FINANCIAL IMPLICATIONS OF CARBON PRICING ON HIGH-EMISSION SECTORS IN VIETNAM'S INDUSTRIAL ZONES

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Abstract:

This study examines the financial implications of carbon pricing on high-emission sectors in Vietnam, including manufacturing, textiles, energy, and cement. Using a Dynamic Stochastic General Equilibrium (DSGE) model, the study finds that carbon pricing leads to increased operational costs and short-term declines in profitability, particularly in the energy and cement sectors, while simultaneously encouraging investment in clean technologies. However, smaller firms face greater financial constraints compared to larger firms. Complementary qualitative insights reveal concerns about declining international competitiveness in export-oriented industries and emphasize the need for stronger government support. The study concludes that although carbon pricing is effective in reducing emissions, its overall success depends on supportive policies to ensure a balanced and sustainable transition to a low-carbon economy.

Keywords: *Carbon pricing, high-emission sectors, clean technology investment, Dynamic Stochastic General Equilibrium (DSGE), operational costs, profitability, international competitiveness.*

DOI:

Hàm ý tài chính của việc định giá carbon đối với các ngành phát thải cao trong các Khu công nghiệp tại Việt Nam

Tóm tắt:

Nghiên cứu này xem xét tác động tài chính của cơ chế định giá carbon đối với các ngành phát thải cao tại Việt Nam, bao gồm sản xuất, dệt may, năng lượng và xi măng. Sử dụng mô hình cân bằng tổng thể ngẫu nhiên Động (DSGE), kết quả cho thấy định giá carbon làm gia tăng chi phí vận hành và làm giảm lợi nhuận trong ngắn hạn, đặc biệt ở các ngành năng lượng và xi măng, đồng thời thúc đẩy đầu tư vào công nghệ sạch. Tuy nhiên, các doanh nghiệp nhỏ phải đối mặt với nhiều hạn chế tài chính hơn so với doanh nghiệp lớn. Kết quả định tính bổ sung cho thấy những lo ngại về sự suy giảm năng lực cạnh tranh quốc tế của các ngành xuất khẩu, đồng thời nhấn mạnh sự cần thiết của hỗ trợ từ Chính phủ. Nghiên cứu kết luận rằng, mặc dù định giá carbon có hiệu quả trong việc giảm phát thải, nhưng để đạt được chuyển đổi cân bằng và bền vững sang nền kinh tế carbon thấp, cần có các chính sách hỗ trợ đi kèm.

Từ khóa: *Định giá carbon, các ngành phát thải cao, đầu tư công nghệ sạch, Mô hình cân bằng tổng quát ngẫu nhiên động (DSGE), chi phí vận hành, lợi nhuận, khả năng cạnh tranh quốc tế.*

1. Introduction

Climate change mitigation has become a global priority, prompting countries to adopt policies such as carbon pricing to reduce emissions and promote sustainable development. As a participant in the Paris Agreement, Vietnam aims to cut greenhouse gas emissions by 9% by 2030, or up to 27% with international support. Carbon pricing is considered a key tool to internalize environmental costs and encourage cleaner production.

Vietnam's industrial sector, accounting for over 49% of total energy consumption and a large share of CO_2 emissions, plays a central role in this transition. High-emission industries like manufacturing, textiles, energy, and cement contribute significantly to GDP and employment but face challenges in balancing growth with stricter environmental regulations.

Globally, carbon pricing mechanisms such as carbon taxes and emissions trading systems (ETS) have been widely adopted. However, their financial impacts on Vietnam's industries remain underexplored. Evidence from other regions shows that such policies can increase production costs and affect competitiveness, especially in energy-intensive sectors.

This study addresses this gap by applying a DSGE model to assess the financial impacts of carbon pricing on key Vietnamese industries. It evaluates effects on costs, profitability, and emissions, providing insights into the trade-offs between economic growth and environmental goals, and offering policy recommendations for a low-carbon transition.

2. Literature Review

2.1. Carbon Pricing and its Global Adoption

Carbon pricing is a key policy tool used to mitigate climate change by assigning a cost to carbon emissions, thereby encouraging firms to adopt cleaner technologies and improve energy efficiency (World Bank, 2023). The two main mechanisms are carbon taxes and emissions trading systems (ETS), which either directly price emissions or create a market for emission permits.

Globally, over 68 jurisdictions have implemented carbon pricing, covering about 23% of emissions. Notable examples include the EU ETS, as well as policies in China and South Korea, which have contributed to emission reductions in energy and manufacturing sectors (European Commission, 2019; Zhang & Chen, 2021).

However, these policies also impose financial burdens on high-emission industries. Evidence shows that carbon pricing can increase operational costs by up to 10% in the EU and around 7.4% in China. These impacts highlight the need to assess how similar policies may affect industries in emerging economies like Vietnam.

2.2. Carbon Pricing in Vietnam

Vietnam is in the early stages of developing carbon pricing policies to meet its Paris Agreement commitments, targeting a 9% emissions reduction by 2030, or up to 27% with international support (MONRE, 2020). Although its industrial sector contributes over 37% of GDP and nearly 50% of energy consumption (IEA, 2022), carbon pricing has not yet been fully implemented, but carbon taxes and ETS are being considered.

The adoption of these policies is expected to significantly impact high-emission sectors such as manufacturing, textiles, energy, and cement. While these industries are vital to economic growth, their heavy reliance on fossil fuels makes them highly vulnerable to rising production costs. Therefore, assessing the financial impacts of carbon pricing is essential for designing effective and sustainable policy frameworks in Vietnam.

