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Environmental Impact-Adjusted Firm Value and Debt: A Multi-Country Analysis

Paolo Saona[1,2,3] | Antonio Renzi[4] | Gianluca Vagnani[4] | Pietro Taragoni[4]

[1]Saint Louis University, Madrid Campus, Madrid, Spain | [2]Universidad Pontificia Comilllas, Madrid, Spain | [3]Universidad Católica de la Santísima Concepción, Concepción, Chile | [4]Sapienza University of Rome, Rome, Italy

Correspondence: Paolo Saona (paolo.saona@slu.edu)

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ABSTRACT

The study finds a nonlinear, inverted U-shaped relationship between leverage and environmental impact-adjusted firm value (*EIAFV*), confirming the trade-off theory. The firm value increases with leverage up to an optimal point, approximately 58%–61% of total assets, after which higher leverage leads to value erosion due to rising default risk and financial distress costs. Our results also reveal that higher leverage is associated with lower environmental impact. Quantile regression analysis highlights that the impact of leverage varies across the distribution of *EIAFV*, with stronger effects observed at higher quantiles. Contextual country-level variables, such as capital market development, positively influence *EIAFV*, while banking system inefficiencies, like higher net interest margins and banking crises, negatively affect it. Despite data limitations for country-specific variables, the findings remain robust, emphasizing the nuanced relationship between leverage and firm value in a multi-country context.

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1 | Introduction

Massive environmental damage, growing income and wealth inequality, and stress and depression within developed economies are examples of how the current value creation and distribution system is in crisis (Serafeim et al. 2019).[1] In this context, as the planetary boundaries are shrinking due to overconsumption of natural resources and nature degradation, organizations are facing a broad social demand to change the scope of business, and doing "business as usual" is no longer an option, as recently emphasized by Sjåfjell (2018) and (Faria et al. 2022). Traditional proxies of firm value (e.g., Tobin's Q) are limited in scope for understanding the value creation and distribution processes, being driven by shareholder primacy while failing to account for other stakeholders such as the community and the environment. Hence, as argued by Barlett and Partnoy (2020), traditional measures of value can drive misleading behavior and biased decisions. In this vein, one of the deepest challenges for both managers and investors is to understand how different environmental impacts[2] can be measured, compared, and integrated into the decision-making process, thus allowing for a better and more seamless management of risk and return, as well as a more efficient and sustainable resource allocation (Freiberg et al. 2021).

On the other hand, decisions on corporate financial leverage are among the most critical decisions made by corporate executives and have been the focus of intense theoretical research aimed at understanding the composition of capital structure, between debt and equity, that affects the firm's value. Since the seminal work of Modigliani and Miller (1958), who hypothesize that in a perfect market, capital structure, analyzed in terms of financial leverage, is irrelevant to the firm's total value (asset value) according to market logic, there has been a succession of theories on corporate financial policies, focusing primarily on taxes, contracting costs, and information costs (Barclay and Smith 2020).[3]

Such theories aim to determine the leverage level that maximizes total firm value.

The empirical literature reveals that traditional models on the relationship between leverage and firm value or performance are fundamentally influenced by how key variables are measured and focus primarily on the relationship between the firm and its financial claimants without paying attention to other nonfinancial stakeholders (Graham and Leary 2011). Several studies examine the positive (e.g., Berger and Bonaccorsi di Patti 2006), negative (e.g., Cai and Zhang 2011; Le and Phan 2017), and nonlinear (e.g., McConnell and Servaes 1995; Stulz 1990; Lin and Chang 2011) associations between leverage and various measures of firm performance, such as market prices (Black and Khanna 2007), Tobin's *Q* (Pratt et al. 2023; Yu et al. 2018), profitability (Sweeney et al. 1997), productivity indicators (Chung and Cox 1990; González 2013; Min and Smyth 2014), and other accounting measures with empirical support that is far from conclusive. Furthermore, other studies show that the contribution to the firm value of optimal capital structure choices is moderate for most firms (Graham and Leary 2011), demonstrating that the value and importance of capital structure decisions may be modest over a wide range of leverage choices (e.g., Van Binsbergen et al. 2010; Korteweg 2010).

However, the studies mentioned above adopt a "business as usual" perspective driven by shareholder supremacy. Hence, as the world is facing serious sustainability challenges, the literature struggles to establish a sound connection between value creation "within the planetary boundaries" and more traditional financial policies. Only recent and isolated attempts seek to reach broader value configurations by linking environmental practices to current firm value (e.g., Faria et al. 2022). Additionally, research focuses solely on a few stakeholders, such as employees and suppliers (e.g., Titman and Wessels 1988; Berk et al. 2010), without considering the monetization of environmental impact and its integration into the firm value estimates. How much adjusted firm value is subsequently driven by capital structure decisions?

Our paper aims to bridge the gap between traditional financial theories and sustainable finance, incorporating the environmental impact in the definition of firm value. Consequently, the joint analysis of leverage and adjusted firm value might shed light on mechanisms for policymakers, managers, business practitioners, and investors to maximize firm value responsibly. In this respect, our study builds, among others, on Yu et al. (2018) and Gerged et al. (2023) who focused on examining how a publicly listed company's ESG disclosure and global transparency affect firm value measured primarily as Tobin's *Q*. However, these studies fall short of integrating environmental performance into the metric of firm value.

We address these issues by examining the impact of leverage on an expanded value measure that incorporates firms' environmental costs, which we refer to as environmental impact-adjusted firm value (*EIAFV*). In this sense, this study extends the current literature (e.g., Hassan et al. 2021) that mostly focuses on monetizing environmental damage without integrating it into corporate value. Among all the possible measures of firm performance, our analysis focuses on an expanded measure incorporating environmental externalities, which markets do not directly price into current firm value. *EIAFV* is an enhanced metric that modifies the traditional Tobin's *Q* measure, borrowed from macroeconomics, by incorporating the environmental impact monetized through the impact-weighted accounts (IWA) methodology.[4] Therefore, our starting point for examining the relationship between leverage and *EIAFV* is the literature on leverage and firm value. Specifically, we build on the trade-off theory, which explains firms' choice of leverage through a trade-off between debt costs and benefits (Fama and French 2002). We focus on the trade-off and not on other hypotheses for a fundamental reason. Because we are interested in understanding the leverage that increases a firm value in the presence of environmental costs, we search for an optimal level of debt above which excessive debt also negatively impacts a firm's value and externalities.

