Do Sustainable Operations through Energy Effectiveness Reduce Cost of Debt in Medium and High-tech Industries? Evidence from an Emerging Economy

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ABSTRACT

Access to low-cost finance is a significant factor influencing firms' investment decisions in research and development, which is crucial for corporate success. The goal becomes critical when the firm's sustainability policy channels energy consumption, resulting in optimal capital allocation for new, resource-efficient technologies. Despite its significant relevance in policymaking, there has been little academic study on the potential influence of energy efficiency on enterprises' cost of debt, particularly in emerging countries such as India. To gain a deeper understanding, this study examines the impact of a firm's energy efficiency, a strategic step in sustainable operational practices, on the cost of debt for high- and medium-tech firms in India. For this purpose, we conducted a panel data analysis using 7,603 observations classified as high and medium tech from 2010 to 2022, employing two-stage least squares Tobit regression models. The findings show that firms with policies on energy efficiency measures could benefit from lower borrowing costs in their financing decisions. The findings reveal a curvilinear relationship between firms' energy efficiency and the cost of debt in both the high-tech and medium-tech sectors, suggesting that efficient energy consumption can yield financial advantages beyond a certain point, after which a diminishing effect may occur. However, the findings do not hold when firms are less energy efficient and ownership changes to foreign control. The insights of the study may guide firms in developing countries in formulating their energy policy toward environmental sustainability, designing an effective ownership structure, and allocating resources while reducing financing expenses, thus aligning corporate interests with economic objectives. Financial institutions can also leverage these outcomes when formulating a lending policy that considers firms' energy efficiency.

Keywords: Sustainable Operation, Energy efficiency, Cost of Debt, High-Tech, Medium-Tech

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1. INTRODUCTION

Sustainable operational practices, including energy efficiency, are crucial in fostering sustainable economic development by addressing greenhouse gas emissions and combating climate change. The manufacturing sector, as a significant energy consumer and contributor to emissions, can play a pivotal role in this context. Improving energy efficiency in manufacturing not only yields substantial environmental benefits but also offers significant economic and social advantages for present and future generations (Bai et al., 2021). Simultaneously, the availability of capital is vital in driving business operations, exerting significant influence on firms' behaviours and decision-making processes (Wang & Tang, 2023). The active engagement of capital providers in financing energy-efficient projects can unlock multiple benefits, including reduced environmental impact, enhanced operational efficiency, and improved long-term financial performance for businesses.

The incentive, in terms of the reduced cost of debt (hereafter COD), is a significant factor that impacts a firm's financial viability and ability to secure capital for future investments. It represents the interest rate a firm pays on borrowed funds and is influenced by various factors, including its creditworthiness, market conditions, macroeconomic factors and competitive landscape (Valta, 2012). The competitive landscape can have a notable influence on the interest rates charged by banks when lending, and there are several potential reasons for this relationship.

However, with the evolving business landscape, firms are increasingly focused on energy efficiency, which has captured the attention of investors. Firms increasingly recognise the importance of energy efficiency for environmental and societal reasons, as well as its profitability considerations (Lin et al., 2021). The growing awareness of environmental concerns and energy consumption patterns has heightened investors' focus on the reputational risks associated with energy-intensive firms (Eliwa et al., 2021). This measure, in turn, has motivated lenders to incorporate sustainability metrics in their credit assessments (Roy et al., 2022). On the other hand, a higher COD can indicate a higher risk, potentially negatively influencing investors' interest. Therefore, gaining insight into energy efficiency in the business that influences the COD is crucial for firms to make informed financing decisions and improve their financial performance. The theoretical foundation is based on the premise that enterprises using less or alternatives are more likely to address social and environmental concerns effectively. On the contrary, firms that consume substantial endure an additional risk for investors. Firms that engage in energy-intensive practices may participate in activities that increase liabilities and impact the cost of their borrowings.

To explore the impact of energy efficiency on the cost of debt (COD), we use panel data from 2011 to 2021 for all listed firms on the Bombay Stock Exchange (BSE). We categorise the firms into two groups, high-tech and medium-tech, based on the classification by the Organisation for Economic Co-operation and Development (OECD) (Sandven et al., 2005). We also address the possible issue of endogeneity. The lack of agreement in the empirical literature on the relation between energy efficiency and the cost of debt can be partly attributed to endogeneity. If firms with lower debt costs are more inclined to invest in energy efficiency, this could create a reverse causality issue. In other words, firms with already lower borrowing costs may have the financial resources and incentives to implement energy-efficient practices rather than energy efficiency directly influencing the cost of debt. We employ an instrumental variable (IV) Tobit model to address these concerns and provide more reliable estimates to examine the link between energy efficiency and COD. This model is particularly suitable for analysing right-censored data, where the dependent variable is truncated and only observable within a specific range. By applying the IV Tobit approach, as suggested by Chesher et al. (2023), we aim to overcome the limitations associated with endogeneity and enhance the coherence and robustness of our findings.

In addition to the link between energy efficiency and COD, this analysis recognises critical intermediate processes such as research and development (R&D) investment and foreign ownership. R&D investment is critical because it often supports a company's ability to invent and apply energy-efficient technologies, which can improve operational efficiency and reduce costs. Firms that invest in R&D are likely to develop more sophisticated, energy-efficient methods, resulting in reduced COD due to improved financial performance and creditworthiness. Furthermore, foreign ownership adds a complicated element to this dynamic. Foreign-owned businesses often face obstacles due to agency issues and informational asymmetries, which may impact their loan costs. However, by implementing energy-efficient procedures, these businesses may alleviate these difficulties and position themselves as lower-risk assets to lenders. Thus, analysing R&D investments and foreign ownership is critical for understanding how energy efficiency affects COD, and this study seeks to delve further into these connections.

This paper makes a few significant contributions to the literature. First, this study emphasises operational approaches firms could employ to promote environmental sustainability and financial profit. Energy efficiency, encapsulated through technological adoption and investments in energy conservation initiatives, could achieve a firm's sustainability. Second, this study examines whether such energy-efficient strategies can benefit firms by enabling them to make financing choices with lower debt costs and ultimately gain easier access to financial resources. The study's empirical analysis examines the relationship between energy efficiency and COD, comparing it with existing research findings (Roy, 2023). This exploration extends beyond simple assumptions of linear relationships, aiming to identify the precise nature of the relationship. The study can help policymakers to optimise resource utilisation and maximise benefits by revealing the energy efficiency levels that might optimise the COD. This research also reveals energy efficiency levels that improve the firm's financials and reduce risk, yielding benefits in COD. At the same time, the research will help lenders and financiers formulate better financing terms for businesses engaged in energy-efficient measures. Third, this study broadens the analysis to determine the characteristics of this association across various sectors and ownership structures. This research examines whether medium-tech enterprises derive the same benefits from energy efficiency as high-tech firms do. In developing nations like India, where the economic landscape is constantly evolving, it is crucial to comprehend the diverse benefits of energy efficiency across various industries. High-tech sectors often have more access to modern technology and funding choices, enabling them to better capitalise on energy efficiency for financial advantage. Medium-tech enterprises, on the other hand, may face distinct challenges such as limited access to financing, slower technological growth, and varying regulatory requirements. This study not only sheds light on sector-specific dynamics but also gives ideas for policymakers and investors on how to customise their support and investment strategies. Understanding these contrasts is critical for encouraging sustainable behaviours across diverse technology spectrums and maximising the advantages of energy efficiency in a broader context within a growing economy. Thoroughly analysing these sectors allows policymakers to comprehend the specific dynamics and difficulties related to energy efficiency within each industry. Unlike previous studies of developed economies, the analysis of COD of energy-efficient high-tech and medium-tech firms in India contributes to the literature in emerging markets.

The remainder of the article is organised as follows. Sections 2 and 3 discuss the literature and theoretical foundations for the hypotheses. Section 4 presents data and variables. Section 5 proposes the empirical models. Finally, Section 6 discusses the findings and policy implications, and Section 7 concludes the article.