2.3. Financial Impacts of Carbon Pricing on High-Emission Sectors

The financial impacts of carbon pricing are widely documented across both developed and emerging economies. Evidence shows that carbon pricing increases operational costs due to emission taxes, carbon credit purchases, and investments in cleaner technologies. For example, studies in the EU indicate that energy-intensive industries such as cement and steel experienced cost increases of 5–15% after carbon pricing implementation (Anderson et al., 2020).

In emerging markets, these impacts are often more severe. Research from China shows that high-energy industries struggle to balance profitability with compliance costs (Zhang & Chen, 2021). Similarly, in South Korea, smaller firms are disproportionately affected due to limited financial capacity to invest in emission-reduction technologies, unlike larger firms (Kim et al., 2021).

2.4. Theoretical Framework

This study is grounded in environmental economics, particularly the polluter-pays principle, which states that firms responsible for pollution must bear the associated costs. Carbon pricing applies this principle by assigning a monetary cost to emissions, thereby internalizing negative externalities such as environmental damage (Pigou, 1920).

The research employs a Dynamic Stochastic General Equilibrium (DSGE) model as its main analytical framework. DSGE models are widely used to analyze interactions between economic agents and to assess both short- and long-term impacts of policy interventions. Under carbon pricing, firms are expected to adjust by adopting cleaner technologies, improving efficiency, or passing costs to consumers (Pindyck, 2013).

In the context of Vietnam, the DSGE model is used to simulate different carbon pricing scenarios, considering factors such as demand elasticity, technology adoption costs, and their effects on sectoral output and emissions.

2.5. Research Model

This study develops a research model to evaluate the financial impacts of carbon pricing on high-emission sectors in Vietnam, including manufacturing, textiles, energy, and cement. Two main policy instruments are examined: carbon taxes and emissions trading systems (ETS), both of which impose costs on emissions and are expected to affect sectoral financial performance. The model focuses on key variables such as operational costs, profit margins, and investment in clean technologies. Carbon pricing is expected to increase production costs, especially in energy-intensive sectors, thereby reducing profit margins in the short term. At the same time, firms may respond by investing in cleaner technologies to improve efficiency and reduce emissions. The model also considers differences between large and small firms, with larger firms having greater capacity to adapt.

Within a DSGE framework, the study further analyzes macroeconomic impacts, including sectoral output, emissions reduction, and international competitiveness. While output may decline initially due to higher costs, technological improvements could enhance efficiency in the long run. The model also examines the potential loss of competitiveness in export-oriented sectors, particularly under rising carbon-related costs.

2.6. Research hypothesis

Carbon pricing, through carbon taxes or ETS, internalizes environmental costs by imposing emission-based financial burdens on firms. High-emission sectors such as energy, cement, manufacturing, and textiles-especially in fossil fuel-dependent economies like Vietnam-are therefore expected to face significant increases in operational costs.

H1: Carbon pricing will significantly increase operational costs in high-emission sectors.

At the same time, carbon pricing creates incentives for firms to invest in clean technologies (e.g., energy efficiency, renewable energy, CCS) to reduce emissions and compliance costs.

H2: High-emission sectors will increase investment in clean technologies in response to rising carbon prices.

In the short term, increased costs may reduce profitability; however, in the long term, technological adoption can improve efficiency and help firms recover profit margins.

H3: Carbon pricing will reduce profitability in the short term but improve it in the long term through technological adaptation.

By raising the cost of emissions, carbon pricing encourages firms to reduce CO_2 output through operational changes and cleaner production.

H4: Carbon pricing will significantly reduce emissions in high-emission sectors.

Additionally, international policies such as the Carbon Border Adjustment Mechanism (CBAM) may negatively affect export-oriented industries by increasing trade-related costs.

H5: Export-oriented sectors will face reduced competitiveness due to carbon-related trade policies.

Finally, smaller firms are likely to face greater challenges due to limited financial resources and lower capacity to invest in clean technologies compared to larger firms.

H6: Smaller firms will face greater financial constraints in adapting to carbon pricing than larger firms.

3. Research Methodology

3.1. Research Methodology for the Quantitative Phase

The quantitative phase applies an econometric approach using a DSGE model to evaluate the financial impacts of carbon pricing on high-emission sectors in Vietnam. The analysis focuses on key variables including operational costs, sectoral output, profitability, clean technology investment, and emissions reduction. This section covers the main methodological steps, including data collection, model specification, calibration, estimation, and simulation.

3.1.1. Data Collection

The quantitative analysis uses data collected from multiple sources to assess the impact of carbon pricing on high-emission sectors, including manufacturing, textiles, energy, and cement. Key variables include sectoral output, operational costs, emissions, and investment in clean technologies. Data is primarily obtained from the Vietnam General Statistics Office (GSO), International Energy Agency (IEA), and World Bank, covering the period 2010-2023 to establish a baseline.

Macroeconomic data such as GDP, inflation, and interest rates are sourced from the IMF and World Bank to ensure consistency in modeling. In addition, sectoral reports and firm disclosures provide further insights into current investments in clean technologies and energy efficiency.

3.1.2. DSGE Model Specification

The DSGE model is the core analytical framework, capturing interactions between households, firms, and the government under carbon pricing policies.

Firms: Maximize profits using capital, labor, and energy inputs. Carbon pricing (tax or ETS) adds emission-based costs, leading firms to adjust production and invest in cleaner technologies.

Households: Maximize utility through consumption and labor supply, with income determined by wages in equilibrium.

Government: Implements carbon pricing and collects revenues, which may be reinvested through subsidies or renewable energy initiatives.

The model assumes perfect competition and applies standard production functions (e.g., Cobb-

Douglas) to represent the relationship between inputs and output.

3.1.3. Model Calibration

Model calibration assigns values to key DSGE parameters to reflect the characteristics of Vietnam's high-emission sectors, based on data from GSO, IEA, and prior studies.

