

The Differential Impact of Carbon Tax Policy on the Economic Competitiveness of Small and Medium-sized Enterprises Across Various Sectors and Regions: A Quantitative Analysis

Tiangeng Lyu

*The Experimental High School Attached to Beijing Normal University, Beijing, China
lyutiangeng@outlook.com*

Abstract. Under mounting pressure from global climate change, carbon pricing mechanisms - particularly carbon taxes - have emerged as pivotal policy instruments for emissions reduction. As integral components of the economy, small and medium-sized enterprises (SMEs) demonstrate heightened sensitivity to carbon tax policies due to their distinctive characteristics including energy intensity, resource accessibility, and transition flexibility. Drawing on a mixed-methods approach, this study integrates quantitative and qualitative data sources to capture both macro patterns and firm-level dynamics. This study systematically examines the mechanisms and magnitude through which carbon tax policies influence the economic competitiveness of heterogeneous SMEs, while identifying critical determining factors. The analysis reveals substantial heterogeneity in the competitive impacts of carbon taxation across SME sectors. Energy-intensive manufacturing industries and resource-constrained micro-enterprises experience the most severe negative repercussions, whereas certain service-sector firms exhibit enhanced competitiveness through innovation offset effects. These findings underscore the necessity for policy frameworks that incorporate targeted technical assistance and collaborative platforms specifically designed for vulnerable enterprise groups.

Keywords: Carbon Tax Policy, Small and Medium-sized Enterprises (SMEs), Economic Competitiveness, Heterogeneity Analysis, Quantitative Evaluation

1. Introduction

Against the backdrop of intensifying global climate crises, achieving carbon neutrality has become a core strategic objective for nations worldwide. Carbon pricing policies (such as carbon taxes and emissions trading systems), as key economic instruments for emission reduction, have been widely adopted to address climate change [1]. Among these, carbon taxes have proven to be an effective means of internalizing the external costs of carbon emissions due to their policy transparency and market flexibility [2,3]. However, the economic impacts of carbon taxes show significant

heterogeneity, particularly on small and medium-sized enterprises (SMEs), which constitute an important component of national economies.

SMEs account for over 90% of all businesses globally, contribute to more than 50% of employment, and generate about 40% of GDP [4]. Research indicates that carbon tax policies may lead to an average decline of 2.3% in SME profit margins, with vulnerable groups such as energy-intensive manufacturers and micro-enterprises experiencing reductions exceeding 8% [5]. This phenomenon raises core research questions: How do carbon tax policies specifically affect the economic competitiveness of SMEs? Are the impacts positive, negative, or mixed? What are the key influencing factors and mechanisms?

This study aims to systematically evaluate the impact of carbon tax policies on the economic competitiveness of small and medium-sized enterprises (SMEs) through quantitative analysis methods, while identifying the sources of heterogeneity. The specific objectives are:

To quantitatively assess the effects of carbon taxes on multidimensional competitiveness indicators of SMEs, including: Profit margins, R&D investment intensity, Carbon productivity;

To identify key heterogeneous factors influencing these impacts, particularly as industry characteristics (e.g., energy-intensive manufacturing vs. service sectors) including Firm size (micro, small, and medium enterprises), regional disparities (developed vs. developing regions);

To develop policy optimization recommendations that: provide empirical evidence for designing differentiated carbon tax mechanisms [6], support SMEs in achieving green transition [7], balance environmental effectiveness with economic competitiveness.

Based on these considerations, this study proposes the following hypotheses.

H1: Carbon taxes will exert significantly stronger negative impacts on SMEs in energy-intensive industries compared to those in service sectors.

H2: The overall effect of carbon taxes on SMEs will be mixed, demonstrating both: Negative short-term effects on operational costs and profitability; Positive long-term effects on innovation and productivity through the "innovation compensation effect".

2. Literature review

2.1. Theoretical perspectives on the economic impacts of carbon taxation

Carbon Tax is an environmental policy instrument based on the Pigouvian tax theory [2]. It imposes a specific tax on the carbon content of fossil fuels to increase the cost of high-carbon energy use, thereby incentivizing low-carbon transition [1]. Unlike command-and-control regulations, carbon taxes allow enterprises to autonomously choose emission reduction approaches (such as technological upgrades, energy substitution, or cost absorption), theoretically achieving cost-effective emission reduction.

Existing studies generally agree that the macroeconomic effects of carbon taxation exhibit "short-term pains but long-term gains" [3,8]: short-term GDP suppression (European data show that every €10/ton CO₂ tax reduces GDP growth by 0.1%-0.3%), but long-term benefits through green investment creating new growth drivers (as demonstrated by Sweden's case showing positive effects) [4,6]. Job losses in traditional energy sectors coexist with green job creation, with OECD estimating a long-term net employment effect of +0.5%-1.2% [9]. Rising energy prices directly increase CPI (EU data: every €10/ton CO₂ raises CPI by 0.2%-0.4%), though this can be mitigated through tax rebate mechanisms [7].

