CARBON PRICING AND FINANCIAL PERFORMANCE: EVIDENCE FROM INDIAN FIRMS

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ABSTRACT
This study investigates the financial implications of carbon pricing exposure for Indian firms, focusing on accounting-based and market-based performance indicators. Using firm-level data from the ORBIS database for the period 2010–2023, we examine the relationship between carbon exposure, proxied by industry carbon intensity and energy cost shares, and firm profitability (Return on Assets), market valuation (Tobin's Q), and stock market valuation. Employing fixed-effects panel regressions with robust standard errors, we find that carbon-intensive firms experience significantly lower profitability and market valuation, while non-carbon-intensive firms remain largely unaffected. The negative effects are more pronounced for market-based measures, indicating that investors actively price carbon-related regulatory and transition risks. Heterogeneity analyses confirm that the financial burden of carbon pricing is concentrated in carbon-intensive sectors, suggesting a reallocation rather than uniform decline in firm value. The results remain robust to alternative performance measures, lagged exposure, and industry exclusions. The findings highlight the importance of predictable carbon pricing pathways, credible carbon disclosure, and proactive low-carbon investment strategies for corporate managers. By providing the first large-scale, firm-level evidence from India, this study extends the literature on carbon pricing and financial performance in emerging economies and offers insights for policymakers and investors navigating the low-carbon transition.

Keywords: Carbon-intensive industries, emissions, ROA, stock market valuation, Tobin's Q.

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INTRODUCTION

Climate change represents a defining challenge for 21st-century economic policy, and carbon pricing has emerged as a central instrument for internalizing the external costs of greenhouse gas emissions. Carbon pricing mechanisms, such as carbon taxes and emissions trading systems (ETS), place an explicit or implicit cost on carbon emissions, incentivizing firms to reduce their environmental footprint while stimulating investment in cleaner technologies. Although India does not currently impose a uniform carbon tax, a suite of implicit carbon pricing instruments, especially fuel excise taxes, effectively imposes a positive price on over half of the nation's greenhouse gas emissions (53.9%). Concurrently, India is developing its domestic carbon market under the Carbon Credit Trading Scheme (CCTS), which aims to facilitate least-cost abatement across sectors while rewarding low-emission performance through tradable credits. This evolving policy landscape makes India a compelling context for understanding how firms respond financially and strategically to carbon pricing signals.

Empirical research from advanced economies has linked carbon pricing to varied firm outcomes, including altered profitability metrics and changes in market valuation (Shingade et al., 2022). However, empirical evidence for emerging markets, particularly India, remains sparse. Indian carbon pricing instruments are nascent, heterogeneous, and often intertwined with other policy levers, such as fuel taxes, border carbon adjustments, and carbon credit pilots. Moreover, Indian firms face external carbon price pressures, notably the EU's Carbon Border Adjustment Mechanism (CBAM), which imposes additional costs on exports unless decarbonization strategies are accelerated. These dual pressures, domestic policy evolution and international carbon levies, create a multifaceted incentive structure that can meaningfully influence firm behavior and market valuation (Li et al., 2022).

Understanding the financial performance implications of carbon pricing is therefore essential. Indicators such as Return on Assets (ROA), Tobin's Q, and stock market valuation not only reflect operational efficiency and growth prospects but also capture market perceptions of firms' adaptation to regulatory and environmental risk (Tambunan, 2023). Using firm-level data from ORBIS, this study examines how carbon pricing affects these financial performance metrics across Indian firms, filling a critical gap in the emerging-market literature (Makan & Kabra, 2021).

This study aims to empirically investigate the impact of carbon pricing mechanisms on the financial performance of Indian firms. Specifically, it examines the relationship between carbon pricing exposure and firm profitability, as measured by ROA, while controlling for firm size, industry characteristics, and market conditions. It further assesses how carbon pricing influences Tobin's Q, thereby capturing the effect of carbon costs on firm growth prospects and intangible market value. The study also analyzes the effect of carbon pricing on stock market valuation, determining whether investors systematically price in carbon risk and regulatory signals. Finally, it explores heterogeneous effects across industries, distinguishing carbon-intensive sectors from less carbon-intensive ones to evaluate differential financial impacts by emission exposure.