2. LITERATURE REVIEW

In recent years, the global community has recognised the need to reduce emissions and protect the environment due to compounding growth in energy intensity caused by global economic expansion (Zhang et al., 2016). Reducing energy intensity leads to lower polluting emissions and contributes to lower production costs, increased productivity, and enhanced competitiveness for firms (Li et al., 2021). Governments, public society, and businesses have all been pushed into action by the growing interest in energy efficiency and sustainability. In response to the UN's call to action in its Sustainable Development Goals (SDGs) and the increasing attention of investors to non-financial reporting, a growing number of US corporations are assessing, disclosing, and managing sustainability risks and opportunities.

Incorporating stakeholder theory into the context of energy efficiency gives a solid foundation for understanding the varied pressures that enterprises encounter from different stakeholders. According to stakeholder theory, organisations must consider the interests of all parties impacted by their operations, including shareholders, workers, consumers, suppliers, and the larger community (Freeman, 1984). This viewpoint is especially significant for companies involved in energy-intensive operations, as investors increasingly demand greater transparency and accountability for environmental performance. Eccles et al. (2014), for example, found that businesses with good sustainability policies generally outperform in terms of financial performance, highlighting the impact of stakeholder demands on corporate strategy. Furthermore, stakeholders are actively pursuing businesses' pledges to greener practices as a condition for ongoing support, driving enterprises to improve their energy efficiency (Grewal & Dharwadkar, 2002). At the same time, institutional theory explains how legislative frameworks, social conventions, and industry standards influence business behaviour towards sustainability projects. According to DiMaggio and Powell (1983), institutions offer the stability and unanimity that drive corporate operations, especially in the face of environmental issues. Firms may adopt energy-efficient techniques not just for economic reasons but also to comply with institutional demands and earn credibility in their business (Oliver, 1991). Thus, institutional theory predicts that organisations impacted by firm-level legitimacy would adopt environmentally friendly practices to comply with public norms, regulatory requirements, and competitive pressures. For example, Nasir et al. (2021) demonstrate how institutional forces influence enterprises in developing nations to adopt energy-efficient technology, highlighting the importance of external norms and expectations in shaping internal sustainability plans.

Furthermore, the interaction of stakeholder and institutional theories may explain variations in firm energy efficiency levels, particularly in emerging markets where institutional frameworks and stakeholder expectations differ significantly from those in developed economies (Jadiyappa & Krishnankutty, 2022). This perspective emphasises the need to incorporate ownership structure into energy management processes, hence confirming energy efficiency as a critical strategic initiative for risk mitigation and competitive advantage.

In addition to the environmental benefits, energy efficiency has important implications for firms' financial performance. Previous studies have shown that energy efficiency positively relates to various financial performance measures, including profitability and firm value (Gallardo-Vázquez et al., 2019; Peng et al., 2022). Moreover, lenders have become increasingly aware of the reputational risk of financing firms that exhibit poor environmental performance, including high energy consumption (Xie et al., 2023). Consequently, lenders may consider financing such firms as facilitation, which could lead to negative stakeholder responses (Eliwa et al., 2021). These risks have prompted investors to embrace sustainability in their investment decisions (Roy et al., 2022).

Lenders worldwide have also joined the United Nations Environment Programme, which has led to greater recognition of sustainable initiatives through risk premiums on investments (Andersen, 2021). Such recognition encourages firms to adopt many sustainable measures, such as energy efficiency, to benefit from such policy initiatives (Krueger & Starks, 2020). Furthermore, energy sources are scarce, increasing insecurity in firms' earnings estimates. Additionally, investors may require a premium for taking on such risks (Jadiyappa & Krishnankutty, 2022). According to the literature, there is a growing need for sustainability, where the natural environment is critical to the firm's day-to-day action, such as energy conservation (Nasir et al., 2021). As firms increase their commitment to the environment by reducing carbon emissions, shareholders respond positively to the issuance of green financial instruments (Flammer, 2021). Levi & Newton (2016) explored the return traits of green firms as characterised by greenness. The research indicated that environmentally friendly stock returns surpass those of polluting companies when adjusted for risk. The data indicated a strong, albeit economically minor, attention impact, accompanied by a more enduring and substantial influence on desirable quality, which in turn affects green returns. The authors discovered that being ecologically concerned may be beneficial. This may occur because green businesses are less inclined to face ecological lawsuits, which has a detrimental influence on their financial results (Levi & Newton, 2016). Besides environmental benefits, pursuing enhanced energy efficiency within society might be seen as a favourable circumstance for fostering innovation, yielding advantages that transcend the objectives of governmental efforts. Enhancing energy efficiency to boost business profits has the potential to augment societal wealth while concurrently safeguarding the sustainability of our current quality of life for future generations (DeCanio, 1993).

Energy efficiency has emerged as a crucial factor influencing firms' financial success, particularly in high- and medium-tech sectors. Studies have shown that by reducing operating costs associated with energy consumption, energy-efficient techniques can result in significant cost savings (Trianni et al., 2013). For example, enterprises with lower energy expenses are often perceived as less risky by lenders because they are better positioned to manage operational uncertainty and energy price volatility (Worrell et al., 2009). This reputation may lead to a reduction in COD, as lenders may offer better terms in conjunction with effective energy management techniques.

A study by Worrell et al. (2009) argues that energy-efficient firms are better equipped to adapt to future energy crises or regulatory changes, ensuring their long-term viability. Adopting energy-efficient technology and techniques may also help to reduce operational and regulatory risks. Companies that prioritise energy efficiency are better prepared to comply with increasingly stringent environmental rules, thereby lowering the risk of non-compliance fines and reputational harm (De Groot et al., 2001). Furthermore, energy-efficient businesses are less susceptible to fluctuations in energy prices, resulting in fewer interrupted production processes and lower expenses. This risk reduction feature is exciting to creditors, as it enhances the consistency of a firm's cash flows. Consequently, energy-efficient businesses may benefit from a lower risk profile (Porter & van der Linde, 1995).

Moreover, stakeholder pressure, including expectations from investors, consumers, and regulators, has driven high- and medium-tech companies to adopt more energy-efficient practices. Firms that demonstrate a commitment to sustainability generally benefit from increased reputational capital, which can enhance their access to finance. For example, studies have shown that enterprises with good environmental, social, and governance (ESG) performance measures, such as energy efficiency, are more likely to attract investment and get loans at lower interest rates (Gagliardi et al., 2016). This is especially important for medium-tech firms, which often depend on external funding to fuel innovation and development. By aligning with stakeholder expectations, these companies may enhance their financial position and reduce their loan costs.

While the existing literature generally supports the argument that energy efficiency is significantly related to profitability, it is critical to recognise the nuances and limitations of these results. For example, research by Trianni et al. (2013) and Worrell et al. (2009) demonstrates that the relationship between energy efficiency and profitability is often situation-dependent. Firm size, industry characteristics, and regional energy costs may all impact the financial benefits generated by energy efficiency. For example, small and medium-sized firms (SMEs) in medium-tech sectors may face greater initial expenditures for energy-efficient technology, which can delay the realisation of profitability gains (Cagno et al., 2013). Furthermore, the economic advantages of energy efficiency are often dependent on practical implementation and management methods, which may differ among organisations (De Groot et al., 2001). Addressing these intricacies strengthens the assertion and reflects the complexity of the link between energy efficiency and profitability.

Furthermore, the existing study primarily focuses on global and US-centric trends, which limits its applicability to the Indian context. India's emerging economy, characterised by its distinctive energy environment, presents both significant challenges and opportunities for high- and medium-technology companies. For example, the Indian government has developed several programs to encourage energy efficiency, including the Perform, Achieve, and Trade (PAT) program under the National Mission for Enhanced Energy Efficiency (NMEEE). This market-based approach encourages energy-intensive enterprises to cut their consumption and exchange energy-saving certificates (Bureau of Energy Efficiency, 2015). However, barriers to the widespread adoption of energy-efficient techniques among Indian enterprises include high capital costs, limited access to funding, and a shortage of technical skills (Singh et al., 2018). Additionally, India's regulatory framework and stakeholder expectations differ significantly from those in the United States and Europe. For example, local and international stakeholders are increasing pressure on Indian businesses to embrace sustainable practices, but they often face financial restrictions that limit their capacity to invest in energy-efficient technology (Garg et al., 2019). Including a discussion of these India-specific policies and issues will not only increase the review's relevance but also provide a more thorough understanding of the variables driving energy efficiency and its financial implications in India.