Consistent with the relevant literature, we do not intend to establish the irrelevance of other capital structure theories in our sample, as most are not mutually exclusive (Barclay and Smith 2020; Graham and Leary 2011). Specifically, taking into account the benefits and costs of leverage, we verify whether considering *EIAFV* an inverted U-shaped relationship with leverage exits: at low levels of leverage, as debt increases, firms benefit from the tax deduction of debt and the *EIAFV* should increase. In contrast, at relatively high levels of leverage, as debt continues to grow, the risk of default increases, which causes the *EIAFV* to fall. The optimal point is obtained by equalizing the marginal benefits with the marginal debt costs. Using *EIAFV*, the net benefit coming from financial debt extends to the environmental component.

Our sample consists of 14,238 firm-year observations from 2086 nonfinancial companies, focusing on those whose environmental impact monetization data is reported by IWA firms.

Our estimates confirm a nonlinear, inverted U-shaped relationship between leverage and environmental impact-adjusted firm value, extending the trade-off theory to a new perspective on firm value. In particular, *EIAFV* increases with leverage up to an optimal point, approximately 58%–61% of total assets, after which higher leverage leads to value erosion due to rising default risk and financial distress costs. Quantile regression analysis highlights that the impact of leverage varies across the distribution of *EIAFV*, with stronger effects observed at higher quantiles. Because of the relevance of contextual country-level (Antoniou et al. 2008; Öztekin 2015; Psillaki and Daskalakis 2009; Turk Ariss 2016), some control variables were introduced as controls. Among them, we noticed that capital market development positively influences *EIAFV*, while banking system inefficiencies, like higher net interest margins and banking crises, negatively affect it. Moreover, in the robustness section, we also controlled for differences in country-level environmental regulation stringency.

This study contributes to the literature in several ways. First, it extends the literature on the relationship between capital structure and value, and particularly the trade-off theory, by providing empirical evidence on the choice of optimal capital structure adopting a more integrative approach to measuring firm value that incorporates the interests of various stakeholders on environmental issues. Second, the paper provides a multi-country analysis that allows the drawing of more general conclusions suitable to fit multiple institutional settings through an appropriate methodology to address endogeneity and individual heterogeneity issues. Third, this study contributes to the United Nations Sustainable Development Goals (SDGs) by addressing the intersection of environmental impact and corporate financial strategies. Precisely, it aligns with SDG 12 (Responsible Consumption and Production) by promoting sustainable resource allocation through the integration of the environmental effects into corporate decision-making and SDG 13 (Climate Action) by emphasizing the reduction of environmental externalities to support climate change mitigation. It also supports SDG 8 (Decent Work and Economic Growth) by examining how capital structure decisions can foster inclusive and sustainable growth and SDG 9 (Industry, Innovation, and Infrastructure) through its innovative approach to measuring firm value with environmental externalities in mind. Ultimately, these contributions highlight the importance of sustainable economic practices while filling critical gaps in the literature by integrating environmental costs into corporate value assessments.

The remainder of the paper is structured as follows. Section 2 reviews the relevant empirical research on the relationship between leverage and firm value. Section 3 introduces our model. Section 4 presents the results. Section 5 concludes.

2 | Theoretical Background

The trade-off theory of capital structure represents a core theory that analyses the linkage between leverage and a firm's market value. According to this theory, the firm's financial choices reflect managers' attempts to weigh the costs and benefits of debt (Kraus and Litzenberger 1973). The benefits of debt include, for example, the tax deductibility of borrowing costs and the reduction of free cash flow agency problems. The costs of debt, by contrast, may relate to the risk of financial distress (i.e., bankruptcy costs) and agency conflicts between shareholders and debtholders. For instance, it has been shown that highly leveraged firms not only suffer from a debt overhang problem, which reduces their incentives to invest in productive investments but their attention is also diverted from productivity improvements by the need to generate cash flows to pay off their debts (e.g., Coricelli et al. (2012)). The trade-off theory predicts that the net benefits of debt financing increase for companies with low leverage but decrease when leverage increases, implying that these benefits are a nonmonotonic function of leverage. At the optimal level of leverage, the benefit of the last amount of debt offsets the cost. Thus, this theory predicts a reversed U-shape relationship between leverage and firms' market value: value initially increases with debt (due to tax benefits and discipline) but eventually declines as bankruptcy and agency costs dominate, implying an optimal leverage point where marginal benefits equal marginal costs.

We propose that environmental considerations enhance the traditional trade-off theory. This proposition arises from the concern that "capital structure could either enhance or impede productive interactions among the stakeholders" (Frank and Goyal 2009, 6). Accordingly, taking into account other stakeholders and measures of value that include these stakeholders might alter the relationship between leverage and firms' market value. Consequently, we assert that a firm's value is pertinent to stakeholders, specifically those focused on the environmental dimension. In this context, we consider a firm's value that internalizes the environmental impact expressed in terms of expected monetary income flows and is, therefore, consistent with the value configuration articulated by Tobin's *Q*.

Considering the environmental impact on the firms' market value, we argue that leverage might influence such impact by shifting strategic incentives, as formalized by Brander and Lewis (1986). The latter authors stated, "*As firms take on more debt, they will be incentivized to pursue output strategies that raise returns in good states and lower returns in bad states. The basic point is that shareholders will ignore reductions in returns in bankrupt states, since bondholders become the residual claimants. As debt levels change, the distribution of returns to shareholders over the different states changes, which in turn changes the output strategy favored by shareholders*" (p. 956). A "good state" can here refer to a scenario where the firm avoids significant environmental incidents, penalties, or reputational damage. Conversely, a "bad state" denotes situations triggered by substantial environmental harm that threaten the firm's financial stability or lead to bankruptcy.