Capital-labor shares: 0.35 (manufacturing), 0.25 (textiles), 0.40 (energy), 0.30 (cement), reflecting input structures across sectors.

Depreciation rate: Fixed at 5% for all sectors.

Elasticity of substitution: Set at 0.8 between clean and carbon-intensive energy sources.

Macroeconomic parameters are also calibrated using national data, with the discount factor (β) set at 0.96 to represent household time preferences.

3.1.4. Estimation

After calibration, the DSGE model is estimated using Maximum Likelihood Estimation (MLE). The model's parameters are estimated based on historical data from 2010 to 2023. The estimation process aims to fit the model's predicted output, costs, and investment levels to actual observed data from Vietnam's industrial sectors. Given the potential limitations of data availability, Bayesian estimation techniques are also employed. Bayesian methods allow for the incorporation of prior information about parameter distributions, derived from studies conducted in other emerging markets such as China and India, which have implemented carbon pricing schemes.

The estimation process ensures that the DSGE model accurately reflects the dynamics of Vietnam's economy, particularly the responsiveness of high-emission sectors to carbon pricing policies. The estimated parameters provide the foundation for conducting scenario analysis and evaluating the impact of different carbon pricing mechanisms on key economic variables.

3.1.5. Simulation Scenarios

The DSGE model is used to simulate multiple carbon pricing scenarios to evaluate their financial impacts on high-emission sectors:

- Baseline: No carbon pricing (reference case).

- Low pricing: \$10/ton CO_2.

- Medium pricing: \$20/ton CO_2.

- High pricing: \$30/ton CO_2.

-Technological shock: Reduced cost of clean technologies.

External trade shock: Impact of mechanisms like CBAM on exports.

For each scenario, the model assesses changes in operational costs, sectoral output, profitability, investment in clean technologies, and emissions. This enables comparison of trade-offs between economic performance and environmental outcomes under different policy settings..

3.1.6. Extensions to the DSGE Model

To improve robustness, the DSGE model is extended to incorporate sectoral heterogeneity and international linkages. Firms within each sector are differentiated by emission levels, allowing for a more detailed analysis of how they respond to carbon pricing.

In addition, the model includes international trade linkages to assess the impact of external shocks, such as CBAM, on Vietnam's global competitiveness. These extensions provide deeper insights into the varying effects of carbon pricing across firms and the broader implications for export-oriented sectors.

3.2. Research Methodology for the Qualitative Phase

The qualitative phase of this research aims to complement the quantitative analysis by capturing expert insights and stakeholder perspectives on the financial and operational impacts of carbon pricing on high-emission sectors in Vietnam. Through a series of semi-structured interviews with industry experts, policy makers, and business leaders, this phase seeks to understand the broader contextual factors that influence how firms respond to carbon pricing mechanisms. The qualitative phase will also explore potential barriers to adopting clean technologies and the strategies firms employ to mitigate the financial burden of carbon pricing.

3.2.1. Research Design

The qualitative phase is designed as an exploratory study that focuses on gathering in-depth insights from key stakeholders in Vietnam's high-emission sectors: manufacturing, textiles, energy, and cement. Given the complexity of the issues surrounding carbon pricing, a semi-structured interview approach is chosen to allow for flexibility in exploring various themes while maintaining a consistent set of core questions across interviews.

The research is guided by the following overarching questions:

How do firms in high-emission sectors perceive the financial implications of carbon pricing mechanisms such as carbon taxes and emissions trading systems?

What barriers exist to adopting clean technologies in response to carbon pricing?

How do firms plan to balance profitability with the need to reduce emissions?

These research questions aim to reveal the underlying factors that drive firms' decision-making processes regarding carbon pricing, technology investment, and emissions reductions.

3.2.2. Sampling and Participant Selection

A purposive sampling method is used to select participants for the qualitative phase. The study targets individuals with extensive knowledge and experience in the high-emission sectors, including:

Industry Experts: Senior executives and managers from the manufacturing, textiles, energy, and cement sectors who are directly involved in decisions related to production, investment, and environmental compliance.

Policy Makers: Representatives from Vietnam's Ministry of Industry and Trade, Ministry of Natural Resources and Environment, and other government bodies responsible for designing and implementing carbon pricing policies.

Sustainability Consultants: Experts from environmental consultancies who advise firms on strategies for reducing carbon emissions and navigating regulatory changes.

Academic Experts: Scholars and researchers specializing in environmental economics, carbon pricing, and industrial emissions.

The selection of these stakeholders ensures that the study captures a wide range of perspectives on the impact of carbon pricing and the strategies used to mitigate its effects. A total of 15-20 participants will be interviewed, ensuring sufficient data saturation while allowing for a manageable volume of qualitative data.

3.2.3. Data Collection: Semi-Structured Interviews

Semi-structured interviews are used as the primary data collection method due to their flexibility in capturing in-depth perspectives while maintaining focus on key research themes. Interviews are conducted in person or via videoconferencing, lasting approximately 45–60 minutes.

Key topics include:

Perception of carbon pricing: Expected impacts on costs and profitability.

Barriers to technology adoption: Financial, technological, and regulatory challenges.

Mitigation strategies: Adoption of clean technologies, alternative energy, or carbon offsets.

Long-term impacts: Effects on competitiveness, profitability, and exposure to policies like CBAM.

All interviews are recorded (with consent) and transcribed for thematic analysis.

3.2.4. Data Analysis: Thematic Analysis

Qualitative data from interviews is analyzed using thematic analysis to identify key patterns in stakeholders' perceptions of carbon pricing in Vietnam's high-emission sectors.

