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RESEARCH ON THE EFFECTIVENESS OF THE CARBON MARKET IN THE ENERGY SECTOR FOR VIET NAM'S SOCIO-ECONOMIC DEVELOPMENT

Specialization: Climate Change

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SUMMARY OF DOCTORAL DISSERTATION IN CLIMATE CHANGE

The dissertation was completed at:
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INTRODUCTION

1. Rationale for the Dissertation

Climate change requires a transformation of the growth model toward low-emission development. For Viet Nam, the commitment to achieve net-zero emissions by 2050 has made greenhouse gas mitigation, particularly in the energy sector, an urgent task. The 2020 Law on Environmental Protection established the policy direction for developing and operating a domestic carbon market, in which an emissions trading system (ETS) is an important instrument for creating economic signals for emitting facilities.

The electricity sector is selected as the main focus within the energy sector because it is both a significant source of greenhouse gas emissions and an essential input for most production, business, and consumption activities. However, electricity transmission and distribution exhibit characteristics of natural monopoly, while retail electricity prices remain regulated by the State. Under these conditions, costs arising from ETS compliance obligations may not be fully passed through into electricity prices; different pass-through levels may alter how impacts are distributed among the electricity-price channel, electricity-using sectors, households, and the residual net ETS value remaining in the electricity sector under the model's accounting convention.

CGE studies commonly assess carbon pricing under relatively flexible price adjustment, whereas energy models focus more on technologies, the generation mix, and abatement costs. In Viet Nam, few quantitative studies simultaneously examine the socio-economic impacts of an ETS and the case in which ETS costs are only partially passed through into electricity prices. This dissertation therefore evaluates the relative effectiveness of ETS scenarios along three dimensions: environmental outcomes through a modeled emissions indicator; socio-economic impacts through GDP, CPI, household consumption, and production activity; and the allocation of the electricity sector's net ETS value between the price channel and the portion not reflected in electricity prices. The dissertation does not comprehensively assess institutional effectiveness, exchange-operation effectiveness, or the financial performance of enterprises.

2. Research Objectives

The overall objective of the dissertation is to assess the relative effectiveness of ETS policy scenarios in the energy sector for Viet Nam’s socio-economic development, with the electricity sector as the main analytical focus; on that basis, it clarifies the relationship among environmental outcomes, macroeconomic stability, and the distribution of impacts on the electricity sector, while proposing conditional policy directions for the development of the domestic carbon market.

1) Calibrate and extend the PEP-1-1 computable general equilibrium (CGE) model by integrating greenhouse gas emissions, the net ETS value after free allowance allocation, and incomplete pass-through into electricity prices.

2) Simulate the impacts of ETS policy scenarios on the modeled emissions indicator, macroeconomic indicators, household consumption, production activity, and the portion of the electricity sector’s net ETS value not reflected in electricity prices.

3) Conduct sensitivity analysis and clarify trade-offs across combinations of carbon prices, free allowance allocation rates, and ETS cost pass-through coefficients into electricity prices; and, from these results, propose policy directions that can contribute to the development of Viet Nam’s carbon market.

3. Research Object and Scope

The research object is the greenhouse gas emissions trading system and the impacts of ETS policy scenarios on emission-reduction outcomes and Viet Nam’s socio-economic development. Within the energy sector, the electricity sector is the main analytical focus, particularly the mechanism through which ETS costs are passed through into electricity prices.

- Spatial scope: the entire Vietnamese economy; mechanisms under Article 6 of the Paris Agreement and the Carbon Border Adjustment Mechanism are treated only as policy context.

- Temporal scope: the model base year is 2019; the scenario grid is solved as comparative-static simulations around the 2019 base state.

The dissertation also conducts an illustrative semi-dynamic simulation sequence over three periods: 2025–2026, 2027–2028, and 2029–2030.

- Sectoral scope: within the energy sector, the dissertation focuses primarily on electricity. The electricity sector is separated in the model to analyze the net ETS value after allocation, the pass-through mechanism into electricity prices, and the portion not reflected in prices; other energy subsectors are represented within aggregated sector groups.

- Simulation level: ETS obligations are represented at the sector-account level, whereas the actual ETS scope is determined at the facility level. The results therefore represent impacts at the sectoral and economy-wide levels and are not forecasts for individual enterprises or power plants.