Managers may pursue high-risk environmental strategies, potentially resulting in higher short-term profits (referred to as "good state" payoff), but also entail the risk of failures ("bad state"). For example, cutting environmental spending functions like Brander and Lewis (1986)'s "high-output strategy"; such actions boost profits in solvent states but, in insolvent conditions, increase the likelihood of environmental claims and litigations associated with the considered high-risk environmental strategies (see Parker (1995), Guo (2025))—a risk that creditors bear. At low to moderate debt levels, shareholders are incentivized to favor environmental risk-taking strategies as they benefit from increased short-term profits from reduced environmental expenditures (e.g., cutting environmental compliance costs). However, they tend to overlook the downside costs of environmental issues in potential bankruptcy scenarios, as these losses predominantly impact debtholders (Brander and Lewis 1986). This shareholder pressure contributes to increased environmental impact. Nevertheless, when leverage exceeds a critical threshold, debtholders' elevated overall risk of bankruptcy prompts decisive intervention. Recognizing environmental impact as a significant threat to their claims, creditors implement stricter covenants and environmental standards, requiring reduced environmental risk and mitigation measures to safeguard collateral value and repayment prospects (e.g., Albuquerque et al. 2019). This creditor discipline overrides the shareholders' risk-taking incentives, prompting a strategic shift toward environmental responsibility and a resulting decrease in environmental impact at high debt levels (see also Al Amosh et al. 2024).

In summary, we argue that leverage influences firms' market value, measured from the asset side perspective, and works specifically for both financial and nonfinancial stakeholders' values. Once divided into the traditional component and the environmental impact, holding the reversed U-shaped relationships between leverage and firms' market value, we suggest that for a moderate increase in leverage, the tax advantages of debt claimed by the trade-off theory are partially offset by an increasing environmental impact associated with managers' incentives in taking environmental risks. As leverage exceeds a specific threshold, incremental increases in debt heighten debtholders' exposure to the risk of financial distress associated with firms' reduced ability to meet debt obligations, amplifying their concerns regarding reputational damage, regulatory scrutiny, litigation liabilities, and potential environmental liabilities associated with environmentally risky investment options. In other words, holding a nonmonotonic, reversed U-shaped relationship between leverage and firms' market value, considering environmental impact alters the optimal debt level, giving firms more extended opportunities to increase their leverage.

Alternative theories of firms' capital structure exist. Specifically, Modigliani and Miller (1958)'s seminal paper shows that capital structure is irrelevant. Five years later, the same authors introduced a "tax correction" study, suggesting that firm value is maximized through full debt financing in the presence of corporate taxes, given the ability to deduct interest payable on debt (Modigliani and Miller 1963). According to the "tax correction" paper, in the presence of market frictions, one of the main theories of capital structure, based on agency theory (Jensen and Meckling 1976), is the pecking order theory (Myers 1984a, 1984b).[5] This theory posits that due to varying financing costs, a hierarchical preference system exists for financing new investments: retained earnings are utilized first, followed by safe debt, then risky debt, and finally, equity (Frank and Goyal 2003, 2008). The pecking order model represents an evolution of the signaling theory (Barclay and Smith 2020; Bhattacharya 1979; Ross 1973), which suggests that increased debt is a credible signal of higher future cash flows. To minimize the informational costs of issuing securities, a firm is more likely to issue debt (stock) if the firm appears undervalued (overvalued). Another leading capital structure theory is the market timing theory, which focuses on equity market timing to explain corporate financial choices. The theory states that "capital structure is the cumulative outcome of attempts to time the equity market" (Baker and Wurgler 2002, 3), which implies that when a firm is overvalued—i.e., when the market value is high relative to book value and past market values—it issues equity instead of debt, and tends to repurchase equity when its market value is low. In other words, the considered theory introduces a contingent behavioral component according to which managers set the leverage, not only considering the tax benefits but also grasping opportunities that originate from market conditions. Despite the relevance of the considered alternative theories, the trade-off theory offers the most relevant foundation for this analysis. Its explicit focus on balancing quantifiable costs and benefits is essential for modeling how the internalization of environmental impact alters the fundamental leverage-value relationship at the firm level.

The trade-off theory has been extensively investigated with extant empirical studies broadly supporting the trade-off theory prediction of an inverted U-shape leverage-value relationship at the firm level (e.g., see Botta and Colombo 2022). Among the empirical studies that find results consistent with the trade-off hypothesis, in a panel of Taiwanese companies listed during 1993–2005, Lin and Chang (2011) used a panel threshold regression model to test whether a "threshold" debt ratio causes asymmetric relationships between debt ratio and firm value. Using Tobin's *Q* as a proxy for firm value, the results reveal two thresholds. Tobin's *Q* increases by 0.0546%, with a 1% increase in the debt ratio. When the debt ratio is between 9.86% and 33.33%, Tobin's *Q* increases by only 0.0057%, with a 1% increase in the debt ratio. However, above 33.33%, there is no relationship between debt ratio and firm value. Coricelli et al. (2012), examining observations from a panel of firms from Central and Eastern European (CEE) countries during 1999–2008, use a threshold regression to demonstrate the nonmonotonic relationship between leverage and a particular measure of firm performance borrowed from macroeconomics, namely total factor productivity (TFP) growth. The results reveal the existence of an optimal leverage ratio in which the net productivity-enhancing benefits of debt are exhausted. The authors show that leverage has similar nonmonotonic effects on ROA and ROE. Consistent with previous studies, Cotei et al. (2011), using a sample of firms from 37 countries with diverse institutional settings, show that firms across all countries adjust toward their target leverage in line with the trade-off theory of capital structure. Specifically, they find that long-term debt accounts for 64% of the adjustment rate in common law countries and 51% in civil law countries.

Given the trade-off theory and acknowledging the indisputable contribution offered by extant empirical studies, we extend the trade-off theory by conceiving that environmental considerations amplify and modify this nonmonotonicity when firm value internalizes environmental impacts. Therefore, we further hypothesize and empirically test a reversed U-shaped relationship between leverage and environmentally internalized firm value (EIAFV), where the disciplining benefits of debt at high levels enhance market value, thus making the environmental impact influence the optimal leverage point.