As a result, the research focused on industrialised economies, which may have underestimated the dynamics of energy efficiency in rising markets such as India. For example, whereas Porter and van der Linde (1995) emphasise the importance of innovation in increasing energy efficiency, their results may not be immediately applicable to Indian enterprises, which often operate in resource-limited situations. Similarly, Gagliardi et al. (2016) emphasise the advantages of digitalisation for energy efficiency, although infrastructural shortages and high prices frequently hamper the implementation of such technologies in India. Recognising these limitations and combining ideas from developing market studies allows the study to present a more balanced and global viewpoint.

3. THEORETICAL BACKGROUND AND HYPOTHESIS DEVELOPMENT

The discussion about being "green and competitive" through various measures has intensified over the years but remains under investigation. According to the literature, integrating the environmental factor into a firm's strategy and actions may result in various advantages in terms of i) market standing, such as higher sales, growth in new markets, and improved competitive advantage (Dangelico & Pontrandolfo, 2015). Shareholders and authorities have become increasingly concerned about the environmental impact of the company's activities (Jiraporn & Chintrakarn, 2013). According to theory, shareholders should worry about energy efficiency for several reasons. First, some investors deemed intrinsically receptive to sustainability issues might include the energy effectiveness in their valuation (Neumann, 2021), and second, other shareholders who are not inherently responsive to environmental problems are compelled to think about them due to the pressure placed on regulators from activists for the environment and other pressure groups for regulatory actions toward a better environment (Jadiyappa & Krishnankutty, 2022).

Firms' energy efficiency might influence the COD through several key mechanisms. First, firms that implement energy-efficient practices often show increased operational efficiency and lower energy costs, which may improve their financial stability and creditworthiness (Broadstock et al., 2018). Lenders may view such businesses as lower-risk borrowers, as they are better positioned to fulfil their financial commitments due to decreased operational expenses and increased cash flows. Second, energy efficiency demonstrates a company's commitment to sustainability, which can enhance its image and mitigate reputational risks associated with environmental issues (Eliwa et al., 2021). This reputational boost may result in more favourable loan conditions as lenders may view these enterprises as better aligned with societal and regulatory standards. Finally, energy efficiency can reduce exposure to energy price volatility, thereby lowering the financial risks associated with variable energy prices (Zhang et al., 2020). These strategies work together to reduce the cost of financing for energy-efficient enterprises.

Previous research has investigated the impact of the environment on business performance and value. Some researchers have shown a linear link (Jacob & Nerlinger, 2021; Roy, 2023), whereas others have found a non-linear relationship (Lin et al., 2021). However, this research recognises that energy efficiency has a desirable impact on COD but does not give enough information about the link. The relationship between energy efficiency and COD is more complex than its monetary benefits, extending beyond the basic positive, negative, or neutral association. Due to positive investor responses and the acquisition of funds, the benefits of energy-efficient engagement are expected to initially enhance businesses' competitive advantages, followed by a diminishing effect (Horowitz et al., 2007; Wang et al., 2020). Given the increasing focus on sustainability and the importance of energy efficiency in mitigating environmental concerns, it is crucial to investigate the relationship between energy efficiency and COD emissions for firms.

In this study, we aim to clarify the complex relationship between energy efficiency and COD. Our primary hypothesis posits that energy efficiency has a positive influence on a firm's financial dynamics by reducing its COD over time. This expectation is grounded in the premise that firms adopting energy-efficient practices can present themselves as less risky investments to lenders. By reducing their energy consumption and operational costs, these firms enhance their overall financial health, which in turn improves their creditworthiness (Jacob & Nerlinger, 2021; Roy, 2023). As a result, lenders may offer lower interest rates, effectively reducing the cost of debt for firms that successfully implement energy-saving measures. Therefore, this research tries to find the link between the two by testing the following hypothesis.

H1: Firms' sustainable performance through energy efficiency reduces their cost of debt (COD)

For a going-concern firm, the controlling shareholder may insist on direct distributions of business assets (dividends) rather than supporting a manager's investment decisions, thereby lowering the mean of the firm's predicted cash flows and increasing debt risk (Ringel, 2017). It focused on the relationship between environmental practices, specifically energy efficiency, and the firm's success in terms of investors' interest, as reflected in the risk premium of the cost of debt. Kostka et al. (2013) observed that Owners frequently view energy savings through an administrative standpoint rather than a technical one regarding "energy efficiency". They often described it as "technological upgrading," "reducing labour costs," and "minimising overall electricity expenses in absolute terms" instead of "costs per unit" or "energy efficiency". Likewise, most proprietors or administrators see the value of capitalising on novel equipment. A limited number consider strategies such as optimising energy use or transitioning to more environmentally friendly energy sources. Therefore, we have extended our debate to examine the firm's ownership structure on the COD via the energy efficiency of the firms by testing the following hypothesis.

H2: The ownership structure of firms influences the COD of energy-efficient firms

Corporate environmental performance may be defined as a company's obligation to protect the natural environment (Albertini, 2013). As a result, the stronger a company's compliance with environmental performance, the greater its concern for the consequences of its operational processes on natural resources and the resulting reduction of environmental hazards and potential benefits on firm value (Dangelico et al., 2017). The synergistic relationship between environmental practises and a firm's success in terms of their maturity may contribute to energy efficiency by increasing motives and providing incentives for a higher propensity to achieve environmental compliance, including resource utilisation (Song & Oh, 2015). Brinkerink et al. (2019) also found that segmentation by company type indicates that capital investments of enterprises in high-tech, energy-intensive, and low-labour-intensive sectors do not correspond with increases in energy efficiency, although capital expenditures on technology do.

Thus, it is relevant that energy efficiency may impact the COD of high-tech and medium-tech sectors differently due to their distinct operational characteristics, technological capabilities, and stakeholder expectations. Firms in the high-tech industry are often at the forefront of innovation, having made substantial expenditures in R&D and new technology (Sandven et al., 2005). Energy efficiency is commonly incorporated into their fundamental operations, resulting in significant cost savings and increased competitive advantage (Chen et al., 2021). Consequently, lenders see high-tech enterprises that achieve high levels of energy efficiency as lower-risk borrowers, resulting in lower COD owing to greater financial stability and operational efficiency (Broadstock et al., 2018). However, the early expenditures of introducing cutting-edge, energy-efficient technology may be prohibitively expensive, temporarily increasing COD until the long-term advantages of lower energy consumption and operating costs become apparent. In contrast, the medium-tech sector, which encompasses businesses such as automotive and equipment, often employs more conventional technology and exhibits lower

R&D intensity (Sandven et al., 2005). While energy efficiency is crucial for these businesses, it is often driven by regulatory compliance and cost-cutting measures rather than innovation (Kostka et al., 2013). Medium-sized companies may face more challenges in implementing energy-efficient solutions due to the capital-intensive nature of their operations, resulting in a smaller initial impact of EE on their COD. However, if these companies reach a certain level of energy efficiency, the financial benefits—such as lower energy costs and enhanced operational performance—can contribute to a significant decrease in COD (Zhang et al., 2020).