Carbon taxation exerts divergent effects across industries: Energy-intensive sectors (e.g., steel, cement) face cost increases that may reduce exports by 5%-15% without border adjustment

measures (CBAM) [8]. However, stringent carbon taxes can stimulate low-carbon technology investments, as demonstrated by Norway's aluminum industry where hydropower transition lowered long-term costs [10].

2.2. Empirical studies on carbon tax impacts on enterprises

Large enterprises employ two primary strategies to respond to carbon taxes. The first is global production relocation: 15% of EU multinational corporations have outsourced carbon-intensive production to low-tax regions [11]. The second is technological innovation: large Chinese manufacturing enterprises experienced an 18% increase in clean technology patents following carbon tax pilot implementation [5].

Small and medium-sized enterprises (SMEs), constrained by "limited cost-pass-through capability" and "financing constraints", demonstrate passive adaptation characteristics: Southeast Asian micro-enterprises faced an 8.5% increase in raw material costs due to CBAM, with 90% unable to transfer these costs through price adjustments [5]. In Japan, 62% of small enterprises opted for workforce reductions or extended equipment lifespans, while only 5% invested in technological upgrades [12].

Large enterprises such as those in Swedish manufacturing have reduced energy intensity by 23% [13] and tend to adopt long-term technologies (e.g., carbon capture). In comparison, SMEs' low-carbon investments amount to only 1/10th of large enterprises', primarily focusing on short-term energy-saving equipment [14].

2.3. Research gaps

Existing studies predominantly focus on large enterprises, with insufficient analysis of heterogeneity among small and medium-sized enterprises (SMEs) and a lack of evaluation on policy mixes (e.g., carbon tax + subsidies).

3. Methodology

3.1. Data collection and sources

This study employs a mixed-methods research approach, systematically analyzing the impact of carbon taxes on SME operational performance through the integration of quantitative and qualitative data.

Secondary data were obtained from government statistical databases, including OECD SME indicators [9], the "Standards for Classification of SMEs" issued by China's Ministry of Industry and Information Technology, and the National Bureau of Statistics' data on above-scale industrial enterprises (2017-2023). Corporate annual reports and carbon disclosure data, such as from the Wind Financial Database and CSMAR Database, cover SMEs across 16 industry sectors (2019-2023). Policy documents include domestic and international carbon tax policy files (e.g., EU CBAM, China's carbon tax pilot policies).

This study utilizes a mixed-methods dataset comprising both quantitative and qualitative components.

Quantitative data primarily encompass firm-level economic indicators such as profit margins, R&D expenditure, and the proportion of energy costs, along with external variables including carbon tax rates and sector-specific carbon emission intensity.

Qualitative data are derived from semi-structured interview transcripts, coded policy documents, and comparative case studies of selected enterprises.

3.2. Analysis tools

A fixed-effects model was constructed to examine the impact of carbon taxes on operational performance: $Performance_{it} = \alpha + \beta CarbonTax_{it} + \gamma Controls_{it} + \epsilon_{it}$. The dependent variables include profitability (ROA) and operational capacity (inventory turnover ratio), while the core explanatory variable is the effective carbon tax rate. Control variables encompass firm size, industry attributes, and region.

Heterogeneity analysis was conducted through subgroup regressions based on firm size (micro/small/medium), industry (high/low energy intensity), and region (eastern/central/western China).

Content analysis was employed to code policy texts and extract the stringency and coverage of carbon tax provisions (e.g., exemption thresholds, subsidy mechanisms). A case comparison method was used to analyze the differences in carbon tax response strategies among three representative firms (high-energy-intensity manufacturing vs. service industries).

3.3. Research design

Industry selection was primarily based on the "China Industrial Enterprise Carbon Emission Intensity Guidelines," focusing on industries with carbon emission intensity above the industry average (e.g., cement, steel, textiles) while including service sectors (e.g., logistics, retail) as controls.

Firm size was classified according to MIIT standards: micro (<10 employees), small (10-50 employees), and medium (50-300 employees) enterprises.

Regional classification covered eastern (e.g., Yangtze River Delta), central (e.g., Henan), and western (e.g., Sichuan) areas, accounting for regional policy differences (e.g., Western Development Tax Incentives).

Using the 2019 policy implementation in China's carbon tax pilot provinces (e.g., Guangdong, Hubei) as the reference point, the study analyzes enterprise performance changes over a 3-year period before and after (2017-2022).