Some indirect conflicting evidence supporting the trade-off theory must be acknowledged. Early studies find linear adverse effects, consistent with firms operating beyond optimal leverage (e.g., Fama and French 2002). Another research stream focused on the zero-levered firms (e.g., Strebulaev and Whited 2012; Morais et al. 2022). This stream suggests that a firm's benefits and costs vary, and so does the leverage-value association because of managers' short-term behaviors and, more relevantly, of demand or supply side debt conditions (e.g., Faulkender and Petersen 2006; Devos et al. 2012). Similarly, another stream focused on stakeholder theory notices that capital structure could promote or hinder productive interactions between the firm and its stakeholders (Frank and Goyal 2009). Thus, considering other stakeholders and measures of value that include these other stakeholders might alter the relationship between leverage and firms' value. Such conflicting evidence suggests that different circumstances may change the balance between leverage's benefits and costs and, thus, the leverage firms' value association. Our study delves into such circumstances, proposing and empirically testing that environmental impact matters in understanding the leverage benefits and costs to firms' market value.

3 | Methodology

3.1 | Background on Calculation of Corporate Environmental Impact Using the IWA Methodology

The corporate environmental impact valuation metric from the Impact-Weighted Accounts Project (IWA), developed by Harvard Business School, follows a structured process rooted in life cycle assessment (LCA) and monetary valuation of environmental damages at the firm level per year (Freiberg et al. 2021). This approach quantifies the societal costs of a firm's environmental footprint, focusing on emissions and natural resource consumption. By applying scientific models and environmental damage coefficients, the IWA framework translates corporate environmental outputs—such as carbon emissions, air pollutants, and water usage—into monetary values. This pioneering metric integrates environmental externalities into financial reporting, providing a new level of transparency and accountability for businesses. Consequently, Impact-Weighted Accounts' Corporate Environmental Impact methodology provides a framework for quantitatively assessing the economic cost in monetary units of corporate capital resource consumption (Steen 2019).

Previous research has primarily focused on global transparency measures, such as those discussed by Gerged et al. (2023) to assess corporate commitment to disclosure. However, these studies do not account for the monetary quantification of disclosed impacts. In contrast, the IWA methodology aims to quantify environmental impacts in monetary terms, facilitating comparability across companies, industries, and regions. This section details the components, data requirements, and computational processes behind this innovative measure, as outlined in the Practitioner Guide to Calculating Corporate Environmental Impact.[6]

The IWA methodology is rooted in LCA and monetary valuation of environmental impact. It traces corporate activities' environmental outputs (emissions, resource use, water consumption, etc.) and translates them into economic outcomes based on scientifically derived coefficients. By monetizing environmental impacts per company and year, firms can reflect their environmental footprint in financial terms, which can then be integrated into conventional financial metrics to enhance decision-making.

The methodology primarily focuses on the following key environmental outputs: (i) air emissions, including greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (NO_x), and sulfur oxides (SO_x); (ii) water consumption, focusing on the amount of freshwater used by corporate operations; and (iii) abiotic resource consumption, which includes the use of nonrenewable resources such as metals and minerals.

The foundation of the IWA methodology is corporate disclosure. The system relies heavily on firms providing accurate data on their environmental impacts through sustainability reporting. Key data sources include: (i) scope 1, 2, and 3 emissions (direct, indirect, and value chain emissions); (ii) water usage and discharge; and (iii) consumption of abiotic resources, such as minerals and raw materials.

Data are typically extracted from financial databases such as Bloomberg, Refinitiv, and S&P Capital IQ and through environmental disclosures made to platforms like CDP (Carbon Disclosure Project). In cases where data are incomplete, the methodology employs imputation techniques. This involves filling in missing values using machine learning algorithms and sector averages based on datasets like EXIOBASE, a detailed multi-regional supply-use input–output table covering emissions and resource use.

The central innovation of the IWA methodology is its ability to transform environmental data into monetary values. This process is achieved by applying specific monetization coefficients to the environmental outputs, which estimate the economic cost of environmental damage. The coefficients used are derived from scientific research and models such as the Environmental Priorities Strategies (EPS), developed in collaboration with the Swedish Environmental Research Institute and Volvo, and follow the principles of the ISO 14008:2019 standard for monetary valuation of environmental impacts, considering (i) air emissions, (ii) water consumption, and (iii) abiotic resource use.

Monetizing air emissions involves calculating the societal cost of pollutants such as CO_2, NOx, SOx, and particulate matter ($PM_{2.5}$). These pollutants are responsible for climate change, health impacts, and environmental degradation, and the following steps measure their economic impact:

- Greenhouse gases (GHGs): Emissions of CO_2 and other GHGs are monetized using a social cost of carbon (SCC), which estimates the long-term economic damage caused by 1 t of CO_2 emitted into the atmosphere. For example, the IWA methodology uses global parameters to calculate the damage to productivity, infrastructure, and health caused by climate change induced by GHGs.
- NOx and SOx: These pollutants contribute to smog, acid rain, and respiratory diseases. Their monetization is based on the cost of health care, productivity losses, and environmental remediation associated with air quality degradation.

Water scarcity poses a significant risk to businesses and society. The IWA methodology accounts for this by monetizing water usage based on its geographical scarcity. The Waterfund Global Water Price Index and AWARE (Available Water Remaining) model are applied to adjust the cost of water use depending on the location and scarcity of freshwater resources. Water-intensive industries in regions facing high water stress bear a higher economic cost for their water use, reflecting the broader societal impact of their operations on water availability.

The depletion of nonrenewable resources, such as metals and minerals, is quantified based on the cost of replacing these resources with sustainable alternatives. The economic impact is measured as the cost of restoration or substitution. This is particularly relevant for industries like mining, steel production, and construction, where resource extraction plays a significant role in operations.

Once the environmental outputs are monetized, the next step is to aggregate these costs to determine the total corporate environmental impact. This aggregate figure represents the monetary economic damage caused by a firm's environmental activities. The outputs are helpful not only for internal decision-making but also for external decision-making. They can be communicated externally to stakeholders as a reflection of the company's environmental performance.