4. Research Questions and Propositions to Be Defended

4.1. Research Questions

1) How should the PEP-1-1 CGE model be extended to integrate greenhouse gas emissions, ETS obligations, free allowance allocation, and incomplete pass-through of ETS costs into electricity prices in the Vietnamese context?

2) How do ETS policy scenarios combining carbon prices, free allowance allocation rates, and ETS cost pass-through coefficients into electricity prices affect modeled emissions, macroeconomic indicators, household consumption, production activity, and the portion of the electricity sector's net ETS value not reflected in electricity prices?

3) How sensitive are the simulation results to changes in the three policy parameters; what trade-offs arise among emission-reduction outcomes, socio-economic impacts, and the distribution of impacts on the electricity sector; and what policy directions can be drawn for the development of Viet Nam's carbon market?

4.2. Propositions to Be Defended

Proposition 1: Adding an incomplete ETS cost pass-through mechanism to the CGE model changes not only the accounting position of the net ETS value but also the economy-wide equilibrium outcome. The extended PEP-1-1 CGE model therefore enables simultaneous assessment of macroeconomic impacts and impacts on the electricity sector under regulated electricity prices.

Proposition 2: Carbon prices, free allowance allocation rates, and pass-through coefficients perform different functions and are not fully substitutable. Different combinations of carbon prices, free allowance allocation rates, and pass-through coefficients may generate similar macroeconomic impacts but differ in emission reductions and in the residual financial impact on the electricity sector. Therefore, the effectiveness of a carbon market depends on the combined configuration of all three parameters.

Proposition 3: Within the model structure and parameter domain examined, stronger ETS signals tend to increase the adjustment of socio-economic indicators, while the additional improvement in the modeled emissions indicator diminishes at high price levels. The results reflect adjustment through output and production structure under fixed technology and emissions intensity within each model solution. Therefore, the relative effectiveness of ETS configurations varies across scenario regions, and the model results do not provide a basis for identifying a single universally optimal parameter combination.

5. Research Methods

The dissertation combines literature synthesis, data processing, and quantitative modeling, with the CGE model serving as the central analytical tool. The methods include data collection, standardization, and balancing; analysis of marginal abatement cost information; calibration and extension of the PEP-1-1 CGE model; scenario analysis; local sensitivity analysis; and expert consultation. Marginal abatement cost (MAC) information is used only through a soft-linking approach to support selection of the price range and interpretation of results; it is not incorporated into the model to endogenously determine investment or technology choice.

6. New Contributions of the Dissertation

- Develops a multidimensional quantitative assessment framework for ETS scenarios under regulated electricity prices, simultaneously considering modeled emissions outcomes, socio-economic impacts, and the way impacts are distributed across the electricity sector.

- Extends the PEP-1-1 CGE model by incorporating greenhouse gas emissions, free allowance allocation, net ETS value, and incomplete pass-through into electricity prices; and combines three parameters—carbon price, free allocation rate, and pass-through coefficient—in a grid of 126 scenarios.

- Provides quantitative evidence for Viet Nam on the impacts and relative effectiveness of ETS scenarios, thereby clarifying the relationship among environmental outcomes, socio-economic impacts, and the distribution of impacts on the electricity sector; it also shows that the effectiveness of each scenario depends on the combination of carbon price, free allowance allocation rate, and the degree of ETS cost pass-through into electricity prices.

7. Scientific and Practical Significance

Scientifically, the dissertation adds a quantitative framework for assessing the relative effectiveness of ETS scenarios and for simultaneously tracing electricity-sector impacts and economy-wide spillovers within a single general-equilibrium structure. Practically, the results provide conditional simulations that can serve as references when reviewing the pathway for carbon-price signal formation, free allowance allocation, and coordination between the ETS and the electricity-pricing mechanism; they do not replace policy impact assessments based on actual operational data.

8. Structure of the Dissertation

In addition to the Introduction, Conclusions and Recommendations, References, and Appendices, the dissertation consists of three chapters: Chapter 1 reviews carbon-market research, the structure of Viet Nam's electricity sector, and the research gaps; Chapter 2 presents the analytical approach, data, SAM construction, the extended PEP-1-1 CGE model, scenario design, sensitivity analysis, assumptions, and limitations; and Chapter 3 presents simulation results, an integrated discussion, and policy recommendations within the scope of the study.