Main steps include:

Familiarization: Reviewing transcripts to understand overall content.

Coding: Identifying key ideas related to core themes (e.g., cost pressures, technology adoption).

Theme development: Grouping codes into broader themes such as cost concerns, investment barriers, regulatory uncertainty, and innovation.

Review and refinement: Ensuring themes accurately reflect the data.

Definition: Clearly naming and linking themes to research objectives.

Reporting: Integrating themes with supporting quotes into the analysis.

This approach helps explain how firms respond to carbon pricing and highlights key challenges and opportunities in transitioning to cleaner production..

3.2.5. Validation and Triangulation

To ensure the credibility and validity of the findings, triangulation is employed by comparing the qualitative data from interviews with the quantitative results obtained from the DSGE model analysis. This process involves cross-referencing the perceptions and strategies reported by participants with the financial and operational outcomes predicted by the model. For instance, if the model predicts significant cost increases in the energy sector due to carbon pricing, the interviews will provide context on how firms in the energy sector are preparing to manage these increased costs. Additionally, member checking is conducted, where participants are invited to review the findings to verify that their views have been accurately represented. This step helps to enhance the reliability of the data and ensure that the interpretations are grounded in the participants' experiences.

4.1. Data analysis results of quantitative phase

The quantitative phase of this study focuses on evaluating the financial and operational impacts of carbon pricing on high-emission sectors in Vietnam. Using a Dynamic Stochastic General Equilibrium (DSGE) model, the analysis examines the effects of various carbon pricing scenarios on key variables such as sectoral output, operational costs, investment in clean technology, profitability, and emissions reductions. The analysis is based on data spanning the period from 2010 to 2023, covering four high-emission sectors: manufacturing, textiles, energy, and cement.

4.1.1. Descriptive Statistics for High-Emission Sectors

The energy sector shows the highest average output and operational costs, reflecting its high emissions intensity and capital-intensive nature. This sector also has the highest average profit margin, at 22%, though it is expected to face significant financial challenges under carbon pricing. The manufacturing sector includes the largest number of firms (150), with an average output of 850 billion VND and a profit margin of 18%

Table 1: Descriptive Statistics of Key Variables (N = 300 firms)

Variable	Manufacturing (N=150)	Textiles (N=80)	Energy (N=40)	Cement (N=30)	Total (N=300)
Avg. Sectoral Output (Billion VND)	850	560	920	650	-
Avg. Operational Costs (Billion VND)	150	90	250	140	-
Avg. Profit Margin (%)	18%	14%	22%	16%	-
Avg. CO2 Emissions (Million Tons)	130	90	270	160	-
Investment in Clean Technologies (Billion VND)	100	80	150	90	-

This sector is critical for Vietnam's industrial economy but faces moderate emissions reduction challenges compared to energy and cement. The manufacturing sector includes the largest number of firms (150), with an average output of 850 billion VND and a profit margin of 18%. This sector is critical for Vietnam's industrial economy but faces moderate emissions reduction challenges compared to energy and cement.

The textiles sector shows lower output and operational costs, but given its significant role in exports, carbon pricing could impact its international competitiveness.

The cement sector, with 30 firms, contributes significantly to emissions, with 160 million tons of CO2 per year, and shows a profit margin of 16%. This sector will require substantial investment in clean technology to meet emissions reduction targets.

4.1.2. Model Calibration

Model calibration is essential for aligning the DSGE model with empirical realities. The model parameters are calibrated using data from the Vietnam General Statistics Office (GSO), the International Energy Agency (IEA), and industry reports from manufacturing, textiles, energy, and cement sectors. Calibration focuses on key economic parameters such as capital-labor ratios, depreciation rates, and the elasticity of substitution between energy sources.

The capital-labor ratio varies across sectors, reflecting the different levels of capital intensity in production processes. The energy sector, with its heavy reliance on capital investment in infrastructure, is assigned a capital-labor ratio of 0.40, while the manufacturing and textiles sectors, which are less capital-intensive, have lower ratios. The depreciation rate is standardized at 5%, consistent with findings from existing literature on capital depreciation in industrial sectors. The elasticity of substitution between carbon-intensive and clean energy is calibrated at 0.8, indicating the relative difficulty firms face in transitioning to cleaner energy sources.

Table 2: Key Parameters for Model Calibration

Parameter	Value	Sectoral Application	Data Source
Capital-Labor Ratio (Manufacturing)	0.35	Manufacturing sector output allocation	Vietnam General Statistics Office (2023)
Capital-Labor Ratio (Textiles)	0.25	Textiles sector capital intensity	Vietnam General Statistics Office (2023)
Capital-Labor Ratio (Energy)	0.40	Energy sector, reflecting capital-intensive production	International Energy Agency (2023)
Capital-Labor Ratio (Cement)	0.30	Cement sector, medium capital and labor mix	Industry Reports (2023)
Depreciation Rate (δ\deltaδ)	5%	All sectors, standard depreciation rate	Literature Review
Elasticity of Substitution	0.8	Substitution between carbon-intensive and clean energy	International Studies on Energy Markets

4.1.3. Model Estimation

Table 3: Variables Used in Model Estimation

Variable	Data Source	Time Period	Notes
Sectoral Output (Billion VND)	Vietnam General Statistics Office (2023)	2010-2023	Collected annually for 300 firms
Operational Costs (Billion VND)	International Energy Agency (2023)	2010-2023	Costs include labor, energy, and capital
Profit Margins (%)	Industry Reports	2010-2023	Average profit margins by sector
Emissions (Million Tons CO2)	Vietnam Ministry of Natural Resources	2010-2023	Emissions data by sector and firm
Investment in Clean Technologies	Firm-Level Surveys	2010-2023	Data on capital expenditures in green technology

After calibration, the DSGE model is estimated using a combination of Maximum Likelihood Estimation (MLE) and Bayesian estimation techniques. The estimation process relies on historical data from 2010 to 2023, enabling the model to capture the responsiveness of firms in high-emission sectors to carbon pricing. MLE is used to optimize the fit of the model by maximizing the likelihood that observed data is generated by the model. Bayesian estimation is employed where data is sparse, allowing prior distributions from international studies to inform parameter estimation.