LITERATURE REVIEW

The nexus between carbon pricing and firm financial performance has garnered increasing academic attention as climate policy initiatives expand globally. Scholars differentiate between accounting-based performance measures, such as ROA, and market-based indicators, like Tobin's Q and stock market valuation, as these capture distinct aspects of firm outcomes and investor expectations (Bendle & Butt, 2018). Empirical evidence, however, remains mixed regarding the direction and magnitude of carbon pricing impacts.

A substantial strand of literature suggests that carbon risk and emissions exposure depress firm profitability and valuation (Putri & Arieftiara, 2023). Meta-analyses indicate a negative correlation between carbon risk and financial performance, with carbon-intensive firms exhibiting lower ROA and Tobin's Q relative to less carbon-intensive peers (Miah et al., 2021). Market valuation studies similarly show that high fossil fuel reliance can lead to valuation discounts, reflecting anticipated regulatory costs and future losses (Arino et al., 2017).

Conversely, a growing body of research posits that carbon pricing and proactive carbon management can enhance firm performance under certain conditions. Internal carbon pricing and carbon disclosure are associated with improved ROA and operational efficiency among Indian firms, suggesting that sustainability strategies can bolster financial outcomes (Ma & Kuo, 2021). In emerging markets, voluntary carbon mechanisms may signal managerial commitment to climate risk mitigation and align with investor preferences, potentially increasing firm value (Gahramanova & Kutlu Furtuna, 2023).

Distributional effects are also emphasized: high-emission firms experience relative value declines, whereas low-emission firms may benefit, reflecting a reallocation of market valuation rather than uniform loss (Desai & Raval, 2022). Non-linear relationships have been observed, where moderate carbon pricing initially depresses valuation but later generates gains as firms adopt cleaner technologies and capture first-mover advantages (Narassimhan et al., 2023).

Despite these insights, critical gaps remain for India. Most studies originate from developed markets with mature carbon taxation or ETS regimes, while Indian evidence is limited and typically focuses on internal carbon pricing or environmental accounting without linking external carbon exposure to financial performance (Ogunyemi, 2023). Additionally, comprehensive cross-sectional analyses using datasets like ORBIS are scarce, limiting understanding of industry heterogeneity (Aves et al., 2017).

Research Gap

Three primary gaps motivate this study. First, firm-level evidence from India linking carbon pricing exposure to both accounting and market-based performance is limited. Second, insufficient attention has been given to implicit carbon pricing regimes, which dominate in emerging economies. Third, there is a lack of comprehensive analysis using large-scale databases such as ORBIS to examine heterogeneous effects across industries with varying carbon intensities.

Hypotheses

Based on theoretical considerations and prior research, the study proposes the following hypotheses:

H1: Exposure to carbon pricing is negatively associated with firm profitability (ROA), particularly in carbon-intensive sectors.

H2: Carbon pricing exposure is negatively associated with Tobin's Q, reflecting reduced market expectations of growth.

H3: Carbon pricing exposure is negatively associated with stock market valuation, indicating that investors price carbon regulatory risk into equity values.

Conceptual Framework

The study conceptualizes carbon pricing exposure as the key independent variable affecting three primary financial performance outcomes: accounting performance (ROA), market valuation (Tobin's Q), and stock market valuation (market capitalization). Control variables include firm size, leverage, capital intensity, sales growth, and firm age, while firm and year fixed effects account for unobserved heterogeneity. The framework depicted in Fig-1 posits that carbon pricing influences firms through increased compliance costs, altered investment incentives, and investor risk assessments, ultimately affecting profitability and valuation.

Fig-1: Carbon pricing impact on firm performance

METHODOLOGY

Research Design

This study adopts a quantitative, firm-level panel design to examine how carbon pricing exposure affects the financial performance of Indian firms. Using ORBIS data, it analyzes both accounting-based (ROA) and market-based (Tobin's Q and market capitalization) performance measures. Panel econometric techniques control for unobserved heterogeneity and capture cross-sectional and time-series variation.

Data Source and Sample Selection

Firm-level financial data are obtained from the ORBIS database, covering Indian non-financial firms from 2010 to 2023. Financial firms are excluded due to distinct regulatory frameworks. The final unbalanced panel includes firms with complete financial records, after winsorizing outliers at the 1st and 99th percentiles. Industries are classified using NACE/ISIC codes, with carbon-intensive sectors identified as power, cement, steel, chemicals, mining, and oil & gas.