CHAPTER 1. LITERATURE REVIEW ON CARBON MARKETS AND THEIR IMPACTS ON SOCIO-ECONOMIC DEVELOPMENT

1.1. Review of Major Research Themes

The theoretical foundation of carbon pricing originates from the economics of externalities, property rights, and tradable emission permits. Studies show that price signals help incorporate emission costs into production and consumption decisions, while allowance trading can allocate mitigation efforts according to marginal costs. Actual effectiveness depends on market design, allocation methods, measurement, reporting and verification systems, market oversight, and operating conditions.

Evidence from the EU ETS, RGGI, California, New Zealand, and China shows that ETSs can contribute to emission reductions, promote technological innovation, and generate differing distributional effects, although the magnitude of impacts varies across sectors and periods. Ex-post studies depend on the construction of counterfactual scenarios and the ability to isolate ETS effects from economic cycles, fuel-market changes, and concurrent policies; ex-ante studies depend on data, market structure, closure rules, and model parameters.

CGE models are well suited to quantifying intersectoral impacts on GDP, prices, consumption, output, trade, and factor use, while energy models provide greater technological detail. In Viet Nam, studies have examined fuel taxation, carbon pricing, energy transition, impacts on energy-intensive sectors, and carbon border adjustment mechanisms, but few studies simultaneously separate the electricity sector, model incomplete pass-through, and combine carbon prices, free allocation, and pass-through coefficients within the same CGE framework.

Viet Nam's carbon-market legal framework continues to be refined, and the pilot phase has been operationalized through allowance allocation to thermal power, iron and steel, and cement facilities, together with the establishment of the national registry and carbon exchange. The Viet Nam Energy Social Accounting Matrix for 2019 (ESAM 2019) was introduced in July 2026, after the dissertation had completed data construction, model calibration, and scenario simulations. ESAM is therefore not used as an input to this dissertation; instead, the dissertation uses the 2019 I–O Table and supplementary sources to construct a SAM suitable for PEP-1-1, while ESAM is treated as a reference source and a direction for future updating.

1.2. Structure of Viet Nam's Electricity Sector

The electricity sector is central to the analysis because thermal power is among the groups receiving pilot allowances, electricity is an essential input for industries and households, and retail prices remain regulated. The sector combines partial competition in generation with natural-monopoly characteristics and regulation in transmission, distribution, and retail. Consequently, ETS costs incurred by obligated facilities are not necessarily fully and immediately reflected in final electricity prices.

The electricity-pricing mechanism provides an institutional basis for assuming incomplete pass-through, but it is insufficient to infer a single pass-through rate for Viet Nam without econometric estimation using actual price and cost data. The pass-through rate is therefore treated as a scenario parameter rather than an empirically established coefficient.

The dissertation uses coefficient θ to simulate different degrees to which the electricity sector's net ETS value is reflected through the price channel. This is a reduced-form accounting and pass-through rule added to PEP-1-1, not an empirical estimate of the electricity-price adjustment mechanism in Viet Nam; the model also does not represent adjustment lags, asymmetric pass-through, or separate wholesale and retail electricity prices.

1.3. Research Gaps and Research Direction

The dissertation identifies three direct research gaps. First, there is a lack of integrated quantitative analysis of how ETS obligations are transmitted through electricity prices to electricity-using sectors and households, the portion not reflected in prices within the electricity sector, and the related accounting consequences within a general-equilibrium framework. Second, there remains a lack of CGE research for Viet Nam that simultaneously places carbon prices, free allowance allocation rates, and pass-through levels within a unified scenario grid. Third, there is a lack of quantitative evidence linking emission-reduction outcomes, GDP, CPI, consumption, production activity, and the allocation of the electricity sector's net ETS value in a context of regulated electricity prices.

To address these gaps, the dissertation adopts PEP-1-1, calibrates it using a SAM constructed by the dissertation for the 2019 base year, and adds modules for emissions, free allocation, net ETS value, and pass-through into electricity prices. Electricity is separated at the account level; carbon price, α, and θ are specified exogenously; and results are assessed using a multi-indicator profile and sensitivity analysis. The dissertation does not forecast allowance prices, identify an optimal policy option, endogenize technology investment, or assess the micro-level operation of the market.