Furthermore, the reputational advantages of energy efficiency may be less evident in medium-sized enterprises than in high-tech firms, as stakeholders in these sectors may place less emphasis on sustainability (Eliwa et al., 2021). These sector-specific dynamics underscore the need to consider industrial characteristics when evaluating the relationship between energy efficiency and COD, as the processes and magnitude of impact can differ significantly between high-tech and medium-tech industries. From a policy standpoint, authorities must understand company investment processes to determine when and where energy efficiency enhancements are achievable across business types and expansionary production methods. Therefore, we further decompose energy efficiency into high-tech and medium-tech to assess whether they impact the cost of debt intensity differently. Therefore, this study aims to fill this gap by testing the following hypothesis:

H3: Energy efficiency influences the COD of medium-tech and high-tech firms differently

4. DATA AND VARIABLES

Data: In this study, we have utilised the Prowess-CMIE, a database managed by the Centre for Monitoring the Indian Economy Private Ltd. Previous research has regularly used this Prowess database (Jadiyappa et al., 2021; Singh et al., 2023) and it is primarily regarded as one of the most thorough sources of information about Indian businesses. The information in the panel set comprises an unbalanced panel of 2,284 corporations listed on the BSE, India's oldest stock exchange, with an aggregate market capitalisation of INR 280,489 billion. The sample removed the firms whose chosen variables data did not exist or whose power consumption rate exceeded 50% of sales. Table 1 represents the summary statistics of variables for all the

TABLE 1
Descriptive Statistics of Sample

	All firms				
Variable	Obs	Mean	SD	Min	Max
CoD	7603	2.54	1.67	0.00	9.99
EE	7603	3.78	1.25	0.21	9.78
R&D	3852	0.77	1.11	0.00	7.06
Size	7575	2.76	1.82	0.00	9.01
Liquidity	6789	0.97	0.68	0.01	7.61
Leverage	6605	0.72	1.63	0.00	12.81
Age	7603	3.60	.49	0.00	5.07
Owners*	7603		1=4804 0=2799		

*Ownership 0= Domestic and 1 indicates= Foreign holding above10%

TABLE 2
Descriptive Statistics of Medium-Tech and High-tech Industry

Medium-Tech					High-Tech				
Obs	Mean	SD	Min	Max	Obs	Mean	SD	Min	Max
5569	2.57	1.00	0.00	9.90	2034	2.47	1.70	0.00	9.99
5569	3.76	1.24	0.21	9.78	2034	3.85	1.25	0.57	9.41
2690	0.71	1.06	0.00	7.06	1162	0.93	1.20	0.00	5.92
5548	2.78	1.81	0.00	9.01	2027	2.70	1.86	0.01	8.46
4971	0.95	0.66	0.01	7.61	1818	1.01	0.71	0.02	6.98
4849	0.74	1.63	0.00	12.81	1756	0.67	1.61	0.00	11.41
5569	3.65	0.51	0.00	5.07	2034	3.48	0.42	0.69	4.46
		1=3497 0=2072					1=707 0=1327		

*Ownership 0 = Domestic and 1 indicates = Foreign holding above10%

industries, while Table 2 exhibits the summary statistics for the aggregate sample bifurcated based on high-tech and medium-tech industries.

Table 2 shows that the mean EE of all firms is 3.78, compared to 3.76 and 3.85 for medium and high-tech industries, respectively. This indicates that high-tech firms' energy efficiency is above the mean of both medium-tech and high-tech industries. Further, the mean COD of high-tech firms is 2.47 compared to 2.54 for all firms and 2.57 for medium-tech firms. The summary statistics support the idea that energy efficiency reduces debt costs.

The study reveals that the average EE values for high-tech firms (3.85) are slightly higher than those for medium-tech firms (3.76). While this difference may appear modest, it is statistically significant and reflects underlying variations in the operational characteristics, technological capabilities, and strategic priorities of these sectors. The slight but significant difference in EE between high-tech and medium-tech firms has important implications for both sectors. For high-tech firms, higher energy efficiency not only reduces operational costs but also enhances their reputation as environmentally responsible organizations, potentially leading to lower costs of debt (COD) and improved access to financing (Eliwa et al., 2021). For medium-tech firms, the lower EE scores suggest that there is room for improvement in adopting energy-efficient practices. Enhancing energy efficiency in this sector could lead to significant cost savings, improved competitiveness, and better access to financing, particularly as regulatory and stakeholder pressures continue to grow (Zhang et al., 2020). While prior research has often treated energy efficiency as a uniform factor across industries, this study demonstrates that even slight differences in energy efficiency (EE) can reflect significant variations in operational practices, technological capabilities, and external pressures. These findings highlight the importance of tailoring energy efficiency strategies to the specific needs and characteristics of different sectors, offering valuable insights for policymakers, lenders, and firms seeking to optimise their energy management practices.

Variables: This study analyses the relationship between a firm's energy efficiency and the COD. Additionally, we have controlled for relevant variables that influence time-variant factors. To mitigate the year effect, we have used price-deflated information at every level, based on the Consumer Price Index (CPI), with 2010 as the base year. The description of each variable is mentioned.

Dependent Variable

Cost of debt (COD): The firm's COD is obtained from the financial statements and computed as interest costs over average loans in this research (Du et al., 2017; Gao et al., 2022; Roy, 2023). Interest-bearing debt consists of various financial obligations, such as short-term borrowings, long-term borrowings maturing within a year, bonds, and long-term payables. The sample firm's data represents emerging economies like India, so they are not exposed to market-driven debts such as corporate bonds, debentures, and commercial papers. Hence, we utilised financial statement-based measures to align COD with those of Gao et al. (2022). This study examines the impact of energy efficiency on COD at the firm level to comprehend the driving factor.

Independent Variables

Energy Efficiency: Energy efficiency is often described as the measurable link between actual production and energy consumed within a certain period (Chen et al., 2021). In this research, energy efficiency refers to the quantifiable relationship between the actual productivity achieved and the energy expended within a designated time frame. Following Montalbano & Nenci (2019), this study estimates the energy efficiency of each firm in the dataset by determining the aggregate expenditure on power and fuel as the organisation's energy expenses, while the overall turnover was regarded as an output indicator (Bu et al., 2019). However, an alternative measure of EE, such as the Fisher Index (Fisher, 1921), could have been considered; this measure requires sectoral composition. However, providing a helpful insight into the correlates between energy consumption and productivity based on detailed firm-level data is academically well-considered (Montalbano & Nenci, 2019). By measuring the aggregate annual energy expenses as $AEE_{it} = E_f + E_{fe}$, this research calculates energy intensities using the following formula:

$$EI_{1,it} = \frac{AEE_{it}}{AT_{it}} \tag{1}$$

where AT_{it} is the annual turnover of the firm.

Additionally, this study employed regression analysis to investigate the relationship between energy expenditures and financial costs (Zhang et al., 2020). This approach is used since enterprises may have different markups, meaning sales data alone may not adequately assess energy efficiency. This measure functions as a means of assessing the resilience and stability of a system.

Control Variables: The present research incorporates several firm-level attributes as control variables, including size, leverage ratio (defined as total external liabilities divided by total common equity), and current ratio (calculated as current assets divided by current liabilities) to mitigate the influence of time-varying factors. Table 3 provides a comprehensive description of the variables used in the research.

Multicollinearity: We calculated pairwise correlation (PWC) and Variance Inflation Factor (VIF) to investigate potential multicollinearity among variables. The results of the PWC and VIF of variables are presented in Table 4 to test for multicollinearity.

The correlations among many explanatory factors are less than 0.7, excluding multicollinearity. Furthermore, the highest VIF among the variables is 1.81, which is well below the threshold level of 10. Hence, the sample ruled out any existence of multicollinearity (Li et al., 2018).

TABLE 3
List of various types of variables, their descriptions, and the references

Variables	Symbol	Descriptions	Sources
Cost of debt	COD	Aggregate interest costs over average debts availed	(Sun et al., 2022)
Energy efficiency	EE	The firm's revenue over energy expenses	(Choi et al., 2017)
Research & Development	R&D	The amount used in research and development of the firm in a year	(Roy, 2023)
Size	SIZE	Logarithm of total assets	(Zhang et al., 2020)
Liquidity	LIQ	Current assets divided by current liabilities	(Cardillo et al., 2022)
Leverage	LEV	Total outside liabilities divided by total common equity	(Gao et al., 2022)
Ownership	OWNER	Logarithm of net financial expenses	(Wang & Yuan, 2018)
Age	AGE	Age as of firm as of 2021	

TABLE 4
Pairwise correlations and VIF of variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	VIF
(1) EE	1.000								1.032
(2) R&D	0.090*	1.000							1.819
	(0.000)								
(3) Size	0.061*	0.320*	1.000						1.799
	(0.000)	(0.000)							
(4) Liquidity	0.041*	0.315*	-0.142*	1.000					1.571
	(0.001)	(0.000)	(0.000)						
(5) Leverage	0.001	-0.047*	0.016	-0.027*	0.020	1.000			1.020
	(0.960)	(0.006)	(0.194)	(0.037)	(0.113)				
(6) Ownership	0.006	-0.199*	0.002	-0.137*	0.111*	-0.065*	1.000		1.084
	(0.620)	(0.000)		(0.000)	(0.000)	(0.000)			
(7) Age	-0.060*	0.001	0.128*	-0.018	-0.080*	0.009	0.005	1.000	1.045
	(0.000)	(0.933)	(0.000)	(0.144)	(0.000)	(0.464)	(0.636)		
								Mean VIF	1.308

Note: The symbols ***, **, and * indicate significance *** *p<.01,* ** *p<.05,* * *p<.1*, respectively.