The aggregation process results in a single monetary value that can be integrated into financial reporting and used for comparative benchmarking. In this sense, the monetary impact can be reported alongside traditional financial metrics, such as operating income or net revenue, allowing firms and investors to consider risk–return and risk–return impact profiles. Additionally, since the metric translates environmental impacts into comparable monetary units, it will enable firms to benchmark their environmental performance against peers within and across industries. In order to understand the complexity of the computations of the monetization of environmental impact, Figure 1 describes the process, inputs, and outputs needed as well as a brief description of the monetization methodology.

Briefly, according to Freiberg et al. (2021), the IWA methodology offers an innovative and practical approach to monetizing corporate environmental impacts. Transforming environmental outputs into economic terms gives firms a powerful tool to integrate sustainability into their financial and strategic planning. Despite certain limitations, it represents a significant advancement towards a future where environmental externalities are fully accounted for in corporate decision-making. This methodology has the potential to reshape how businesses and investors evaluate long-term corporate performance, aligning financial success with environmental sustainability. Hence, due to these advantages, we consider this USD-monetized measure to compute our environmental impact-firm value-adjusted metric for the dependent variable described below.

3.2 | Sample and Variables Definition

Our sample consists of 14,238 firm-year observations from 2086 nonfinancial companies, spanning the period from 2008 to 2022. This dataset provides an average of 6.82 continuous observations per company. The sample includes listed firms from 66 countries, focusing on those whose environmental impact

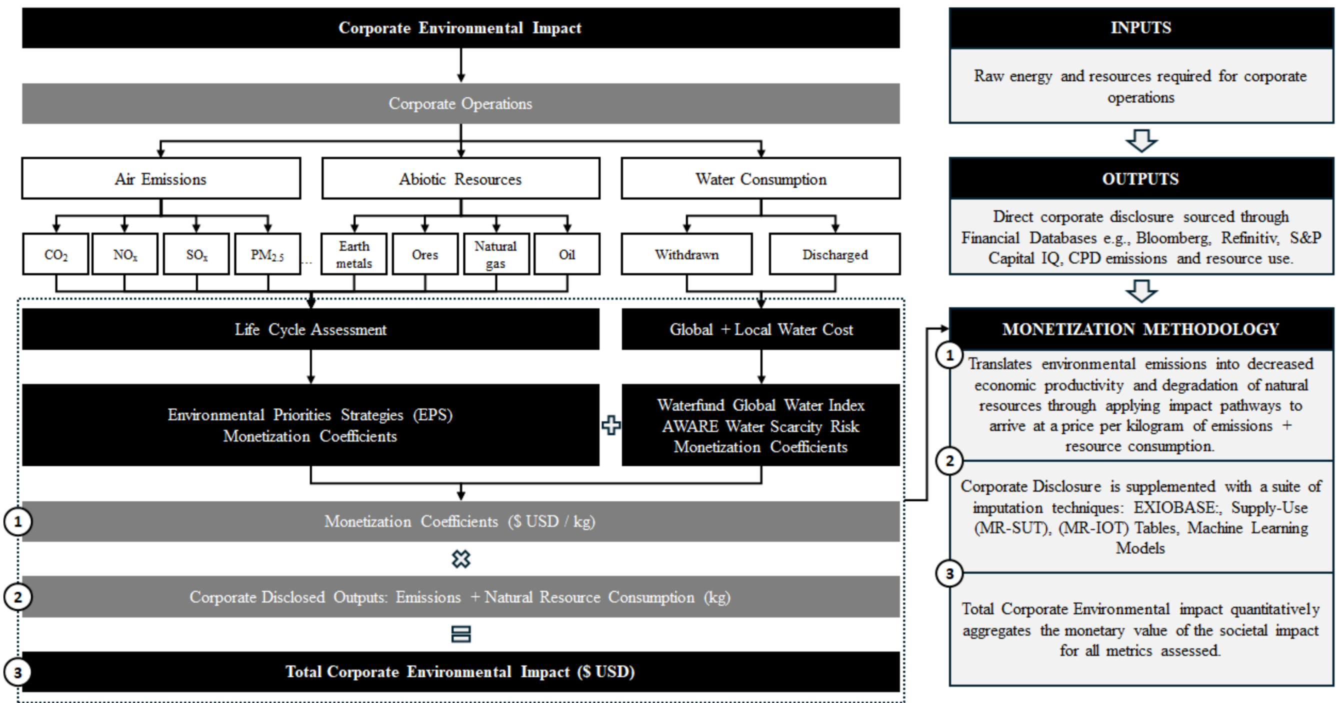

FIGURE 1 | Monetization of the environmental impact. Made from the Figures 11, 12, and 13 from the Practitioner Guide to Calculating Corporate Environmental Impact (Velez Caicedo 2022). To conduct a corporate environmental impact valuation, the process involves four steps: (1) data collection and management; (2) data pre-processing and verification; (3) application of the IWA valuation tool; (4) data outcomes analysis and interpretation. The IWA's general modelling framework utilizes data on corporate natural capital inputs to produce environmental outcomes, which are subsequently translated into economic impacts affecting diverse stakeholder groups. These impacts are quantified through monetary valuations, expressed in financial terms. Specifically, the monetary valuation of corporate environmental impacts involves translating firms' resource inputs into corresponding environmental emissions and resource depletion. These impacts are then monetized using life cycle assessment (LCA) methodologies, which estimate the economic value of environmental damage. By applying LCA across inputs, firms obtain a monetary valuation of their environmental footprint, reflecting both ecological and financial outcomes.

monetization data is reported by IWA firms. Appendix Table A1 and Table A2 present the distribution of observations by country and year, respectively. As shown in Table A1, Japan (18.48%) and the United States (15.23%) contribute the largest number of observations. In terms of temporal distribution, the sample is generally well balanced across the study period, though the earliest years (2010 and 2011) and the most recent year (2022) account for comparatively fewer observations. Each of these three years accounts for about two-thirds of the observations typically observed in the other years analyzed in this study.[7]

The selected firms represent the following industry sectors according to Thomson Reuters classification: academic and educational services (1.44%), basic materials (15.16%), consumer cyclical (16.49%), consumer noncyclical (10.58%), energy (5.24%), healthcare (5.08%), industrials (17.61%), real estate (6.41%), technology (16.89%), and utilities (5.10%). Financial firms (SIC 6000–6999) were excluded due to their regulated status and the distinct nature of their financial statements, which are incompatible with those of nonfinancial firms. Companies in technical bankruptcy or those with missing data for key variables were also excluded (Saona and San Martín 2016).