This estimation process ensures that the model reflects both short-term firm responses and long-term structural adjustments to carbon pricing. By incorporating both sectoral output and profit margins, the estimation captures the broader economic dynamics, including the transition to clean technologies.

4.1.4. Simulation Scenarios

The DSGE model is used to simulate various carbon pricing scenarios, providing insight into how firms in high-emission sectors adjust to regulatory changes. Each scenario models the impact of different carbon pricing levels, including a baseline with no carbon pricing, and low, medium, and high carbon tax levels.

Table 4: Carbon Pricing Simulation Scenarios

Scenario	**Carbon Tax Level (Per Ton CO2)**	**Description**
Baseline Scenario	0	No carbon pricing, used for comparison
Low Carbon Pricing Scenario	$10	Modest regulatory intervention
Medium Carbon Pricing Scenario	$20	Greater pressure on firms to reduce emissions
High Carbon Pricing Scenario	$30	Aggressive carbon pricing with significant financial impacts

In the baseline scenario, firms continue to operate without regulatory interventions, allowing the study to establish a control. Under the low carbon pricing scenario, a $10 per ton carbon tax is introduced, representing an initial step toward emissions reductions. The medium and high carbon pricing scenarios simulate increasing levels of regulatory pressure, forcing firms to make significant adjustments in their operational practices, including investments in cleaner technologies.

Additionally, two more complex scenarios are simulated:

Technological Shock Scenario: This scenario introduces a positive technological shock, reducing the cost of clean technology investments. It explores how advancements in technology impact the adoption of green practices.

External Trade Shock Scenario: This scenario examines the effects of external trade policies, such as carbon border adjustments, which impose taxes on carbon-intensive imports, affecting export-oriented sectors like textiles and manufacturing.

4.1.5. Extensions to the DSGE Model

To enhance analytical depth, the DSGE model is extended to better capture firm behavior and global interactions:

Sectoral heterogeneity: Differentiates firms by size and emission intensity, highlighting that smaller firms face greater financial constraints than larger ones.

Endogenous technological change: Allows firms to adjust investments in clean technology over time, creating a feedback loop that supports innovation and emissions reduction.

International linkages: Incorporates global policies such as CBAM to assess impacts on export-oriented sectors.

Policy feedback mechanisms: Models the reinvestment of carbon tax revenues into subsidies or green initiatives to support low-carbon transition and competitiveness.

These extensions provide a more comprehensive view of the economic and policy impacts of carbon pricing.

4.2. Hypothesis Testing for the Quantitative Phase

4.2.1. Increase in Operational Costs Due to Carbon Pricing (Hypothesis 1)

Operational costs are expected to increase as firms face carbon taxes or emissions permit costs. Hypothesis 1 suggests that carbon pricing will significantly increase operational costs for high-emission sectors

Table 5: Increase in Operational Costs Due to Carbon Pricing (Billion VND)

Sector	Baseline Costs	Carbon Tax ($10/ton)	Carbon Tax ($20/ton)	Carbon Tax ($30/ton)
Manufacturing	150	170	185	200
Textiles	90	110	120	130
Energy	250	300	330	360
Cement	140	160	180	200

Testing Hypothesis 1: Table 5 confirms Hypothesis 1, as operational costs rise significantly under higher carbon pricing levels. The energy sector experiences a 44% increase in costs under the $30/ton scenario, while cement sees a 42.8% increase. The manufacturing and textiles sectors face more moderate but still substantial cost increases of 33.3% and 44.4%, respectively. Conclusion: The data supports Hypothesis 1, demonstrating that carbon pricing leads to significant increases in operational costs, especially in energy-intensive sectors.

4.2.2. Investment in Clean Technologies (Hypothesis 2)

Hypothesis 2 predicts that high-emission sectors will invest significantly in clean technologies to reduce their emissions and manage the rising costs associated with carbon pricing.

Table 6: Projected Investment in Clean Technologies (Billion VND)

Sector	Baseline Investment	Carbon Tax ($10/ton)	Carbon Tax ($20/ton)	Carbon Tax ($30/ton)
Manufacturing	100	130	160	190
Textiles	80	100	120	150
Energy	200	250	300	360
Cement	90	120	140	170

Testing Hypothesis 2: As shown in Table 6, the energy and cement sectors increase their investments in clean technologies by 93.3% and 88.9%, respectively, under the $30/ton carbon tax scenario. This supports Hypothesis 2, as firms in these sectors are highly incentivized to adopt cleaner technologies to mitigate the financial impact of carbon pricing. The manufacturing and textiles sectors also increase their clean technology investments, though to a lesser extent due to their lower emissions intensity.

Conclusion: Hypothesis 2 is validated, as the results demonstrate that firms in high-emission sectors respond to carbon pricing by increasing their investment in clean technologies.

4.2.3. Impact of Carbon Pricing on Sectoral Output (Hypothesis 3)

The DSGE model simulates the effects of various carbon pricing levels-$10, $20, and $30 per ton of CO2-on sectoral output across high-emission industries. Hypothesis 3 suggests that carbon pricing will lead to short-term declines in sectoral output and profitability, as firms adjust to the financial burdens imposed by carbon taxes.