5. EMPIRICAL MODELS

Ordinarily, when analysing regression coefficients, the preferred approach is ordinary least squares (OLS). However, its constraints on discrete dependent variables may result in conflicting parameter estimates throughout the study. To overcome this issue, we applied the Tobit model introduced by Tobin (1958), which uses likelihood estimation to analyse censored data that may be partially or wholly unobservable. Our research aims to investigate the correlation between firms' energy efficiency and their COD, taking into account the potential issue of endogeneity in the context of energy efficiency.

$$u \mid D,W \; follows \; N(0,\sigma_u^2) \tag{2}$$

The error term u, given the variables D (endogenous variable) and W (exogenous variable), follows a normal distribution with mean 0 and constant variance (σ_u^2). However, this assumption may not hold if u is correlated with D due to underlying factors that influence both D and the outcome Y. To address the issue of endogeneity effectively, we employ a simultaneous modelling approach for endogenous variables using instrumental equations (Smith and Blundell, 1986). One potential approach to mitigate this concern involves employing the lag of investments in R&D as an instrumental variable proposed by Si et al. (2020). Nevertheless, it is crucial to ascertain that the lag in R&D is associated explicitly with energy efficiency. If the assumptions are satisfied, using R&D lag as an instrumental variable can mitigate endogeneity (Barreto and Kypreso, 2004). While lagging independent variables by one year (t - 1) is a common technique used to remove endogeneity and establish causal relationships (Barreto & Kypreos, 2004; Bellemare et al., 2017; Danish et al., 2021; Li et al., 2021; Xia & Liu, 2017), it is also a technique used to remove endogeneity and establish causal relationships. Furthermore, we also regress the firm's interest expenses as an additional measure of COD to check the model's robustness (Islam and Nishiyama, 2016).

$$Cost \; of \; Debt_{it} = \beta_0 + \beta_1 Energy \; Efficiency_{i,t} + \beta_2 X_{i,t} + \delta_i + \theta_t + \varepsilon_{i,t} \tag{3a}$$

$$Interest \; Expenses_{it} = \beta_0 + \beta_1 Energy \; Efficiency_{i,t} + \beta_2 X_{i,t} \delta_i + \theta_t + \varepsilon_{i,t} \tag{3b}$$

$$Interest \; Expenses_{it} = \alpha_0 + \alpha_1 R \,\&\, D_{i,t} \beta_2 X_{i,t} + \delta_i + \theta_t + \varepsilon_{i,t} \tag{4}$$

$X_{i,t}$ denotes a vector of control variables. δ_i represents firm-specific fixed effects and θ_t represents time-fixed effect and $\varepsilon_{i,t}$ represent error term.

The paradigmatic illustration of the econometric Tobit model, as developed by Tobin (1958), is shown below.

$$Y_{it} = D_{it} + W_{i,t}\alpha + u_{i,t} \tag{5}$$

$$Y_{it} = max(0, Y_{i,t}^*) \tag{6}$$

The observed outcome $Y_{i,t}^*$ is obtained by applying censoring rules. If the underlying value $Y_{i,t}^*$ falls below 0, the observed value is recorded as 0, and if it exceeds a specific predetermined upper limit (in our case, 10), the observed value is recorded as that upper limit. $D_{i,t}$ is a $1 \times p$ vector of endogenous variables (R&D) and $W_{i,t}$ is a $1 \times I$ matrix of exogenous covariates, which includes variables such as size, age, leverages, and a constant term.

As discussed, endogeneity might be a concern in our analysis due to the potential correlation between the predictors and the errors in our model, which can lead to biased estimates and invalid inferences. Specifically, in examining the relationship between a firm's energy efficiency and its COD, we recognise that not only might energy efficiency influence borrowing costs, but factors influencing those costs—such as a firm's overall financial health or investment strategies—could also impact energy efficiency investments. This reciprocal relationship complicates our ability to establish a clear causal link.

To address this issue, following Terza et al. (2008), we employ a rigorous two-stage least squares (2SLS) approach to estimate the ensuing instrumental variable in the (IV)-Tobit model, using lagged investments in research and development (R&D) as an instrumental variable. The rationale behind this choice lies in the premise that past R&D investments are likely to influence current energy efficiency but are less likely to be directly influenced by current debt costs or other contemporaneous financial conditions. By using this lagged variable, we effectively strip away the confounding effects that may distort the relationship we are trying to estimate, allowing us to capture a more accurate effect of energy efficiency on the COD (Harrou et al., 2023).

In this process, we estimate u using the residuals of the regression of D on Z and W using the least-squares method (fixed effect model). Endogeneity bias in the relevant equation is thought to be caused by variations in unobserved variables, and this two-stage residual inclusion method is based on the idea that u can be used as a proxy measure to capture these variations. Using the instrumental variable Z, this proxy variable can be varied separately from the other independent variable. Our empirical model involves instrumenting the R&D level with energy efficiency (Newey, 1987). Within our theoretical framework, this approach reinforces our understanding of how sustainable operational practices can lead to improved firm performance by demonstrating that past investments in innovation, reflected in R&D activities, can yield long-term benefits in energy efficiency, subsequently impacting financing costs. By establishing this causal pathway, we not only enhance the robustness of our findings but also contribute to the broader literature on sustainability and corporate finance, highlighting the importance of strategic investment decisions in shaping financial outcomes.

To understand the causal relationship between energy efficiency and COD, it is necessary to determine the directional effect of these factors. This research argues that energy efficiency is a crucial factor in lowering COD. Thereby, firms that employ energy-efficient practices tend to reduce operating expenses and increase profitability, making them more appealing to lenders who consider them lower-risk borrowers. While it is possible that reduced COD could encourage more investments in R&D, such as energy-efficient technologies, implying a potential reverse causality, this study focuses on the theoretical foundation that increased energy efficiency contributes to improved financing circumstances and potential investor interest (Panait et al., 2022). This is due to the potential for concurrent impacts, in which energy efficiency positively affects the underlying financial performance or market circumstances, thereby increasing COD. Thus, our primary focus remains on examining the impact of energy efficiency on COD. To address concerns about reverse causation and demonstrate a clear causal direction, we employed instrumental variables, notably lagged R&D spending, to isolate the impact of energy efficiency on COD. As a result, the data show a negative correlation between energy efficiency gains and lower borrowing rates, validating the idea that energy efficiency is an important component in determining enterprises' financing arrangements.

6. RESULTS AND DISCUSSIONS

The present study examines the influence of firms' energy efficiency practices on their COD in developing countries and across industries. The objective is to test the hypothesis that the impact of enterprises' energy efficiency on the COD varies when firms are in high or medium-tech industries. Table 5 represents the results of the Twostep Tobit with endogenous regressor for the total sample of firms. The results comprise five models that examine the relationship individually, using squared terms and control variables.

Energy Efficiency and COD for all firms (Combined)

To enhance the accuracy of our results, we assessed the stability of the primary variable by employing different model specifications, namely Model 1a to Model 1e. The model-1a represents the baseline regression with size as the only control variable. In models 1 b to 1e, we have added control variables ranging from the firm's age, liquidity, and leverage to ownership and the interaction of ownership with energy efficiency and liquidity. Surprisingly, the impact of energy efficiency on the COD remained consistent across all models, and the energy efficiency coefficient is positively significant. The consistency across models gives assurance about the dependability and stability of our results. We discovered an intriguing pattern in the link between energy efficiency and the COD. It shows that initially, a positive relationship exists between the cost of debt and increasing energy efficiency, implying that greater energy efficiency is associated with higher firm borrowing costs. This finding supports the notion that investing in energy-efficient technologies and practices necessitates significant upfront investments, which may increase firms' financial obligations and lead to higher borrowing costs.