To complement the IWA dataset, we integrated financial and market-based information, including multiple ESG scores sourced from the Thomson Reuters Refinitiv Eikon platform. The latter variables are essential to address potential endogeneity associated with third omitted variables. In this vein, Zhao and Zhang (2024) reported that environmental and governance scores are negatively associated with leverage, suggesting that financial constraints may limit firms' ability to invest in those ESG dimensions. In addition, we incorporated country-level contextual variables obtained from the Structure and Development of the Financial Sector database, originally developed by Beck et al. (2000) and publicly available in its updated form from the World Bank.[8] As emphasized by Saona and San Martín (2018), value creation cannot be disentangled from the broader financial system in which firms operate. Including both firm- and country-level variables enables a more comprehensive analysis, capturing the influence of institutional and macro-financial factors, as suggested by Morey et al. (2009) and Öztekin (2022). Moreover, studies such as Claessens and Yurtoglu (2013), Gungoraydinoglu et al. (2017), or Saona et al. (2020) underline the interdependence between corporate governance, financial development, and firm value, noting that weak governance can undermine financial stability. Therefore, the inclusion of country-level drivers is essential to correctly identify the models and more accurately assess our environmentally adjusted measure of firm value. This approach ensures that the effects of firm-specific actions are interpreted within the appropriate institutional and financial context (Beck and Levine 2004; Çolak et al. 2018; Setia-Atmaja 2009).

The dependent variable in this study is the proposed environmental impact-adjusted firm value (*EIAFV*1), an enhanced metric which modifies the traditional Tobin's *Q* measure borrowed from macroeconomics by incorporating monetized environmental impact. Initially introduced by economist James Tobin, Tobin's *Q* is defined as the market value of a firm's assets divided by their replacement cost. Since this measure is typically unobservable to external analysts, finance and law literature often rely on proxy variables. In our study, Tobin's *Q* is approximated as the sum of the firm's market capitalization and total liabilities divided by total assets (Barlett and Partnoy 2020; Perfect and Wiles 1994). The environmental impact-adjusted firm value (*EIAFV*1) refines this proxy by incorporating the monetized environmental impact to the numerator. Specifically, *EIAFV*1 is computed as the sum of the firm's market capitalization, total liabilities, and the monetized environmental impact, divided by total assets. By design, the monetized environmental impact takes negative values when a firm's operations cause environmental harm, and positive values when they result in environmental benefits. Hence, the more negative this value, the greater the environmental damage, and vice versa. This adjusted firm value metric captures not only shareholder interests in risk-adjusted returns but also those of creditors, communities, and the environment. Because the monetized environmental impact enters the numerator, greater environmental harm directly lowers the firm's value.

For robustness, alternative metrics were employed, including the firm's market capitalization plus total financial debt plus monetization of environmental impact, divided by total assets (*EIAFV*2); the firm's market capitalization plus monetization of environmental impact, divided by total assets (*EIAFV*3); the firm's market capitalization plus monetization of environmental impact, divided by total common equity (*EIAFV*4); and the firm's market capitalization plus the debt, including preferred stocks and minority interests minus cash, short-term investments, and monetization of environmental impact, divided by total assets (*EIAFV*6). These variations ensure that the findings remain consistent across different environmental impact-adjusted firm value definitions. Finally, there is a measure only focused on the environmental impact computed as the monetization of the environmental impact over the company's total assets (*EIAFV*5). Unlike the previous metrics, *EIAFV*5 does not measure firm value but the externality caused to the environment by normal operating activities. This metric takes negative values as there is damage to the environment and positive values as there is no damage but a contribution to the environment. Table 1 supplies a description of all variables used in the study.

Leverage (*Lev*) was measured using the ratio of total financial debt to total assets. The analysis also included squared values of the leverage ratio to capture nonlinear relationships (Botta and Colombo 2022).

Control variables include firm size (*Size*), measured as the natural log of the firm's total assets (Frank and Goyal 2009); capital expenditure (*CAPEX*), defined as the percentage change in gross property, plant, and equipment (Choi and Park 2022); and asset tangibility (*Tangible*), used as a proxy of collateral, calculated as net property, plant, and equipment divided by total assets (Almeida and Campello 2007). Firm profitability (*ROA*) is measured as the net income divided by total assets (Öztekin 2015). Additionally, research and development expenses divided by revenues (*RDSales*) is also included as a control variable for research and development intensity, according to Yu et al. (2018). In order to prevent losing large amounts of information when missing values, we followed Greene (2003) using a modified zero-order regression method that codes 1 if the corresponding data is missing and

TABLE 1 | Descriptive statistics.

Acronym	Definition	Reference	Mean	Std. dev.	Min	p25	p50	p75	Max	Kurtosis	Skewness
EIAFV1	Environmental impact-adjusted firm value: (market capitalization +total liabilities + environmental impact) /total assets	Authors´ definition	1.431	0.793	0.016	0.963	1.194	1.670	8.092	10.999	2.232
EIAFV2	Environmental impact-adjusted firm value: (market capitalization +total debt + environmental impact) /total assets	Authors´ definition	1.125	0.790	−0.306	0.643	0.897	1.369	7.777	10.557	2.168
EIAFV3	Environmental impact-adjusted firm value: (market capitalization + environmental impact) /total assets	Authors´ definition	0.857	0.802	−0.580	0.354	0.628	1.125	7.569	9.998	2.084
EIAFV4	Environmental impact-adjusted firm value: (market capitalization + environmental impact) /total equity	Authors´ definition	2.451	4.028	−2.618	0.911	1.506	2.727	50.822	79.378	7.468
EIAFV5	Environmental impact: environmental impact/ total assets	Authors´ definition	−0.071	0.151	−1.133	−0.068	−0.017	−0.005	0.129	23.156	−4.040
EIAFV6	Environmental impact-adjusted firm value: (market capitalization + debt including preferred stocks and minority interest − cash and short-term investments + environmental impact)/total assets	Authors´ definition	1.020	0.808	−0.110	0.540	0.803	1.250	6.445	13.221	2.547
Size	Firm size: logarithmic transformation of the firm's total assets	Frank and Goyal (2009)	22.733	1.456	16.971	21.763	22.717	23.671	27.340	3.024	0.041
Lev	Leverage: total financial debt/total assets	Saona et al. (2014)	0.269	0.149	0.000	0.162	0.262	0.368	0.913	2.863	0.322