Testing Hypothesis 3: The results in Table 7 confirm Hypothesis 3, as all sectors experience a decline in output as carbon prices rise. The energy sector sees a reduction of 13.7% at the highest carbon tax level ($30 per ton), while cement output drops by 13.8%. These declines in output, particularly in energy and cement, reflect the increased operational costs associated with carbon pricing and reduced production efficiency in the short term.

Table 7: Projected Sectoral Output under Carbon Pricing Scenarios (Billion VND)

Sector	Baseline Output	Carbon Tax ($10/ton)	Carbon Tax ($20/ton)	Carbon Tax ($30/ton)
Manufacturing	850	830	810	780
Textiles	560	545	530	510
Energy	1020	960	960	880
Cement	650	620	590	560

Conclusion: Hypothesis 3 is supported, as the results show a clear relationship between rising carbon prices and short-term declines in sectoral output across all industries.

4.2.4. Profitability Impact of Carbon Pricing (Hypothesis 3)

Hypothesis 3 also predicts that carbon pricing will reduce profit margins in high-emission sectors in the short term, with the potential for long-term recovery through technological investment.

Table 8: Profit Margins Before and After Carbon Pricing Implementation

Sector	Baseline Profit Margin (%)	Carbon Tax ($10/ton)	Carbon Tax ($20/ton)	Carbon Tax ($30/ton)
Manufacturing	18%	15%	13%	11%
Textiles	14%	12%	10%	8%
Energy	22%	18%	15%	12%
Cement	16%	14%	12%	10%

Testing Hypothesis 3: The results in Table 8 confirm Hypothesis 3, showing that profit margins decline across all sectors. The energy sector experiences the most significant decline, with margins falling from 22% to 12% under the $30/ton scenario. The cement sector sees a similar reduction, from 16% to 10%. The manufacturing and textiles sectors also experience declines, with profit margins decreasing by 7 percentage points and 6 percentage points, respectively.

Conclusion: Hypothesis 3 is supported, as carbon pricing reduces short-term profitability across all sectors, particularly in energy and cement.

4.2.5. Emissions Reductions Across Sectors (Hypothesis 4)

Hypothesis 4 posits that carbon pricing will result in significant emissions reductions, as firms adopt cleaner technologies and adjust production processes.

Table 9: Projected Emissions Reductions (Million Tons CO2) under Carbon Pricing

Sector	Baseline Emissions	Carbon Tax ($10/ton)	Carbon Tax ($20/ton)	Carbon Tax ($30/ton)
Manufacturing	130	115	100	90
Textiles	90	80	70	60
Energy	270	240	200	170
Cement	160	140	120	110

Testing Hypothesis 4: Table 9 shows that carbon pricing significantly reduces emissions in all sectors, with the energy sector reducing emissions by 200 million tons under the $30/ton scenario. The cement sector also achieves substantial reductions, with a 50 million ton decrease in emissions. The manufacturing and textiles sectors show moderate reductions, reflecting their lower emissions intensity.

Conclusion: Hypothesis 4 is validated, as carbon pricing leads to significant emissions reductions across all sectors, especially in energy and cement.

4.2.6. Impact of Carbon Pricing on International Competitiveness (Hypothesis 5)

Hypothesis 5 suggests that export-oriented sectors, such as textiles and manufacturing, will experience a decline in international competitiveness due to carbon pricing, especially if foreign markets implement carbon border adjustment mechanisms (CBAM).

Table 10: Impact of Carbon Pricing and External Trade Shocks on Export Competitiveness (Billion VND)

Sector	Baseline Exports	Carbon Tax ($10/ton)	Carbon Tax ($20/ton)	Carbon Tax ($30/ton)	With Trade Shock ($30/ton)
Manufacturing	400	380	360	340	310
Textiles	300	280	260	240	200

Testing Hypothesis 5: The results in Table 10 indicate that export-oriented sectors such as textiles and manufacturing face declines in international competitiveness as carbon prices increase. With a $30/ton carbon tax, manufacturing exports decline from 400 billion VND to 340 billion VND, while textiles exports decrease from 300 billion VND to 240 billion VND. The impact is exacerbated when external trade shocks such as CBAM are introduced, causing manufacturing exports to drop further to 310 billion VND and textiles exports to fall to 200 billion VND.

Conclusion: Hypothesis 5 is supported, as the results show that carbon pricing, combined with external trade pressures, leads to a significant reduction in the international competitiveness of export-oriented sectors like textiles and manufacturing.

4.2.7. Financial Constraints for Smaller Firms (Hypothesis 6)

Hypothesis 6 posits that smaller firms in high-emission sectors will face greater financial constraints in adapting to carbon pricing compared to larger firms, particularly in terms of clean technology investment.

Table 11: Clean Technology Investment by Firm Size (Billion VND)

Sector	Large Firms (N=200)	Small Firms (N=100)
Manufacturing	160	100
Textiles	120	80
Energy	240	150
Cement	140	90

Testing Hypothesis 6: As shown in Table 11, smaller firms across all sectors invest significantly less in clean technologies compared to larger firms. In the energy sector, large firms invest 240 billion VND, while small firms invest only 150 billion VND. Similarly, in manufacturing, large firms invest 160 billion VND, while small firms invest only 100 billion VND. These results confirm Hypothesis 6, as smaller firms face greater financial constraints and limited access to capital, slowing their adoption of clean technologies.

Conclusion: Hypothesis 6 is validated, as the data shows that smaller firms invest less in clean technologies compared to larger firms, facing greater financial constraints in adapting to carbon pricing.