However, as we further investigated the nature of the relationship, we introduced the energy efficiency square term to account for the potential non-linear effect. The results indicate that the coefficient of the linear terms of energy efficiency is positively significant, but the squared terms are negatively significant at a significance level of 1% level. It suggests that the relationship between energy efficiency and debt cost becomes negative after a certain level of energy efficiency is reached. This means that higher levels of energy efficiency above the threshold are associated with lower borrowing costs for businesses (Broadstock et al., 2018; Zhang et al., 2020). The findings suggest that lenders generally make loan decisions based not on a project's cash flow but on the strength of the host company's balance sheet and operational benefits (Blyth & Savage, 2011). This non-linear pattern suggests that, while there may be initial costs and challenges associated with implementing energy-efficient measures, firms that exceed the threshold level of energy efficiency can save significantly in terms of lower borrowing costs. Higher levels of energy efficiency enable businesses to demonstrate their commitment to sustainable practices, potentially enhancing their creditworthiness and reducing perceived financial risks.

As evidenced by Borisova et al. (2015), our findings indicate that larger firms tend to benefit from lower interest rates compared to smaller firms. Several factors contribute to this relationship. For starters, larger firms benefit from economies of scale, which allows them to spread fixed costs across a more extensive production base. This cost advantage enhances their profitability and financial stability, making them more appealing to lenders and allowing them to negotiate lower borrowing costs (Pfeffer & Salancik, 2006; Kamil & Appiah, 2022). Second, larger companies usually have broader knowledge, experience, and resources. They may have developed relationships with multiple lenders, allowing them to access a more competitive financing landscape. Larger firms' diverse funding options contribute to lower interest rates as lenders compete for their business.

TABLE 5
Two-step Tobit with endogenous regressor- All Industries

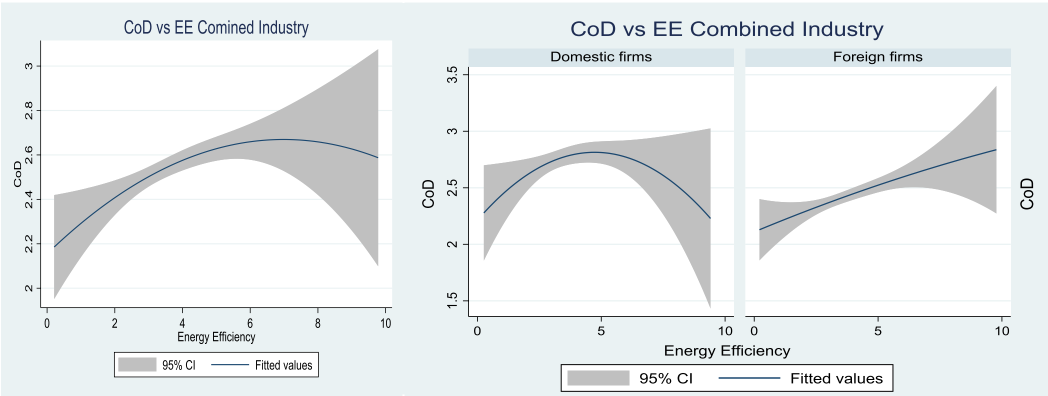
COD	Model-Ia	Model-Ib	Model-Ic	Model-Id	Model-Ie
EE	2.20***	7.59***	7.312***	2.93***	2.907***
	(0.59)	(1.72)	(1.65)	(0.71)	(.669)
EE Sq		-0.89***	-0.86***	-0.34***	-.309***
		(0.21)	(0.19)	(.08)	(0.07)
Size	-0.32***	-.241***	-8.628***	-4.25***	-4.255***
	(0.04)	(.02)	(0.76)	(.54)	(0.53)
Liquidity				.306***	.243***
				(0.04)	(0.04)
Leverage				-.05***	-.051***
				(0.01)	(0.01)
Ownership					1.12***
					(0.34)
Ownership*EE					-.37***
					(0.08)
Ownership*Liquidity					.19**
					(0.08)
Age					.126**
					(.058)
Constant	-4.62**	-11.34***	-9.6**	-2.76*	-3.52**
	(2.136)	(3.30)	(3.24)	(1.439)	(1.46)
Chi-square	78.15***	116.426***	390.54***	248.62	269.10***
Number of observations	3147	3147	3147	3147	3147
Industry fixed effect	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes

Note: The symbols ***, **, and * indicate significance *** $p<.01$, ** $p<.05$, * $p<.1$, respectively.

When we plot energy efficiency versus the COD in Fig. 1, the analysis supports the results and shows a curvilinear, inverted U-shaped relationship. The results suggest that a minimum energy efficiency threshold is likely necessary to achieve the targeted financing term. Only after attaining minimal efficiency do lenders or investors consider the firms for any reward regarding the cost of debts. Therefore, the results generally indicate that energy efficiency is a crucial determinant of COD. The results also support the hypothesis that firms' energy efficiency and COD show a curvilinear relationship. More specifically, energy efficiency up to a certain level may not incentivise the firm. However, once the firms cross the mean level, they get the advantage of the cumulative effect.

To investigate our second hypothesis, whether firms' ownership structure significantly influences the COD of energy-efficient firms, we included foreign ownership as an additional explanatory variable. We interacted ownership with energy efficiency to analyse the moderation impact in model-I-e, as shown in Table 5. The positive and significant coefficient of foreign ownership in our analysis aligns with the existing literature on the relationship between ownership structure and the cost of debt. Numerous studies have extensively documented the presence of various agency conflicts, including asset substitution, claim dilution, and underinvestment, between shareholders and creditors (Brockman & Unlu, 2009; Jensen et al., 1976;

FIGURE 1
Impact of EE on COD for all firms, and split into domestic and foreign control firms



Nini et al., 2009; Strahan & Kroszner, 2005). It is well-established that more pronounced agency conflicts tend to result in higher debt costs (Chava et al., 2009).

Furthermore, foreign-owned firms face specific challenges related to informational asymmetries and agency problems (Doidge et al., 2004). Information asymmetries imply that lenders have limited access to relevant and reliable information about foreign-owned firms. These information gaps increase lenders' uncertainties and perceptions of risk, thereby influencing the cost of debt for these firms. The combination of agency conflicts and informational asymmetries contributes to the observed positive association between foreign ownership and the cost of debt. However, the relationship changes if the firms are energy efficient. Our interaction variable (energy efficiency with ownership) is found to be negatively significant, implying that if firms are foreign and are energy efficient, they tend to have lower COD. This result supports our hypothesis that energy efficiency leads to lower COD.

Impact of Energy Efficiency on COD at the Industry Level: We divided our sample into high-tech and medium-tech sectors, as defined by the Indian National Industrial Classification (NIC), to examine the industry-level effect. The high-tech and medium-tech sectors often exhibit discernible attributes, including technological complexity, innovation intensity, and growth potential (Zhang and Fu, 2022). Separately examining these sectors enables one to comprehend the distinct dynamics and obstacles that may arise concerning energy efficiency in each sector.

Medium-tech industry: As discussed above, energy efficiency measures can lead to cost savings for businesses by reducing energy consumption and operating expenses. Improved energy efficiency can enhance the competitiveness of industries (IEA, 2021). Lower energy costs resulting from energy efficiency measures may positively impact a company's financial performance, including its ability to service debt obligations (Wang et al., 2023). The Tobit regression results for the medium-tech industry indicate that energy efficiency has a significant impact on the cost of debt intensity in all five models, with coefficients ranging from 1.122 to 4.359. However, the squared energy efficiency term showed a negative sign with the COD in all the models, with coefficients ranging from -1.28 to -0.49, suggesting a rebound effect. Firms may initially save money as energy efficiency improves. However, as energy efficiency increases, the decrease in energy consumption may plateau or even reverse, leading to an increase in energy demand and costs (Fu et al., 2023). This rebound effect can explain the inverted U-shaped relationship between energy efficiency and debt cost.