The resulting dataset forms an unbalanced panel reflecting the diversity of firm size, ownership structure, and sectoral characteristics in India. Descriptive statistics of the dataset are presented in Table-1.

Table-1: Data Description

Item	**Description**
Data Source	ORBIS database (Bureau van Dijk)
Country Coverage	India
Firm Type	Non-financial firms
Sample Period	2010–2023
Data Frequency	Annual
Sample Structure	Unbalanced panel
Initial Sample Size	All Indian firms available in ORBIS
Final Sample Size	Firms with non-missing values for key financial variables
Industry Classification	NACE / ISIC codes
Carbon-Intensive Industries	Power, cement, steel, chemicals, mining, oil & gas
Financial Firms Excluded	Banks, insurance companies, financial services
Outlier Treatment	Winsorization at 1st and 99th percentiles
Currency	Indian Rupees (INR)
Stock Market Data	Market capitalization for listed firms

Variables

The study employs three categories of variables: dependent, independent, and control variables.

Dependent Variables

Return on Assets (ROA): ROA is used as an accounting-based measure of profitability and is calculated as:

$$\text{ROA}_{it} = \frac{\text{Net Income}_{it}}{\text{Total Assets}_{it}}$$

where $i$denotes the firm and $t$the year.

Tobin's Q: Tobin's Q captures market expectations of future growth and intangible value and is computed as:

$$\text{Tobin's Q}_{it} = \frac{\text{Market Value of Equity}_{it} + \text{Book Value of Debt}_{it}}{\text{Total Assets}_{it}}$$

Stock Market Valuation: Stock market valuation is measured using the market capitalization of listed firms, expressed in logarithmic form to address skewness.

Independent Variable: Carbon Exposure

Proxied by industry-level carbon intensity combined with energy cost share or a binary indicator for carbon-intensive industries. This captures firm-level sensitivity to carbon pricing signals and regulatory pressures.

Control Variables

In addition to the main independent variable, carbon pricing exposure, the analysis incorporates several control variables to account for firm-specific characteristics that may influence financial performance. Firm size, measured as the natural logarithm of total assets, captures potential scale effects, while leverage, defined as total debt divided by total assets, reflects the firm's financial risk profile. Firm age, represented by the number of years since incorporation, serves as a proxy for operational maturity, and capital intensity, calculated as fixed assets over total assets, indicates the degree of investment in physical capital. Sales growth, measured as the annual percentage change in sales, captures the firm's growth opportunities. To control for unobserved heterogeneity across sectors and over time, industry and year fixed effects are included, accounting for sector-specific characteristics and temporal shocks that may influence performance. Table-2 provides a comprehensive overview of all dependent, independent, and control variables, including their definitions, measurement, and expected signs. Notably, carbon exposure can be operationalized flexibly depending on data availability, using industry-level emissions, energy intensity, or regulatory classifications, ensuring consistency with prior research while capturing firms' relative exposure to carbon-related costs.

Table-2: Variable Definitions

Variable Category	**Variable Name**	**Definition**	**Measurement / Formula**	**Expected Sign**
Dependent Variables	ROA	Return on Assets	Net Income / Total Assets	—
	Tobin's Q	Firm market valuation	(Market Value of Equity + Book Value of Debt) / Total Assets	—
	Market Value	Stock market valuation	Natural log of market capitalization	—
Independent Variable	Carbon Exposure	Exposure to carbon pricing	Industry carbon intensity × energy cost share (or binary indicator)	−
Control Variables	Firm Size	Firm scale	Natural log of total assets	±
	Leverage	Financial risk	Total Debt / Total Assets	−
	Firm Age	Operational maturity	Years since incorporation	±
	Capital Intensity	Asset structure	Fixed Assets / Total Assets	±
	Sales Growth	Growth opportunities	Annual percentage change in sales	+

Fixed Effects	Industry FE	Industry fixed effects	Industry dummy variables	—
	Year FE	Time effects	Year dummy variables	—

Note: Carbon Exposure can be operationalized flexibly depending on data availability (industry-level emissions, energy intensity, or regulatory classification).