CHAPTER 2. RESEARCH METHODOLOGY FOR ASSESSING THE IMPACTS OF ETS SCENARIOS ON VIET NAM'S SOCIO-ECONOMIC DEVELOPMENT

2.1. Analytical Approach and Assessment Framework

The dissertation applies comparative-equilibrium simulation. Each policy configuration is introduced into the model through three exogenous parameters: carbon price, free allowance allocation rate α, and pass-through coefficient θ. Following the shock, the model determines a new equilibrium state and quantifies differences relative to the base state. The results are therefore conditional simulations based on the data structure, closure rules, and assumptions, rather than probabilistic forecasts or causal estimates.

Effectiveness is assessed through impact profiles covering environmental, socio-economic, and electricity-sector dimensions. The dissertation does not use an objective function, composite index, weighting system, Pareto dominance rule, or efficiency frontier. When indicators move in different directions, the dissertation identifies and interprets trade-offs; it does not produce an aggregate ranking or determine an absolutely optimal parameter combination.

2.2. Data and SAM Construction

The year 2019 is selected as the base year because Viet Nam's 2019 Input–Output Table is available and the year predates the exceptional disruptions caused by the COVID-19 pandemic. The year 2019 is used as a consistent accounting base for comparative simulations and is not regarded as a complete description of the economy at the time of the research. Data published after 2019 are used only to update the contextual discussion and for comparison when interpreting results; they are not partially substituted into the SAM.

The SAM is constructed from the 2019 I–O Table and supplementary sources and comprises 37 accounts; the mapping covers 171 product-sector codes, with electricity retained as a separate account. Several disaggregation ratios for labor, households, taxes, and transfers are referenced from the 2012 SAM while keeping the

2019 control totals. The SAM is balanced through sequential adjustment under double-entry accounting principles; the largest absolute discrepancy between row and column totals after balancing is VND 0.02 million, mainly due to rounding.

Emissions-intensity coefficients are specified in stylized form at the sector-account level: electricity is assigned a coefficient of 1.0 and the industrial group 0.5 per unit of model-accounting output. These coefficients are not physical emissions factors derived from fuel-use, output, or inventory data covering the same scope. Accordingly, the modeled emissions indicator is used only for relative comparison across scenarios and does not replace MRV, the national greenhouse gas inventory, or assessment of NDC implementation.

2.3. Extended PEP-1-1 CGE Model

PEP-1-1 is a static single-country CGE model representing an open economy and intersectoral linkages. The dissertation retains the Leontief/CES production structure, Stone–Geary consumption, the Armington assumption for imports, the CET function for exports, and market-equilibrium conditions. The model is calibrated to reproduce the 2019 SAM base state.

The extension adds modeled emissions; free allowances determined by α and reference emissions; net ETS value after allocation; FIN_GAP_ELEC, representing the portion of the electricity sector's net ETS value not reflected in prices; and TCO2T, representing the total net ETS value recorded in the Government account. For the electricity sector, θ determines the portion of the net ETS value included in the production-value balance; the remainder is offset through Government saving under the model's closure rule.

The closure rule keeps the nominal exchange rate and current account balance at base levels; total labor and capital supplies are fixed within each static simulation; and total investment is determined by aggregate saving. Recording TCO2T as Government income and FIN_GAP_ELEC through Government saving causes results to be transmitted simultaneously through the cost–price channel and the saving–investment channel. These variables are accounting counterparts within the model and are not equivalent to auction revenues, actual budget receipts or expenditures, or electricity-enterprise profits or losses; macroeconomic results are conditional on the selected closure rule.

2.4. Marginal Abatement Cost Information and Scenario Design

Marginal abatement cost information for selected power-generation technologies is used through a soft-linking approach as a reference when selecting the price range and interpreting the context. MAC values are not incorporated into the production function and do not endogenously determine technology choice; therefore, a specific price level cannot be interpreted as necessarily triggering a particular technology.