4. Results and discussion

4.1. Heterogeneity analysis results

This study systematically examines the heterogeneous effects of carbon taxes on different types of SMEs through panel regression models. Key findings include:

Industry Differences Energy-intensive manufacturing sectors (e.g., cement, steel) were most severely impacted, with average profit margins declining by 8.2% ($p < 0.01$). This is primarily due to energy costs exceeding 25% of total costs and weak cost-pass-through capability (only 17% of firms successfully passed through >50% of carbon tax costs). Service sectors (e.g., logistics, retail) were less affected, with some firms gaining a 2.1% market share premium ($p < 0.05$) through green certification and achieving 12.7% improvement in carbon productivity ($p < 0.01$), confirming the "innovation offset effect."

Micro enterprises (<10 employees) saw a 4.8% increase in bankruptcy rates, mainly due to financing constraints (only 4.3% increased R&D investment). Medium-sized enterprises (50-300

employees) performed better, offsetting 60% of carbon tax costs through energy-saving retrofits (e.g., the German ESCO model).

In terms of regional differences, Western enterprises experienced a 3.2 percentage-point smaller decline in profit margins compared to eastern enterprises ($\beta=0.193$, $p<0.05$), benefiting from policy support such as tax rebates [13].

As Table 1 shown, Eastern enterprises faced greater supply chain cost transmission (e.g., EU CBAM increased export costs by 8.5%).

Table 1. Example table presentation

	rgin Change	Key Mechanism
Energy-intensive	-8.2%	Cost-pass-through failure (73%)
Service sectors	+2.1%	Green certification premium
Micro enterprises	Bankruptcy rate↑4.8%	Financing constraints limit tech upgrades

4.2. Discussion

Carbon taxes squeeze profits through:

Direct energy cost increases (electricity +23%)

Supply chain cost transmission (raw materials +15%)

SMEs' weak bargaining power results in only 28% cost-pass-through rate (vs. 65% for large enterprises).

Digitally-capable SMEs show 15% R&D response rate (e.g., using AI energy management systems), while traditional enterprises manage only 3%-5% due to technological adaptation barriers.

Sources of Heterogeneity

Energy-intensive manufacturing: High fixed cost proportion makes short-term adjustments difficult.

Service sectors cause faster returns on low-carbon tech investments (e.g., solar rooftop projects with IRR>12%).

Western enterprises lead to benefit from "carbon tax-green credit" policy packages (e.g., loan interest subsidies), while regions with standalone carbon taxes suffer more severe impacts.

5. Conclusion

5.1. Research conclusions

The overall net effect shows SMEs' average profit margin declined by 2.3%, while carbon productivity improved by 7.1%, demonstrating "short-term pains with long-term gains" characteristics.

Vulnerable groups form a "fragility triangle": energy-intensive manufacturers; micro enterprises; enterprises in regions without policy support (Profit margin decline >5%)

Resilient groups achieve win-win outcomes through innovation offsets: Service sector; digitally-enabled medium enterprises (Profit margin +1.8%, carbon reduction +12.7%).

5.2. Policy recommendations

For Short-term (0-2 years), in aspect of exemption mechanisms, 5-year tax exemption for micro enterprises (modeled after German eco-tax exemptions); "Tax refund-emission reduction

performance" linkage for energy-intensive industries (e.g., Canada's Output-Based Pricing System, 30-50% refund rate). In aspect of technical support, establish regional energy audit centers (<\$500 per audit, World Bank data); promote open-source carbon management toolkits (e.g., Japanese ESCO model reduces retrofit costs by 40%).

For medium-term (3-5 years), in aspect of institutional mechanisms, implement credit evaluation systems for green transition (prioritizing ETS-excluded sectors); issue "green transition bonds" ($\geq 70\%$ credit guarantee) to fund CCUS facilities (e.g., Turkey's EPS factory solar project). In aspect of regulatory coordination, avoid overlapping with ETS (e.g., Hubei pilot firms suffered additional 1.8% profit margin decline due to "dual regulation").

For long-term (5+ years), in aspect of dynamic carbon pricing mechanisms with digital tracking tools. In aspect of sector-specific tax frameworks, higher rates for high-emission industries (e.g., chemicals, cement); tax incentives for transitioning sectors.

5.3. Research prospects

Requires quantification of carbon tax-green subsidy interactions (e.g., KfW special funds). Long-term impacts on SME employment quality (e.g., skills training needs), regional balanced development dynamics and potential of digital-enabled dynamic carbon pricing mechanisms should be examined. Carbon-oriented tax policy framework remains crucial for dual-carbon strategy implementation.

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