Econometric Specification

The baseline model is:

$$Performance_{it} = \alpha + \beta_1 CarbonExposure_{it} + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

where $Performance_{it}$is ROA, Tobin's Q, or market valuation; $CarbonExposure_{it}$captures firm carbon risk; X_{it}includes controls; $\mu_i$and $\lambda_t$represent firm and year fixed effects, respectively. Fixed-effects panel regressions with robust clustered standard errors are employed.

Robustness and Additional Analyses

To ensure reliability, alternative performance measures (EBIT-based ROA and market valuation proxies), industry sub-samples (carbon-intensive vs. non-carbon-intensive), lagged carbon exposure, and endogeneity checks using lag structures and instrumental variable approaches are conducted.

RESULTS

Descriptive Statistics

Table-3 presents descriptive statistics for the key variables in the sample. Indian firms exhibit moderate profitability, with a mean ROA of 6.1% and substantial variability across firms (SD = 8.4%). Tobin's Q averages 1.42 (SD = 0.96), reflecting heterogeneous market expectations of growth and intangible value. Market capitalization, measured in logarithmic form, averages 9.87, indicating a wide range in firm size and investor valuation. Carbon exposure varies considerably across industries, consistent with differences in energy intensity and emissions profiles, with a mean of 0.37 and a binary classification for carbon-intensive sectors. Firm characteristics such as size, leverage, and age also display substantial heterogeneity, which justifies the inclusion of control variables and fixed effects in subsequent analyses. The descriptive evidence highlights that while profitability is relatively stable, market-based valuations show significant dispersion, suggesting that investors may respond differently to carbon-related risks across firms and sectors.

Table-3: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
ROA	0.061	0.084	−0.42	0.38
Tobin's Q	1.42	0.96	0.32	6.15
Market Value (ln)	9.87	1.92	5.12	14.63
Carbon Exposure	0.37	0.48	0	1
Firm Size (ln Assets)	10.21	1.67	6.43	15.02
Leverage	0.46	0.22	0.02	0.91
Firm Age	22.6	14.3	2	98

Note: Carbon Exposure is a binary indicator for carbon-intensive industries.

Baseline Regression Results and Hypothesis Testing

Table-4 reports the fixed-effects regression results linking carbon pricing exposure to firm financial performance, controlling for firm size, leverage, age, capital intensity, sales growth, and industry and year fixed effects. The results provide strong empirical support for all three hypotheses.

Hypothesis H1 is supported, as carbon exposure is negatively and significantly associated with ROA ($\beta = -0.014$, $p < 0.01$), indicating that carbon-related costs and regulatory pressures reduce

operational profitability. Hypothesis H2 is also supported: carbon exposure has a pronounced negative effect on Tobin's Q ($\beta = -0.182$, $p < 0.01$), suggesting diminished growth expectations and reduced intangible value among firms facing higher carbon costs. Additionally, Hypothesis H3 is confirmed, with stock market valuation declining significantly with carbon exposure ($\beta = -0.096$, $p < 0.05$), indicating that investors actively price carbon-related risks into equity values. Notably, the magnitude of the effects is largest for market-based measures, highlighting heightened investor sensitivity to regulatory and transition risks associated with carbon pricing.

Table-4: Carbon Pricing Exposure and Financial Performance

Variables	**ROA**	**Tobin's Q**	**Market Value**
Carbon Exposure	−0.014***	−0.182***	−0.096**
	(0.004)	(0.051)	(0.041)
Firm Size	0.008**	0.116***	0.742***
Leverage	−0.031***	−0.214***	−0.167**
Firm Age	0.001	−0.004	0.013
Capital Intensity	−0.019*	−0.098*	−0.061
Sales Growth	0.027***	0.143***	0.082**
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	18,420	12,360	11,745
Adjusted R^2	0.21	0.29	0.41

Note: Robust standard errors clustered at the firm level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Heterogeneity Analysis

The impact of carbon pricing exposure is not uniform across industries. Fig-2 illustrates the differential effects of carbon exposure between carbon-intensive and non-carbon-intensive sectors. Carbon-intensive firms experience significantly larger valuation penalties, consistent with higher operating costs, adjustment frictions, and investor concerns regarding long-term regulatory risks. In contrast, non-carbon-intensive firms exhibit statistically insignificant effects, suggesting partial insulation from carbon pricing pressures. These findings indicate a reallocation effect rather than an aggregate decline in firm value, highlighting that carbon pricing disproportionately affects carbon-intensive sectors while leaving lower-emission firms relatively unscathed. This heterogeneity underscores the strategic importance of sectoral considerations in assessing carbon risk.