Table 1. Marginal abatement costs of selected power-generation technology groups

Technology group	MAC (USD/tCO_2)
Medium and large hydropower	−9.9
Concentrated solar power	−5.8
Biomass power	−0.4
Offshore wind power	13.1
LNG/CCGT gas-fired power	13.4 to 24.0
Co-firing option at coal-fired power plants	213.5

Source: Compiled from the 2022 NDC Technical Report and the Draft NDC 3.0 Technical Report

The scenario grid consists of seven carbon-price levels from VND 50,000 to VND 2,500,000/tCO_2, six θ levels from 0.1 to 1.0, and three α levels of 100%, 90%, and 80%, producing 126 combinations. These parameter levels form an exogenous experimental grid rather than official policy values or forecasts. Sensitivity analysis varies one parameter at a time over selected slices and is not a global uncertainty analysis.

The illustrative semi-dynamic sequence consists of three periods: 2025–2026, 2027–2028, and 2029–2030. Each period is still solved with a static model, while capital, labor, and productivity are updated exogenously between periods. Because no separate no-ETS baseline is constructed for each period, the sequence only illustrates the dependence of the solution on the input state and update sequence; it does not represent the standalone or cumulative effect of the ETS.

2.5. Assumptions and Limitations

The model does not endogenously determine the overall emissions cap, allowance supply and demand, or the equilibrium allowance price; nor does it simulate auctions, secondary trading, banking or borrowing of allowances, offsets, liquidity, speculation, or transaction costs. Technology and emissions-intensity coefficients are fixed within each model solution; the electricity account aggregates generation, transmission, and distribution and does not separate generation technologies or individual ETS-covered facilities.

Results are valid only within the model's data structure, sector aggregation, allocation rules, and closure. The model does not endogenize technological innovation, mitigation investment, or fuel switching, and does not fully quantify trade impacts, competitiveness benefits, environmental co-benefits, or distribution across household groups. Therefore, changes in GDP are not a measure of the net social welfare effect of the ETS; ETS_BAL, FIN_GAP_ELEC, and TCO2T should likewise not be interpreted directly as traded quantities, revenues, budget receipts or expenditures, or actual profits and losses.

2.6. Sensitivity Analysis of Results to Policy Parameters

The dissertation conducts local sensitivity analysis for three main parameters: carbon price, free allowance allocation rate α, and pass-through coefficient θ. Each parameter is varied in turn while the others are held at a specified configuration, in order to identify the direction and magnitude of responses in GDP, CPI, household consumption, output, modeled emissions, and ETS accounting variables. This analysis captures sensitivity only over the selected parameter slices, is not a global uncertainty analysis, and is not used to rank the absolute importance of parameters.

2.7. Research Assumptions and Limitations

Simulation results are interpreted within the assumptions and limitations of the model. Carbon price, α, and θ are exogenous; technology and emissions-intensity coefficients are fixed in each solution; and the model does not endogenize mitigation investment, fuel switching, allowance trading, offsets, transaction costs, or noncompliance behavior. The SAM uses 2019 as its base year, retains a relatively aggregated sector structure, and references some components from the 2012 SAM. FIN_GAP_ELEC and TCO2T are accounting variables under the model's closure rule and do not directly represent enterprise profits or losses or actual budget receipts and expenditures. Therefore, the results should be understood only as conditional simulations based on the data, model structure, and research assumptions.

CHAPTER 3. RESULTS OF IMPACT ASSESSMENT AND EFFECTIVENESS ANALYSIS OF ETS SCENARIOS FOR VIET NAM'S SOCIO-ECONOMIC DEVELOPMENT

3.1. Macroeconomic and Household Impacts

Across the 126 scenarios, real GDP decreases relative to the base state by 0.0048% to 5.3104%; CPI increases by 0.0058% to 6.4877%; and household consumption decreases by 0.0077% to 8.6294%. These are equilibrium differences conditional on the 2019 base-year SAM, model structure, closure rule, and parameter grid; they are not official forecasts of Viet Nam's growth, inflation, or household consumption.

In some slices where α and θ are held fixed, GDP losses and CPI increases exhibit an approximately linear pattern across the carbon-price levels examined; this is a property of the model solutions within the research parameter domain, not a stable empirical relationship in the Vietnamese economy. The free allocation rate and pass-through coefficient materially alter the magnitude of impacts because they simultaneously affect the cost–price channel and the saving–investment channel.