(Continues)

TABLE 1 | (Continued)

Acronym	Definition	Reference	Mean	Std. dev.	Min	p25	p50	p75	Max	Kurtosis	Skewness
Tangible	Tangible: gross property plant and equipment/total assets	Almeida and Campello (2007)	0.311	0.217	0.000	0.135	0.279	0.450	1.000	2.744	0.644
ROA	Profitability: net income/total assets		0.045	0.047	−0.212	0.021	0.042	0.068	0.243	5.471	0.079
ZScore	Default Risk: (1.2*working capital/total assets) + (1.4*retained earnings/total assets) + (0.6*market capitalization/total liabilities) + (0.999*sales/total assets) + (3.3*EBIT/total assets)	Altman (1968)	12.821	11.122	1.511	5.246	9.210	16.299	62.148	7.039	1.928
CAPEX	Capital expenditure: percentage change in gross property plant and equipment	Öztekin (2015)	0.049	0.037	0.000	0.023	0.041	0.066	0.230	5.879	1.448
R&DSales	Research and development: research and development expenditure/sales	Faccio and Xu (2015)	0.017	0.038	0.000	0.000	0.000	0.018	0.216	14.256	3.240
R&DSalesIndicator	Research and development: 1 if research and development expenditure exists and 0 otherwise	Faccio and Xu (2015)	0.419	0.493	0.000	0.000	0.000	1.000	1.000	1.108	0.329
MktCapGDP (%)	Structure and development of financial sector: market capitalization/GDP	Beck et al. (2000)	126.862	167.042	−203.396	67.377	104.622	137.688	1777.540	48.659	6.294
BankNIM (%)	Structure and development of financial sector: banks' net interest margin	Beck et al. (2000)	1.851	1.195	0.368	0.915	1.498	2.800	11.486	5.144	1.242
Spread (%)	Structure and development of financial sector: banks' lending-deposit spread	Beck et al. (2000)	3.025	4.910	−2.596	0.930	2.308	3.263	39.654	32.851	5.279

(Continues)

TABLE 1 | (Continued)

Acronym	Definition	Reference	Mean	Std. dev.	Min	p25	p50	p75	Max	Kurtosis	Skewness
BankCrisis	Structure and development of financial sector: 1 if banking crises and 0 otherwise	Beck et al. (2000)	0.071	0.245	−0.335	0.000	0.000	0.000	1.000	12.513	3.284
StockMktReturn (%)	Structure and development of financial sector: growth rate of annual average stock market index	Beck et al. (2000)	8.040	12.633	−40.490	0.000	6.559	16.913	114.265	4.105	0.583

Note: The variables used in the study are defined, their measures specified according to the primary references, and summary statistics (mean, standard deviation, minimum, and maximum) are reported.

0 otherwise. Empirically, this approach has been applied by Faccio and Xu (2015). Therefore, when research and development expenses are unavailable, missing values are replaced with 0. Consequently, to account for this data censoring, an indicator variable (*RDSalesIndicator*) is added to the regression, which takes a value of 1 when research and development expenditure data are missing and 0 if available.

Default risk was measured with the Altman (1968)'s Z-score, a widely recognized predictor of financial distress. The Z-score is calculated as $ZScore = 1.2WK + 1.4RE + 0.6MKBV + 0.999SALES + 3.3EBIT$; where *WK* is the company's working capital over total assets, *RE* is the retained earnings over total assets, *MKBV* is the market value of equity over the book value of total liabilities, *SALES* corresponds to the company's sales as a share of total assets, and *EBIT* is the earnings before interest and taxes over total assets. To align this measure with increasing default risk, we multiplied it by −1, making higher values indicative of greater risk (Altman et al. 2017; Habermann and Fischer 2023; Vivel-Búa et al. 2018). When appropriate, variables were winsorized at 0.5% or 1% to prevent outliers from biasing the results.[9]

To assess the broader financial environment in which firms operate, we incorporate a set of time-varying country-level variables in our robustness analysis that capture the development of both capital markets and the banking sector. O'Connor (2011) emphasize that both financial development as well as financial internationalization determine a firm's value; suggesting that an economy's financial deepening is value enhancing system, and consequently, financial development variables enter the model specifications. Specifically, we include market capitalization as a percentage of GDP (*MktCapGDP*), reflecting the relative size and depth of the equity market, which plays a key role in firm financing and valuation. Additionally, also on the market side, it is included the stock market return (*StockMktReturn*), defined as the year-on-year growth in the national stock index, to reflect market performance and investor sentiment. On the banking side, we use the net interest margin (*BankNIM*) and the lending-deposit spread (*Spread*) as indicators of banking sector efficiency and pricing behavior. *BankNIM* measures the net interest revenue as a share of average interest-bearing assets, while *Spread* captures the difference between lending and deposit rates, both of which influence credit conditions and financial intermediation and consequently the firm capacity to generate value. We also include a banking crisis dummy (*BankCrisis*) to account for systemic shocks that may distort firm valuations. Together, these variables provide a comprehensive view of financial sector development and dynamics which can drive firm value (O'Connor 2011; Saona and San Martín 2016). Their inclusion allows us to better understand how both market and banking-based financial structures influence the proposed environmentally adjusted firm value measure.