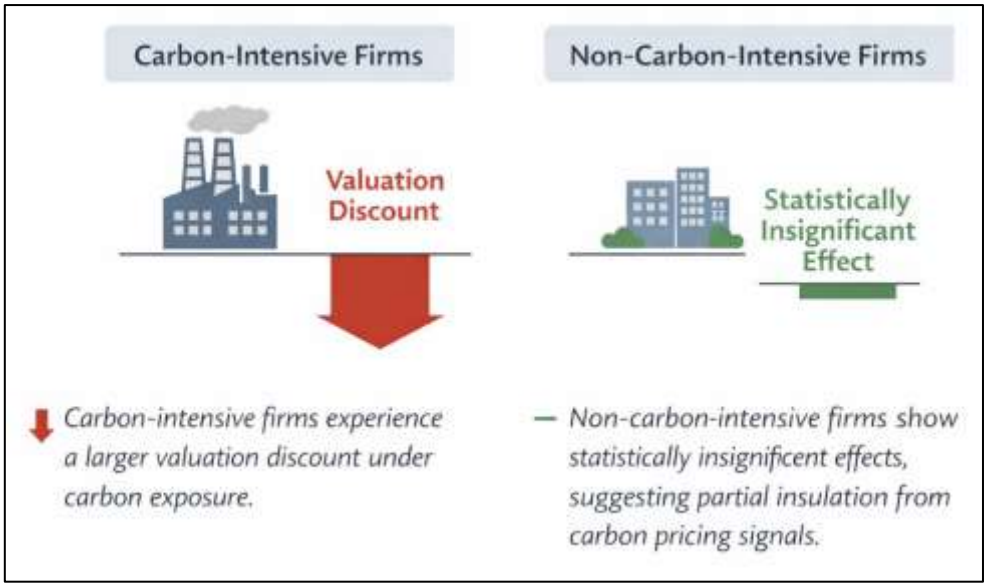

Fig-2: Carbon Exposure Effects by Industry Type (Conceptual Representation)

- Carbon-intensive firms: larger valuation discount under carbon exposure
- Non-carbon-intensive firms: muted or statistically insignificant effects

Robustness Checks

Several robustness analyses confirm the stability of the baseline results. First, using lagged carbon exposure yields similar coefficient signs and levels of statistical significance, suggesting that delayed cost and regulatory effects do not alter the main conclusions. Second, alternative profitability measures, including EBIT-based ROA, produce consistent negative relationships with carbon exposure. Third, excluding sectors with extreme carbon intensity, such as power and mining, does not materially affect the results. Collectively, these additional analyses strengthen confidence in the robustness and generalizability of the findings across different specifications, performance measures, and industry samples.

DISCUSSION

The empirical findings provide robust evidence that carbon pricing exposure negatively affects both accounting-based and market-based financial performance of Indian firms. The negative association with ROA indicates that firms facing higher carbon costs encounter immediate operational pressures, likely due to increased energy expenses, regulatory compliance obligations, and adjustment frictions. These results are consistent with prior studies in developed economies, where carbon regulation exerts short-term profitability constraints, particularly on carbon-intensive firms (Odetunde et al., 2022; Abdul Majid et al., 2023).

More notably, the impact of carbon exposure on Tobin's Q and stock market valuation is substantially stronger, highlighting that investors perceive carbon risk as a long-term strategic concern rather than a transient cost shock. The negative effect on Tobin's Q suggests that anticipated carbon-related costs influence market expectations of future growth and intangible firm value, while declines in market capitalization indicate that investors actively incorporate regulatory and transition risks into equity valuations (Kateb & Belgacem, 2023). This observation is particularly salient in India, where formal carbon pricing mechanisms are still nascent; the results imply that implicit carbon pricing signals and anticipated policy developments are sufficient to shape market perceptions.