4.3. Data Analysis for the Qualitative Phase

The qualitative phase of this study involved interviews with stakeholders from Vietnam’s high-emission sectors-manufacturing, textiles, energy, and cement-to gain insights into the financial and operational impacts of carbon pricing. The interviews from 18 participants were analyzed using thematic analysis, with key themes emerging that provide a deeper understanding of how firms perceive and respond to carbon pricing. The qualitative findings complement the quantitative analysis by offering context-specific insights into the barriers, challenges, and strategies firms employ in adapting to carbon pricing policies.

4.3.1. Perception of Carbon Pricing (Hypothesis 1)

Theme 1: Carbon Pricing as a Financial Burden. One of the most frequently mentioned themes across interviews was the perception of carbon pricing as a financial burden. Participants from the energy and cement sectors emphasized the significant increase in operational costs due to carbon pricing mechanisms such as carbon taxes or emissions trading systems (ETS). A senior executive from the energy sector shared:

"The carbon tax has added pressure to our already tight margins. We are seeing operational costs spike, and without cutting production or investing in expensive clean technologies, it’s difficult to stay competitive."

Firms, especially those with higher emissions, perceive carbon pricing as a direct financial penalty, which has strained their operations.

Analysis: This theme supports Hypothesis 1, which predicted that carbon pricing would significantly increase operational costs for high-emission sectors. The qualitative findings reinforce the quantitative results by illustrating the real-world financial impacts that firms face, particularly in capital- and energy-intensive sectors like energy and cement.

4.3.2. Investment in Clean Technologies (Hypothesis 2)

Theme 3: Clean Technology Investment as a Long-Term Strategy

Larger firms, particularly in the energy and manufacturing sectors, identified investment in clean technologies as a long-term strategy to reduce carbon emissions and offset the costs of carbon pricing. A director from a large energy company explained:

"While the initial costs of transitioning to renewable energy and energy-efficient systems are high, we see this as a long-term investment. We expect these investments to reduce our carbon tax burden and improve our sustainability profile in the future."

Firms that have greater access to capital and resources are more likely to adopt clean technologies proactively, viewing it as a strategic response to carbon pricing and regulatory pressures.

Analysis: This theme supports Hypothesis 2, which predicted that high-emission sectors would invest significantly in clean technologies in response to carbon pricing. The qualitative data show that while smaller firms struggle, larger firms are actively investing in clean technologies as a means to mitigate the financial impact of carbon pricing.

4.3.3. Profitability and Short-Term Financial Strain (Hypothesis 3)

Theme 4: Decline in Profit Margins

Participants from high-emission sectors, particularly energy and cement, expressed concerns about declining profit margins due to carbon pricing. A financial officer from a cement company noted: "Our profit margins have taken a hit since the introduction of the carbon tax. We're trying to balance rising operational costs with maintaining competitiveness, but it's not easy. The margins are getting thinner."

Firms are seeing an immediate decline in profitability as they struggle to adjust to higher costs without sacrificing production capacity. Some firms are considering cutting back on production or making capital investments to recover profitability in the long term.

Analysis: This theme aligns with Hypothesis 3, which posited that carbon pricing would lead to short-term declines in profit margins. The qualitative findings confirm that firms in energy and cement sectors are facing financial strain due to rising operational costs, leading to reduced profitability in the short term.

4.3.4. Regulatory Uncertainty and Need for Government Support (Hypothesis 4)

Theme 6: Uncertainty in Policy Implementation and the Need for Government Support. A recurring theme across all interviews was the uncertainty surrounding policy implementation and the need for government support to ensure that carbon pricing is implemented in a way that does not cripple industries. Many participants emphasized the need for clearer policy guidelines, financial incentives, and subsidies to support the adoption of clean technologies. A policymaker from the Ministry of Industry and Trade shared:

"While we are committed to reducing emissions, it’s important that we also support industries in this transition. Clearer guidelines on how carbon pricing revenues will be reinvested in green technology subsidies are needed to ensure compliance without overwhelming businesses."

Firms expressed frustration with the lack of clarity on how carbon pricing would be rolled out over the long term and emphasized the importance of government intervention to help industries transition to cleaner technologies.

Analysis: This theme supports Hypothesis 4, which posits that firms will need government support to manage the financial and operational challenges of carbon pricing. The findings suggest that while firms are willing to adapt, they require stronger policy guidance and financial incentives to make the transition feasible.

4.3.5. Impact on International Competitiveness (Hypothesis 5)

Theme 5: International Competitiveness Under Threat

Participants from export-oriented sectors such as textiles and manufacturing raised concerns about the impact of carbon pricing on their international competitiveness, particularly in the face of carbon border adjustment mechanisms (CBAM) being implemented by foreign markets. A general manager from a textiles firm noted:

"We're already competing in a tough international market. The carbon tax adds to our operational costs, and if buyers start imposing carbon tariffs on our products, we'll have an even harder time staying competitive."

Export-oriented firms fear that while they face domestic carbon pricing, international competitors may not be subject to the same regulatory pressures, further reducing their competitive advantage in global markets.

Analysis: This theme supports Hypothesis 5, which suggests that export-oriented sectors will experience a decline in international competitiveness due to carbon pricing and international trade mechanisms like CBAM. The qualitative findings illustrate the tangible fears among firms in textiles and manufacturing sectors about their ability to remain competitive globally while facing increasing regulatory costs.

4.3.6. Barriers to Clean Technology Adoption (Hypothesis 6)

Theme 2: Financial Constraints for Smaller Firms Interviews reveal that smaller firms face significant financial barriers when investing in clean technologies. Firms in textiles and cement sectors report difficulties in accessing capital to upgrade equipment or adopt cleaner energy, while larger firms have better access to financing and support. This creates a gap in the ability to comply with carbon pricing regulations.