TABLE 6
Two steps Tobit Regression- Medium Industries

	Panel-A Medium-Tech				
COD	II-a	II-b	II-c	II-d	II-e
Energy Efficiency	1.122***	10.687**	10.847***	4.574***	4.359***
	(.259)	(4.158)	(4.139)	(1.181)	(1.103)
Energy Efficiency Sq		-1.283**	-1.3***	-.546***	-.49***
		(.503)	(.501)	(.142)	(.126)
Size	-.316***	-.206***	-7.243***	-2.706***	-2.801***
	(.035)	(.036)	(1.562)	(.859)	(.827)
Size Sq			3.432***	1.31***	1.361***
			(.761)	(.415)	(.399)
Liquidity				.39***	.304***
				(.062)	(.068)
Leverage				-.049***	-.053***
				(.017)	(.017)
Ownership					1.19***
					(.451)
Ownership*EE					-.399***
					(.117)
Ownership*Liquidity					.25**
					(.12)
Age					-.017
					(.082)
Constant	-.502	-16.996**	-16.339**	-6.242***	-6.138***
	(.891)	(7.859)	(7.982)	(2.374)	(2.307)
Chi-square	98.826	41.311	136.024	124.978	137.49***
Number of observations		2171		2171	
Industry fixed effect		Yes		Yes	
Year fixed effect		Yes		Yes	

Note: The symbols ***, **, and * indicate significance ****p<.01, **p<.05, *p<.1*, respectively.

The size in models II-a and II-b (Table 6, Panel A) shows a significant negative coefficient, indicating that larger firms are more comfortable raising funds at a lower cost. In models-II-d and II-e, both leverage and liquidity significantly affect the COD, showing that comfortable liquidity helps firms raise resources at a lower cost of debt. The results are similar to those obtained in our previous studies for all samples.

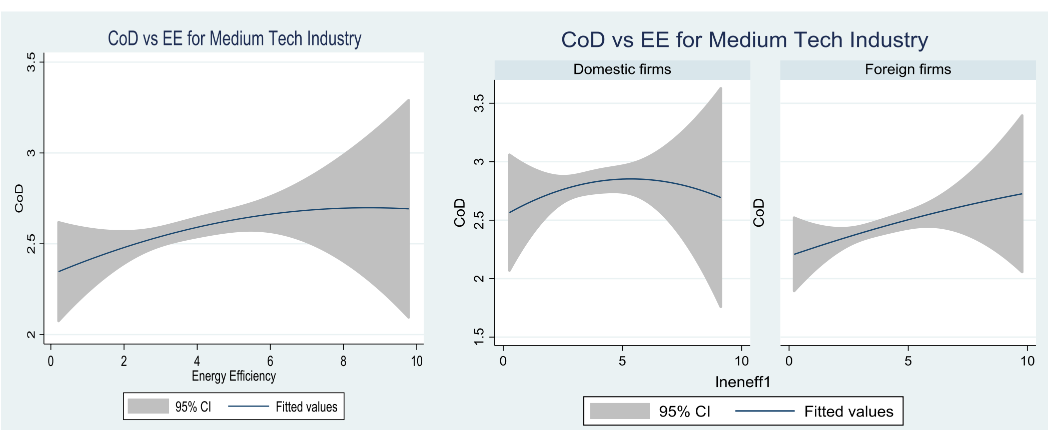
High-tech industry: Consistent with our previous observations on the larger dataset, we have observed an initial increase in COD as energy efficiency improves within the high-tech sector. Nevertheless, a noticeable decline becomes apparent once a specific energy efficiency threshold is exceeded. The observed consistent pattern strengthens the argument for a non-linear correlation between energy efficiency and COD in the high-tech sector. It implies that the influence of energy efficiency on the COD may vary depending on the level of energy efficiency achieved (Fu et al., 2023). Thus, firms in both categories (high tech and medium tech) need to carefully consider the optimal level of energy efficiency to achieve cost savings while avoiding diminishing returns or increased costs associated with exceeding a certain

TABLE 7
Two steps Tobit Regression- High-Tech Industries

	Panel-B High-Tech				
COD	III-a	III-b	III-c	III-d	III-e
Energy Efficiency	-18.21	9.814***	8.816***	5.315***	4.961***
	(32.557)	(2.818)	(2.639)	(1.669)	(1.431)
Energy Efficiency Sq		-1.129***	-1.012***	-.599***	-0.487***
		(.324)	(.304)	(.191)	(.145)
Size	-1.405	-0.293***	-8.881***	-5.324***	-5.168***
	(1.985)	(.045)	(1.356)	(1.153)	(1.071)
Size Sq			4.174***	2.505***	2.434***
			(.66)	(.556)	(.516)
Liquidity				.259***	0.24***
				(.086)	(.101)
Leverage				-.032	-0.037***
				(.028)	(.026)
Ownership					3.449***
					(1.017)
Ownership*EE					-0.963***
					(.267)
Ownership*Liquidity					0.18***
					(.159)
Age					0.222***
					(.136)
Constant	76.178	-16.271***	-12.928**	-7.507**	-8.662***
	(129.847)	(5.646)	(5.395)	(3.464)	(3.35)
Chi-square	1.136	47.376	137.688	76.324	93.389***
Number of observations		976			976
Industry fixed effect		Yes			Yes
Year fixed effect		Yes			Yes

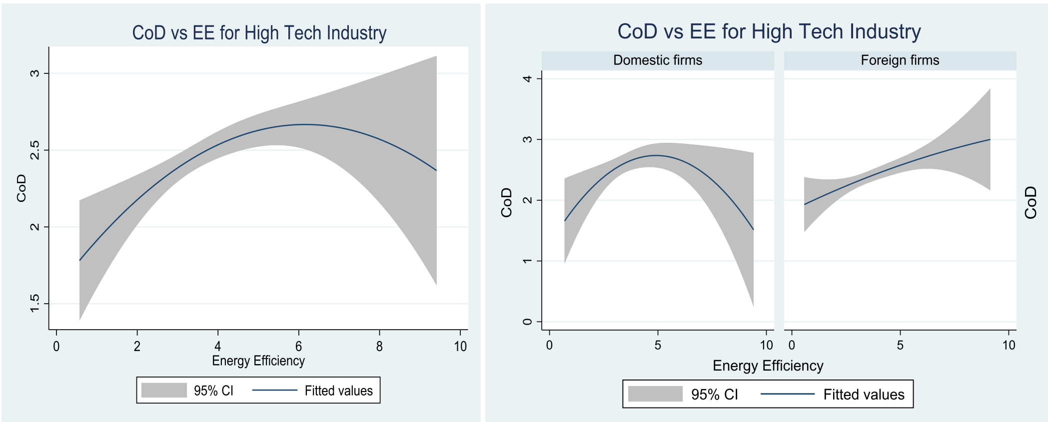
Note: The symbols ***, **, and * indicate significance *** *p<.01, ** p<.05, * p<.1*, respectively

FIGURE 2
Impact of EE on COD of the medium-tech industry with ownership structure as moderator



threshold. In the model-III-b (Table 7- Panel B), the square of EE shows significant and negative results indicating diminishing marginal effect of EE on COD. The relationship between energy efficiency and COD is demonstrated in Fig. 3.

FIGURE 3
Impact of EE on COD of the high-tech industry with ownership structure as moderator



Meanwhile, Model III-e shows that ownership has a significant positive relationship, again indicating that the ownership structure of firms significantly influences the COD of energy-efficient firms. Interestingly, the coefficient for ownership as an explanatory variable was found to be significant and positively associated with energy efficiency. However, when foreign ownership interacts with energy efficiency, the moderating effect changes significantly, helping to reduce the cost of debt. Additionally, leverage has a negative relation with COD, implying that high levels of debt in the firm result in lower borrowing costs. Diminishing the marginal cost of debt with higher leverage implies that borrowers with high leverage can utilise higher investments in technological advancements to implement energy-efficient measures. In contrast, liquidity shows a significant and positive relationship with the COD for both the high-tech and medium-tech industries.

As a robustness measure to examine the influence of energy efficiency on COD, we also regressed energy efficiency with financial expenses. The test was conducted for all sectors and medium- and high-tech sector firms. Table 8 summarises the results. The results replicate a similar trend for all medium and high-tech firms. Once we tested the square terms of energy efficiency, the inverted curvilinear relationship was also shown. The results support the theoretical background of the idea that energy efficiency and COD exhibit an inverted curvilinear relationship, and the benefit of improving efficiency tends to decrease after a certain level of energy efficiency is achieved.

