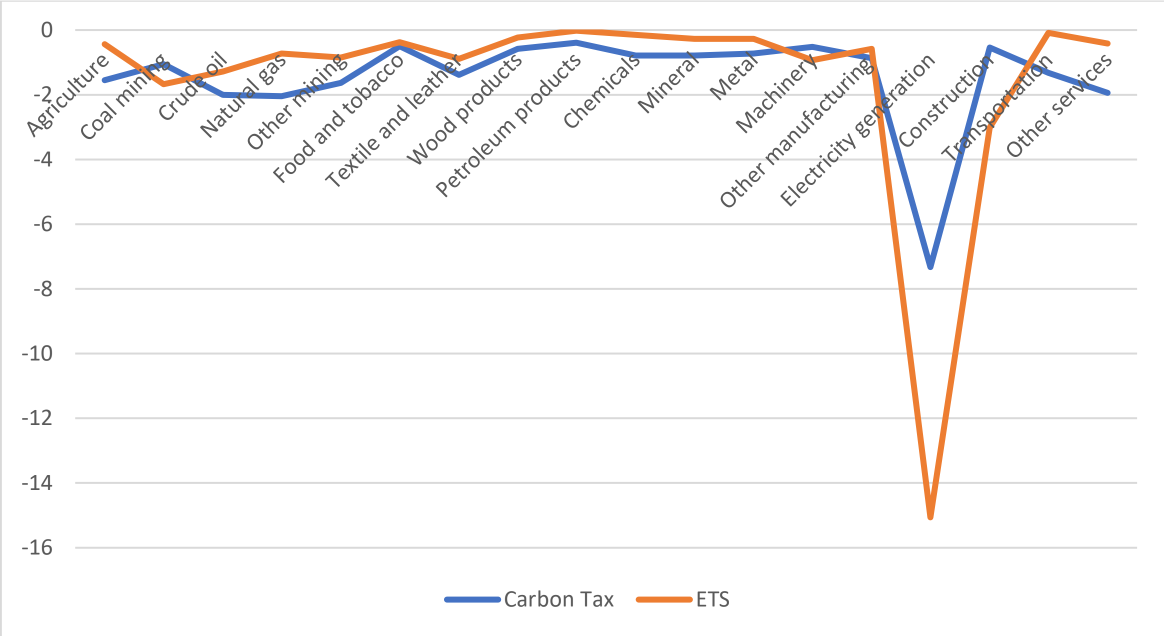


Source: Global Carbon Budget (2022)

Appendix 4.1. Percentage changes in carbon emissions by sector



Appendix 4.2. Percentage changes in output by sector



Appendix 4.3. Percentage changes in commodity price