This finding supports Hypothesis 6, confirming that smaller firms experience greater financial constraints in adapting to carbon pricing. Qualitative evidence reinforces quantitative results, highlighting limited access to funding as a key challenge.

5. Discussion

5.1. Carbon Pricing as a Financial Burden

Results from both quantitative and qualitative analyses confirm that carbon pricing creates a significant financial burden for high-emission sectors. The DSGE model indicates rising operational costs as carbon prices increase, with the energy and cement sectors most affected due to their dependence on carbon-intensive processes. Qualitative findings further support this, as firms-especially in the energy sector-highlight concerns about increased financial pressure and tighter profit margins.

This result is consistent with Hypothesis 1, confirming that carbon pricing significantly raises operational costs. Overall, while carbon pricing is necessary for environmental goals, it poses considerable financial challenges for firms, particularly without adequate policy support or financial assistance mechanisms.

5.2. Investment in Clean Technologies: A Long-Term Strategy

The quantitative results show that investment in clean technologies increases as carbon pricing rises, particularly in the energy and cement sectors. Qualitative findings further indicate that larger firms consider these investments a long-term strategy to reduce carbon costs, comply with regulations, and improve operational efficiency despite high initial expenses.

This finding supports Hypothesis 2, confirming that carbon pricing encourages firms to adopt cleaner technologies. The consistency between model results and firm perspectives suggests that carbon pricing is effective in driving green investment, especially when firms have sufficient financial capacity. Smaller firms face significant barriers due to limited financial resources and access to capital. This supports Hypothesis 6, indicating that smaller firms encounter greater constraints in adapting to carbon pricing and require stronger policy support and financing mechanisms to transition effectively.

5.3. Profitability and International Competitiveness

The findings show that carbon pricing reduces profitability in the short term across all sectors, with the strongest impact on energy and cement due to rising costs. This supports Hypothesis 3. However, firms with greater financial capacity-especially large firms-can recover over time through investments in clean technologies and efficiency improvements.

Export-oriented sectors like textiles and manufacturing also face declining competitiveness, as export volumes decrease under the combined effects of carbon pricing and measures such as CBAM. This supports Hypothesis 5, indicating that carbon policies and trade regulations may disadvantage firms in developing economies, highlighting the need for coordinated international approaches.

5.4. The Role of Government Support

An important theme that emerged from the qualitative phase was the need for government support to help firms adapt to carbon pricing. Participants across all sectors emphasized that without adequate policy guidance, financial incentives, and subsidies, many firms, especially smaller ones, would struggle to comply with carbon pricing regulations. The lack of clarity on how carbon pricing revenues would be reinvested in the economy further added to firms' concerns about the long-term feasibility of these policies.

This finding supports Hypothesis 4, which posited that firms would require government support to manage the financial and operational challenges of carbon pricing. While carbon pricing can drive investments in cleaner technologies, its success depends on complementary policies that provide firms with the financial resources and regulatory clarity needed to navigate the transition. The qualitative data suggest that without such support, the effectiveness of carbon pricing in achieving environmental goals could be undermined by firms' financial limitations.

5.5. Limitations and Future Research Directions

This study provides important insights into the financial impacts of carbon pricing on high-emission sectors in Vietnam, but several limitations should be noted. First, limited firm-level data-especially for small firms-reduces the depth of analysis. Second, the DSGE model assumes sectoral homogeneity, which may not fully reflect differences in firms' financial capacity and emission levels. Third, the focus on a specific time period limits the assessment of long-term impacts. Finally, the Vietnam-focused scope restricts the generalizability of the findings.

The study only partially addresses issues such as international competitiveness, CBAM, and carbon leakage, and does not consider consumer behavior, which may influence firm responses.

Future research should expand firm-level data, incorporate sectoral heterogeneity, and adopt longitudinal approaches. Comparative studies across countries, deeper analysis of global carbon markets, and the role of consumer demand for low-carbon products would further enhance understanding of carbon pricing impacts.

5.6. Implications for Policy and Practice

The findings from this study have several important implications for both policymakers and industry leaders. First, policymakers need to recognize that carbon pricing alone is insufficient to drive a successful transition to a low-carbon economy, especially for smaller firms. Targeted financial assistance, such as subsidies, low-interest loans, or tax breaks for clean technology investments, is essential to ensure that all firms-regardless of size-can comply with carbon pricing regulations. International coordination on carbon pricing and trade policies, such as harmonizing carbon border adjustment mechanisms, is crucial to maintaining the competitiveness of Vietnam's export-oriented sectors. Without such coordination, firms may be disadvantaged in global markets, leading to a decline in exports and economic growth.

The long-term effectiveness of carbon pricing depends on firms' ability to innovate and invest in cleaner technologies. Larger firms are already taking steps in this direction, but smaller firms need greater access to financing to adopt similar strategies. Policymakers should consider implementing programs that facilitate access to green financing for small and medium-sized enterprises (SMEs) to ensure that they are not left behind in the transition to a low-carbon economy.

5.7. Conclusion

The integration of both quantitative and qualitative findings provides a comprehensive understanding of the financial and operational impacts of carbon pricing on high-emission sectors in Vietnam. Carbon pricing, while effective in incentivizing clean technology adoption, imposes significant financial challenges on firms, particularly smaller ones. Profitability declines and international competitiveness are key concerns for firms operating in export-oriented sectors, highlighting the need for coordinated global action on carbon pricing. The study underscores the importance of government support in facilitating the transition to a low-carbon economy and ensuring that firms of all sizes are able to comply with carbon pricing regulations without compromising their financial viability.

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Thông tin bài

Ngày nhận bài: 12/1/2026

Ngày hoàn thành: 23/3/2026

Ngày đăng bài: 27/3/2026

Tác giả liên hệ: Cong Tu Huu