Practical Applicability and Policy Implications: This research presents empirical evidence for adopting sustainable operational practices, such as energy efficiency (reductions in the energy-output ratio) and COD when making a financing decision. The study offers significant theoretical, practical, and policy implications for firms, investors, and regulators in emerging economies such as India. First, the study identifies operational initiatives that firms can adopt to achieve both environmental sustainability and financial gain. The firm's sustainability, measured through energy efficiency, reflects a summary metric of technology adoption and new

TABLE 8
Two-step Tobit with endogenous regressor for robustness of the model using different outcome proxy

	All	High-Tech	Medium-Tech
Energy Efficiency	5.257***	8.786***	7.317***
	(0.861)	(1.975)	(1.463)
Energy Efficiency Sq	-0.585***	-0.896***	-0.843***
	(0.095)	(0.20)	(0.167)
Size	-8.333***	-9.999***	-6.021***
	(.712)	(1.508)	(1.165)
Size Sq	4.354***	5.095***	3.279***
	(.344)	(.726)	(.562)
Liquidity	0.482***	0.464***	0.577***
	(0.062)	(.14)	(0.092)
Debt to equity	1.744***	1.79***	1.819***
	(.084)	(0.178)	(0.131)
Leverage	0.043***	0.044	.049**
	(0.016)	(0.035)	(.023)
Ownership	1.907***	5.716***	1.96***
	(.44)	(1.403)	(0.601)
Ownership*EE	-.561***	-1.543***	-.585***
	(0.115)	(0.368)	(0.156)
Ownership*Liquidity	0.088	0.09	0.186
	(0.105)	(0.22)	(0.161)
Age	0.101	-0.314*	0.086
	(.075)	(0.188)	(0.11)
Constant	-8.963***	-15.635***	-13.409***
	(1.895)	(4.651)	(3.084)
Observations	3147	976	2171
Industry fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes

Note: The symbols ***, **, and * indicate significance ****p<.01, **p<.05, *p<.1*, respectively.

investments in energy-saving measures. The research extends the analysis to explore the nature of this relationship across different industries and ownership structures. To demonstrate these linkages, we investigated the sample by splitting it into high-tech and medium-tech sectors. Distinctly studying these sectors enables policymakers to understand the unique dynamics and challenges that may develop regarding energy efficiency in each sector. The results suggest that the impact on COD varies depending on the degree of energy efficiency achieved (Fu et al., 2023). Although the influence is more pronounced in high-tech firms, it remains important in medium-tech sectors. Medium-sized businesses must, therefore, carefully assess the investment size in energy-efficient technologies to achieve the intended economic benefit.

The study demonstrates that firms that adopt energy-efficient practices can benefit from lower COD. Aligning our study's findings with the Sustainable Development Goals (SDGs), such as Goal 7 (Affordable and Clean Energy) and Goal 13 (Climate Action), provides a framework for integrating corporate sustainability into national economic strategies. By recognising the financial benefits associated with energy efficiency, policymakers can create an ecosystem that fosters sustainable investment, enhances corporate creditworthiness, and ultimately stabilises the energy market by reducing its dependency on fossil fuels. Policymakers in government can leverage this insight by introducing incentives, such as lowering taxes or subsidies, to firms that invest in energy-saving technology, potentially resulting in reduced greenhouse gas emissions and improved environmental performance. It also suggests that governments may strengthen regulatory frameworks to promote energy efficiency among businesses, thereby enhancing enterprises' environmental and financial performance. As banks and financial institutions (FIs) become increasingly cautious about the reputational risks associated with lending decisions, particularly to firms with suboptimal environmental performance, regulators can mandate the inclusion of sustainable metrics in their lending processes. Further, FIs may be incentivised to foster sustainable business practices and possibly reduce financing costs for energy-efficient enterprises. Encouraging environmental regulations could potentially influence the sustainable business process and the resultant access to funding.

This research also finds that the impact of energy efficiency varies across high and medium-tech firms. Thus, policymakers may consider the above observations when formulating strategies to address the various challenges and problems faced by each sector. For example, for an emerging economy like India, medium-tech sectors require a positive differential supporting mechanism compared to high-tech sectors in the context of their potential financial impact possibilities once the firm reaches a high-tech stage. The study also estimates local and foreign ownership controls based on energy efficiency and debt cost. The findings suggest that foreign-owned firms may face specific challenges related to informational asymmetries and agency problems (Doidge et al., 2004), leading to lenders' uncertainties and higher debt costs for these firms. However, the relationship changes if the firms are energy-efficient, implying that they tend to have lower COD if they have a foreign controlling stake and are energy-efficient. The findings may enable regulators and administrative authorities to advocate for desirable changes in ownership patterns while achieving sustainability through energy efficiency, thereby benefiting their financing decisions with lower debt costs.

7. CONCLUSION

The implementation of sustainable operational and business practices to reduce greenhouse gas emissions is the foremost policy challenge. The primary concern with such sustainable business practices is their anticipated economic implications. Conversely, the prospective economic expense may be somewhat mitigated via enhancements in energy efficiency (reductions in the energy-output ratio) prompted by rising energy prices. This enhancement may alleviate the economic burdens of the policy, as it suggests that companies will use less energy per production unit, lowering their production costs while maintaining output levels. The primary strategy for enhancing energy efficiency is deploying energy-efficient capital and investments in new energy-efficient assets. We examined the influence of EE on enterprises' COD during financial decision-making in medium-tech and high-tech Indian firms. By doing so, we established the conceptual background of the nature of the relationship that could exist between firms' sustainable operational practices, such as energy efficiency, and investors' preferences in terms of their CO) while making financing decisions.

To validate the hypotheses, we applied the 2SLS Tobit regression model, considering investment in R&D as an instrumental variable. We segregated the samples into high-tech and medium-tech firms to visualise the effect of technological advancement on sustainable operational practices with the outcome variable. Furthermore, we have included foreign ownership as an explanatory variable and interacted with it with energy efficiency to examine the moderating impact on the cost of debt. We found that the COD initially increases when a firm implements sustainable practices. However, the COD decreases as the firms achieve the threshold level. This result implies that firms initially bear higher risk premiums when implementing energy-efficient measures. However, with an established reputation in the market and having achieved a threshold level of EE, they tend to benefit from lenders in terms of lower COD. These findings are similar for both high-tech and medium-tech firms in India.

An exciting relationship was observed when foreign ownership interacts with energy efficiency; the moderating effect changes significantly and negatively. The results indicate that if firms lack energy efficiency, lenders do not view it as favourable, even though foreign ownership stakes are present, and charge a higher risk premium. However, foreign ownership in energy-efficient firms has a significantly negative impact on the COD. It signifies that lenders view energy-efficient foreign stake firms as less risky and charge a lower cost of debt (COD). To address the endogeneity problem, we used R&D as an instrumental variable for energy efficiency in this research. This research enables energy efficiency to be translated into financial success via COD by using R&D as an instrumental variable for energy efficiency. The regression findings confirm Roy's (2023) findings that enterprises with higher energy consumption may be more inclined towards further investment in energy-efficient technologies, which can be reflected in their performance through the cost of borrowing.

These findings have important implications for emerging economies, such as the Indian industry, particularly for medium-tech firms in their pursuit of sustainable goals and financial gain. Firms can potentially lower their borrowing costs and improve their economic performance by implementing sustainable operational practices. Policymakers can encourage such investments by providing financial incentives and promoting energy efficiency measures. Additionally, lenders should exercise greater caution when extending credit to firms with excessive leverage, as this can lead to higher borrowing costs and financial distress.

The present research has some limitations that might be considered in further investigations. Initially, the calculation of the COD used the division of the interest by the average debt. One may want to explore other sources of finance and examine the potential impact of energy efficiency on capital expenditures. While the criteria investigated in this research are pertinent to embracing sustainable practises, the emphasis of this research was primarily on energy efficiency, neglecting other vital domains such as conservation of natural resources, waste recycling, and waste management. Thus, the effect of environmental legislation on functioning and capital investments may specify novel and stimulating insights into the outcomes presented in this study.

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