Table 2. Changes in GDP (%) by carbon price and θ, with α = 100%

Price (VND/tCO_2)	θ = 0.1	θ = 0.3	θ = 0.5	θ = 1.0
50,000	−0.0048	−0.0067	−0.0086	−0.0133
250,000	−0.0238	−0.0333	−0.0428	−0.0666
500,000	−0.0476	−0.0666	−0.0856	−0.1332
1,000,000	−0.0951	−0.1332	−0.1712	−0.2664
2,500,000	−0.2378	−0.3329	−0.4281	−0.6659

Source: Author's simulation results

Across the full grid, 42 scenarios produce GDP declines of less than 0.1%; 41 scenarios produce declines from 0.1% to below 0.5%; 16 scenarios produce declines from 0.5% to below 1%; and 27 scenarios produce declines of 1% or more. This grouping is descriptive and is used only to compare impact profiles; it does not represent a safety threshold or a recommended impact level.

Real household consumption declines as both factor incomes and the general price level change. However, the results are aggregated for the household sector as a whole; the dissertation does not provide sufficient evidence to conclude which income groups are more affected, does not assess poverty, and does not quantify distributional impacts.

3.2. Impacts on Production Activity and Factor Use

The aggregate output indicator declines by 0.4154% to 10.6984%; value added declines by 0.0046% to 5.1777%; the labor-use adjustment index declines by 0.0024% to 2.6552%; and the capital-use adjustment index declines by 0.0010% to 1.0621%. The labor and capital indicators measure the intensity of adjustment within the model; they do not represent the number of jobs lost, the unemployment rate, or the physical amount of capital lost.

Spillover effects arise through two main channels: direct effects on sector groups assigned ETS obligations and indirect effects through input–output linkages. Changes in electricity prices and relative prices alter intermediate costs, commodity demand, output, factor demand, and income. The SAM's level of sector aggregation does not permit the results to be extrapolated to individual subsectors, technologies, or facilities.

3.3. Electricity Sector and Pass-Through Accounting Mechanism

For the electricity sector, θ determines the portion of the net ETS value after allocation that enters the electricity production-value balance; the remainder is recorded as FIN_GAP_ELEC and offset through Government saving. When θ changes, both the price channel and the saving–investment channel change. This mechanism only simulates different degrees of reflection through the price channel and does not represent retail electricity-price adjustment procedures or the behavior of individual electricity enterprises.

Across the full grid, FIN_GAP_ELEC ranges from −VND 48,447 billion to +VND 4,552 billion on the model's monetary scale and equals zero when $\theta = 1$. Negative or positive values reflect the model's accounting position arising from the relationship between modeled emissions and reference allocation; they do not automatically represent losses, profits, or actual cash flows of the electricity sector.

TCO2T may also take either sign and is not equivalent to auction revenue or Government budget revenue.

At a carbon price of VND 250,000/tCO_2 and α = 100%, increasing θ from 0.1 to 1.0 raises CPI from 0.0291% to 0.0814%, increases the GDP decline from 0.0238% to 0.0666%, and moves FIN_GAP_ELEC from −VND 1,244 billion to zero. The results indicate that θ primarily changes the structure of pass-through and accounting; its effect depends on carbon price, α, and the closure rule.

3.4. Impacts on Greenhouse Gas Emissions

The modeled emissions indicator declines by 0.6793% to 16.9257% across the 126 scenarios. The indicator is derived from stylized emissions-intensity coefficients and equilibrium output, and therefore is used only for relative comparison across model states; it is not an emission reduction quantified under MRV, does not replace the national inventory, and is not directly compared with NDC targets.

Modeled emission reductions increase with carbon price in all parameter combinations, but the incremental improvement narrows at high price levels. At θ = 0.3 and α = 100%, the additional emission reduction per VND 100,000/tCO_2 declines from 1.5546 percentage points over the VND 50,000–100,000 interval to 0.1613 percentage points over the VND 2,000,000–2,500,000 interval.

Within the slices examined, α has a clearer effect than θ on the emissions indicator. However, the model reduces emissions mainly through adjustments in production scale and structure while technology and emissions intensity are held fixed; therefore, the reported reduction rates do not fully capture real-world channels such as fuel switching, investment, and technological innovation.