The heterogeneity analysis further underscores that the financial burden of carbon pricing is unevenly distributed. Carbon-intensive sectors, such as power, cement, steel, and chemicals, experience pronounced valuation discounts, whereas non-carbon-intensive sectors show muted or statistically insignificant effects (Haites et al., 2023). This suggests a reallocation effect, in which carbon pricing

reshapes competitive dynamics rather than uniformly depressing firm performance. Firms with lower emissions intensity appear relatively insulated from regulatory and cost pressures, highlighting the strategic advantage of proactive decarbonization (Agashe & Khan, 2018).

Finally, the findings emphasize the importance of policy credibility and market expectations. Even in the absence of a fully explicit national carbon tax or emissions trading system, Indian financial markets appear to price carbon risk in anticipation of future regulations, international trade pressures, and potential exposure to mechanisms such as the EU's Carbon Border Adjustment Mechanism. This demonstrates that credible signaling of carbon policy, rather than its formal implementation alone, can materially influence firm behavior and valuation outcomes.

Policy Implications

The results of this study carry several important implications for policymakers, regulators, and corporate decision-makers in India. First, the negative short-term financial impacts observed suggest that gradual and predictable carbon pricing pathways are critical to allow firms sufficient time to adjust operational processes, invest in cleaner technologies, and plan capital allocation without undue financial strain. Abrupt or unpredictable carbon pricing may exacerbate profitability pressures, particularly for carbon-intensive firms.

Second, targeted support for carbon-intensive sectors is essential to mitigate competitiveness losses and prevent carbon leakage. Policies such as investment subsidies, green financing mechanisms, and technology transition support can facilitate low-carbon adoption while preserving economic resilience. Third, the findings underscore the importance of strengthening the credibility of India's carbon market. The valuation effects observed even under implicit carbon pricing highlight that clear regulatory frameworks, robust enforcement, and transparent rules under schemes like the Carbon Credit Trading Scheme can enhance price discovery, reduce uncertainty, and promote efficient capital allocation.

Fourth, the study reinforces the role of financial markets and disclosure in shaping firm behavior. Investor sensitivity to carbon exposure indicates that enhanced carbon reporting standards can improve market efficiency by allowing investors to assess transition risks more accurately. Mandatory disclosure of emissions, reduction targets, and transition strategies can reward firms that adopt proactive decarbonization approaches and mitigate valuation discounts associated with carbon risk.

Finally, the findings imply that carbon pricing considerations should be integrated into broader economic and trade policies. For export-oriented firms, particularly those subject to international carbon regulations, aligning production processes with global emissions standards can safeguard market access, reduce potential border adjustment costs, and strengthen international competitiveness. Collectively, these policy recommendations highlight that well-designed carbon pricing regimes can facilitate a just and efficient transition to a low-carbon economy while preserving firm profitability and market stability.

Managerial Implications

The study also yields several critical implications for corporate managers and strategic decision-makers. First, managers should treat carbon exposure as a financial and strategic risk, rather than merely a compliance obligation. Carbon-related costs and regulatory expectations influence not only operational profitability but also firm valuation and access to capital. Proactive carbon risk management, including emissions monitoring, scenario analysis, and integration of carbon costs into capital budgeting, can enhance financial resilience.

Second, the significant market-based valuation penalties associated with carbon exposure suggest that investments in low-carbon technologies may generate indirect financial benefits. Even if such investments increase short-term costs, they can preserve or enhance market value by reducing long-term discount rates applied by investors, improving stakeholder confidence, and signaling managerial commitment to sustainability.

Third, managers should incorporate carbon considerations into strategic planning and capital allocation. Decisions regarding capacity expansion, supply chain configuration, and technology adoption increasingly carry implicit carbon costs. Firms that anticipate future carbon pricing mechanisms and align production technologies accordingly can achieve a competitive advantage over slower-moving rivals.

Fourth, transparent and credible carbon disclosure and investor communication are crucial. Since Tobin's Q and stock market valuation are particularly sensitive to carbon exposure, reporting emissions reduction initiatives, transition strategies, and climate-related risks can mitigate valuation discounts, strengthen market credibility, and signal long-term strategic foresight.