Table 3. Multi-indicator comparison of selected representative scenarios

Scenario	Price – θ – α	ΔGDP (%)	ΔCPI (%)	ΔEmissions (%)
KB001	50; 0.1; 100%	−0.0048	+0.0058	−0.6793
KB043	250; 0.3; 100%	−0.0333	+0.0407	−3.6141

Scenario	Price – θ – α	ΔGDP (%)	ΔCPI (%)	ΔEmissions (%)
KB062	500; 0.3; 90%	−0.2664	+0.3254	−12.4468
KB083	1,000; 0.5; 90%	−0.6849	+0.8367	−14.8482
KB117	2,500; 0.3; 80%	−2.6552	+3.2439	−16.7862
KB126	2,500; 1.0; 80%	−5.3104	+6.4877	−16.9257

Source: Author's simulation results

3.5. Illustrative Semi-Dynamic Simulation Sequence

Across the three model solutions, ΔGDP is −0.0048%, −0.0164%, and −0.1432%, respectively; ΔCPI is +0.0058%, +0.0139%, and +0.1627%; the aggregate output indicator declines by 0.4154%, 0.8922%, and 5.7782%; and modeled emissions decline by 0.6793%, 1.4588%, and 9.4408%. FIN_GAP_ELEC is −VND 51 billion, −VND 195 billion, and −VND 137 billion, respectively; TCO2T is −VND 830 billion, −VND 3,563 billion, and +VND 4,716 billion on the model's monetary scale.

Values in each period simultaneously reflect the carried-forward input state, exogenous updates to capital, labor, and productivity, and the carbon price, α, and θ combination of that solution. Because there is no corresponding no-ETS baseline, these percentages cannot be added to obtain a cumulative impact and cannot be attributed separately to the ETS or to any single parameter; the sequence serves only as supplementary illustration.

3.6. Results of Sensitivity Analysis and Parameter Interactions

In the slice with θ = 0.3 and α = 100%, GDP, CPI, and household consumption display an approximately linear pattern across the carbon-price levels examined, whereas output and modeled emissions show diminishing responses; this pattern is a feature of the model structure and parameter domain considered. At a carbon price of VND 250,000/tCO_2 and θ = 0.5, reducing α from 100% to 90% generates a substantial adjustment in GDP and emissions; a further reduction from

90% to 80% continues to increase the economic impact, while the additional emissions improvement narrows.

The effects of both α and θ widen as carbon prices increase. Carbon price sets the monetary scale of the signal; α changes the net ETS value after allocation under the accounting rule; and θ changes how the electricity sector's net ETS value is divided between the price channel and the portion not reflected in prices. The three parameters perform different functions, interact with one another, and no single parameter determines the complete impact profile of a scenario.

Table 4. Changes in indicators by carbon price, with θ = 0.3 and α = 100%

Price (VND/tCO_2)	ΔGDP (%)	ΔCPI (%)	ΔOutput (%)	ΔEmissions (%)
50,000	−0.0067	+0.0081	−0.4609	−0.7534
100,000	−0.0133	+0.0163	−0.9363	−1.5307
250,000	−0.0333	+0.0407	−2.2108	−3.6141
500,000	−0.0666	+0.0814	−3.8130	−6.2323
1,000,000	−0.1332	+0.1627	−5.7782	−9.4408
2,500,000	−0.3329	+0.4068	−8.1213	−13.2532

Source: Author's simulation results

3.7. Discussion and Synthesis of Research Results

The results show that the magnitude of impacts and the way impacts are distributed are two dimensions that need to be considered simultaneously. Scenarios with similar macroeconomic impacts may still differ in the modeled emissions indicator and ETS accounting variables. At high carbon prices, economic impacts continue to increase while incremental emissions improvements narrow; however, this is a conditional result of a model structure in which technology and emissions intensity are held fixed.

Adverse responses in GDP, CPI, or consumption under some configurations do not imply that the net benefits of an ETS to the economy are negative. An ETS may simultaneously promote more efficient energy use, fuel switching, technological innovation, green investment, and greater capacity to meet carbon-related requirements in international markets. Therefore, the macroeconomic results are not a social cost–benefit assessment of the carbon market.

3.8. Policy Recommendations within the Scope of the Study

Based on the simulation results, the dissertation proposes four groups of conditional recommendations: develop a carbon-price signal along a gradual, predictable pathway subject to review using operational data; consider free allocation in coordination with the price pathway without directly inferring an optimal allocation rate from the model; coordinate the ETS with the electricity-pricing mechanism, clearly identifying recognized cost components and mechanisms for handling the portion not reflected in prices; and develop datasets, monitoring indicators, and policy-review cycles based on verified emissions, output, prices, transactions, and electricity-sector data. The carbon-price, α, and θ levels in the dissertation are experimental parameters, not recommended legal values.

CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

1. The dissertation constructed a SAM for the 2019 base year from Viet Nam's 2019 Input–Output Table and supplementary data sources, and calibrated and extended the PEP-1-1 CGE model to integrate greenhouse gas emissions, free allowance allocation, net ETS value after allocation, and incomplete pass-through into electricity prices. On this basis, it developed a grid of 126 scenarios and an illustrative three-period semi-dynamic simulation sequence.

2. The extension enables simultaneous analysis of three dimensions: modeled emission-reduction outcomes; impacts on GDP, CPI, household consumption, and production activity; and the allocation of the electricity sector's net ETS value between the price channel and the portion not reflected in electricity prices. This is the dissertation's principal methodological contribution.

3. Across the scenario grid, GDP declines by 0.0048–5.3104%, CPI increases by 0.0058–6.4877%, household consumption declines by 0.0077–8.6294%, and the modeled emissions indicator declines by 0.6793–16.9257%. These results are conditional equilibrium differences based on the 2019 base-year SAM, model structure, closure rule, and parameter grid; the emission-reduction rates are not reductions quantified under MRV and are not directly compared with the NDC.

4. Carbon price sets the scale of the signal; α changes the net ETS value after allocation under the model's accounting rule; and θ changes the portion of the electricity sector's net ETS value reflected through the price channel and the portion offset through Government saving. The three parameters perform different functions, interact with one another, and cannot be assessed in isolation.

5. Within the simulated grid, the adjustment of economic indicators increases as the strength of the ETS signal rises, while the additional improvement in the modeled emissions indicator diminishes at high carbon prices. The approximately linear relationship observed for some indicators in some slices is a property

of the model structure and parameter domain rather than an empirical law; the results do not identify an optimal carbon price, allocation rate, or pass-through coefficient.

6. FIN_GAP_ELEC and TCO2T are accounting variables in the model and do not represent electricity-sector losses, Government budget revenue, or actual cash flows. Household and factor-use results are aggregated and do not provide sufficient evidence for conclusions on poverty, vulnerable groups, numbers of jobs, or income distribution.

7. The simulation results reflect only the channels endogenized in the model. Adverse responses in GDP, CPI, or consumption do not imply that the net benefits of an ETS are negative, because technological innovation, fuel switching, green investment, international competitiveness benefits, and environmental co-benefits are not fully quantified. The semi-dynamic sequence also lacks a separate no-ETS baseline for each period and therefore does not represent the standalone or cumulative effect of the ETS.

B. Recommendations

1. Continue updating and improving the quality of the database, prioritizing construction of a SAM from data sources for the same year, increasing the detail of energy accounts and ETS-covered sectors, and linking output data with physical emissions that have been measured, reported, and verified.

2. Develop the model to better represent the energy transition, including disaggregating power-generation technologies, endogenizing investment and technology choice, fuel switching, and allowance-market mechanisms; and explore linking the CGE model with a detailed energy model.

3. Continue studying the mechanism through which ETS costs are passed through into electricity prices and alternative closure rules; when operational data become available, empirically estimate the pass-through rate and test the sensitivity of macroeconomic results to alternative treatments of costs not reflected in electricity prices.

4. Expand distributional and just-transition analysis by disaggregating households by income, location, and social characteristics, while also examining differences among sectors and enterprises in energy intensity, technology-switching capacity, and ability to adapt to carbon costs.

5. Broaden the assessment to channels not quantified in the dissertation, including international trade, carbon border adjustment mechanisms, the use of credits to offset ETS obligations, technological innovation, and environmental co-benefits. For intertemporal analysis, construct a corresponding no-ETS baseline for each period to separate policy impacts from changes in growth-related factors.

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