Finally, for export-oriented firms, proactive decarbonization should be treated as a competitiveness strategy. Aligning production and supply chains with international carbon standards, including the EU Carbon Border Adjustment Mechanism, can reduce trade-related risks, protect market access, and position firms favorably in a global low-carbon economy. Overall, managerial strategies that embed carbon considerations into financial planning, investment decisions, and market communication are more likely to sustain profitability, investor confidence, and competitive advantage in the transition to a low-carbon

CONCLUSION

This study provides the first large-scale, firm-level evidence from India on the financial implications of carbon pricing exposure. Using data from the ORBIS database, we examine the relationship between carbon pricing and key financial performance metrics, including profitability (ROA), market valuation (Tobin's Q), and stock market valuation, across non-financial Indian firms. By situating the analysis in an emerging economy characterized by evolving and largely implicit carbon pricing mechanisms, the study extends the predominantly developed-country literature on carbon policy and corporate outcomes.

The empirical findings indicate that firms with greater exposure to carbon pricing, proxied by participation in carbon-intensive sectors, experience significantly lower profitability and market valuation. While the negative effect on ROA reflects short-term operational cost pressures associated with energy use and emissions intensity, the stronger and more persistent declines in Tobin's Q and market capitalization suggest that investors perceive carbon exposure as a long-term strategic and regulatory risk. These results demonstrate that financial markets in India are increasingly internalizing climate-related transition and regulatory risks, even in the absence of an explicit national carbon tax or emissions trading system.

The study further highlights the heterogeneous nature of carbon pricing impacts. Carbon-intensive sectors, including power, cement, steel, and chemicals, incur disproportionate valuation penalties, whereas less carbon-intensive firms appear relatively insulated. This reallocation effect suggests that carbon pricing reshapes competitive dynamics, penalizing high-emission firms while potentially rewarding low-emission or proactive decarbonizing firms. Moreover, the results underscore that anticipated policy developments, including international carbon regulations such as the EU's Carbon Border Adjustment Mechanism, can influence firm behavior and market expectations prior to the formal introduction of explicit carbon pricing.

Overall, the research contributes to the literature by providing systematic, firm-level evidence from an emerging market, demonstrating that carbon pricing signals materially influence corporate financial outcomes. The findings reinforce the notion that credible carbon pricing, whether explicit or implicit, can shape investment allocation, strategic decision-making, and market perceptions, thereby supporting a transition toward lower-carbon production systems.

Limitations and Future Research

Despite its contributions, this study has several limitations that should be acknowledged. First, the measurement of carbon pricing exposure relies on industry-level proxies rather than firm-specific

emissions or carbon tax payments. While consistent with prior studies and appropriate given current data constraints in India, this approach may obscure within-industry heterogeneity in emissions intensity and mitigation strategies. Future research could leverage firm-level emissions and compliance data as disclosure standards improve, enabling more precise estimation of carbon exposure impacts.

Second, the analysis focuses on short- to medium-term financial effects. Carbon pricing may impose transitional costs initially, but it can generate efficiency gains, innovation, and competitive advantages over longer horizons. Longitudinal studies examining dynamic adjustment paths, technology adoption, and investment responses would provide a deeper understanding of the long-run financial consequences of carbon pricing.

Third, although the fixed-effects framework controls for unobserved heterogeneity, potential endogeneity concerns cannot be fully eliminated. Firms with weaker financial performance may self-select into carbon-intensive industries or delay decarbonization investments. Future studies could strengthen causal inference through quasi-experimental designs, such as difference-in-differences around policy shocks, or instrumental variable approaches.

Fourth, the stock market valuation analysis is limited to listed firms, which may differ systematically from unlisted firms in governance, disclosure, and access to capital. Expanding research to private firms or alternative performance measures could improve generalizability.

Finally, India's carbon pricing architecture remains in flux. The results presented reflect a period characterized by implicit carbon pricing and anticipatory market responses. As India's Carbon Credit Trading Scheme and other explicit mechanisms mature, future research should examine how formal carbon prices influence firm behavior, investment decisions, and financial performance.

By addressing these limitations, future research can provide a more comprehensive and causal understanding of the financial and strategic consequences of carbon pricing, informing both policy design and managerial decision-making in emerging economies undergoing low-carbon transitions.

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