3.3 | Generalized Method of Moments System Estimator (GMM-SE) Approach

Our analysis begins with a linear exploration, followed by investigating whether an optimal leverage level maximizes firm value. Finally, we assess the leverage impact across the entire *EIAFV* distribution spectrum. No other study in this field offers such a comprehensive analysis of the leverage–firm value relationship.

The study employs the generalized method of moments system estimator (GMM-SE), as developed by Blundell and Bond (1998), an enhancement of the Arellano and Bond (1991) estimator. This method, with robust standard errors to address potential heteroskedasticity, is well-suited for addressing issues such as unobserved firm-specific heterogeneity, endogeneity of explanatory variables (see also Roberts and Whited (2013) for the specific issue of endogeneity in corporate finance data), and omitted variable bias (Windmeijer 2005).

While Adams (2016) recommends using instrumental variables or quasi-experimental techniques to mitigate endogeneity in variables that are not strictly exogenous (e.g., boardroom characteristics), identifying valid instruments remains a critical challenge. Valid instruments must correlate with endogenous variables but remain uncorrelated with both the dependent variable and error term (Antonakis et al. 2021). This challenge is further compounded by the unverifiable assumption that instruments and endogenous regressors are uncorrelated with the error term.

Despite these challenges, the GMM-SE approach is well validated in the literature for panel data. As highlighted by Barros et al. (2019), GMM-based models effectively address endogeneity by leveraging lagged values of independent variables as instruments. These instruments are both relevant and uncorrelated with the error term. Empirical comparisons by Barros et al. (2019), Kiviet et al. (2017), and Antonakis et al. (2021) demonstrate that GMM-SE delivers parameter estimates closer to true values than alternative panel regression methods. Consequently, this approach has been widely adopted in similar studies (e.g., Baum et al. 2003).

The baseline model, incorporating robust standard errors, is specified as:

$$EIAFV_{itcj} = \beta_0 + \beta_1 Lev_{itcj} + \beta_2 CV_{itcj} + \gamma_t + \delta_c + \theta_j + \varepsilon_{itcj} \quad (1)$$

where $EIAFV_{itcj}$ represents the environmental impact-adjusted firm value for a firm i in period t, country c, and industry j. Independent variables are as previously defined, where CV_{itcj} denotes control variables. The model incorporates time, country, and industry fixed effects, denoted as γ_t, δ_c, and θ_j, respectively, in addition to the individual firm effects and the stochastic error term, ε_{itcj} with the usual definition.

Several diagnostic tests are used. Given the absence of a specific specification test for the GMM-SE technique comparable to the Ramsey (1969) regression specification error test, a similar approach was employed. Fixed-effects panel regressions were augmented by adding powers of the predicted dependent and independent variables as covariates. None of the additional terms was jointly significant, supporting the absence of specification error.

Multicollinearity was assessed using the variance inflation factor (VIF), with a threshold of 4 adopted per O'Brien (2007). The D'Agostino et al. (1990) test was used to evaluate residual normality.[10] Although normality was rejected at the 1% level, this assumption is not strictly necessary for panel regression, particularly in large samples. This is because even if the error terms are not normally distributed, the estimated coefficients may still be normally distributed as long as the sample size is significant (Bailey 2017). With 14,238 firm-year observations across 2086 firms (averaging 6.82 observations per firm), the sample size exceeds the threshold of four observations per firm recommended by Baltagi (2013).

Instrument validity was confirmed through the Hansen test of overidentifying restrictions, which indicated no correlation between the instruments and omitted variables. The Arellano–Bond test for autocorrelation verified the absence of second-order serial autocorrelation (AR(2)), ensuring consistency in the GMM-SE estimations (Arellano and Bond 1991). While first-order serial autocorrelation (AR(1)) was detected, this does not compromise the validity of the results (Alonso-Borrego and Arellano 1999; Vallelado et al. 2017).

As outlined in Equation (1), the models include time, country, and individual fixed effects.

For nonlinear analysis, we extend the model to include squared leverage terms:

$$EIAFV_{itcj} = \beta_0 + \beta_1 Lev_{itcj} + \beta_2 Lev^2_{itcj} + \beta_2 CV_{itcj} + \gamma_t + \delta_c + \theta_j + \varepsilon_{itcj} \quad (2)$$

To confirm the existence of an inverse U-shaped relationship, we apply the Lind and Mehlum (2010) test, which identifies the extremum point of the function and provides its Fieller (1954) confidence interval.

3.4 | Quantile Panel Regression Approach

A further exploration in this study examines the impact of leverage on the extreme tails of the distribution of environmental impact-adjusted firm value (*EIAFV*). To achieve this, we employ quantile panel data regression. This novel econometric technique provides a more comprehensive understanding than traditional ordinary least squares (OLS) regressions, which focus solely on the relationship between independent variables and the conditional mean of the dependent variable. Prior research in capital structure has typically relied on standard linear regression methods that assume the average effect of leverage is constant across firms (Conyon and He 2017). In contrast, quantile regression captures the relationship between independent variables and any specified percentile of the dependent variable's conditional distribution, offering a more nuanced view.

Huarng and Yu (2014) emphasize the limitations of focusing exclusively on central tendencies, arguing that conditional mean models may overlook key patterns at noncentral locations in the response distribution. They note that "a set of quality-spaced conditional quantities can characterize the shape of the conditional distribution in addition to its central location." This approach enables granular analysis of leverage, revealing heterogeneity in effects across the firm value distribution, as emphasized by Armstrong et al. (2015).

For instance, Rios-Avila and Maroto (2024) demonstrate that quantile regression, coupled with controls for high-dimensional fixed effects, allows for more reliable causal interpretations by accounting for unobservable heterogeneity. In the present study, quantile regression complements the GMM-SE analysis, elucidating and allowing a granular understanding of how leverage influences the shape of the environmental impact-adjusted firm value distribution rather than merely shifting its central location.

Quantile regression offers several methodological advantages. It allows predictions at any percentile of the outcome variable's distribution (e.g., 10th, 25th, 50th, 75th, 90th percentiles), extending beyond the central tendency captured by OLS regression. This ensures that variations in the leverage are accurately assessed, minimizing the risk of misinterpreting their true impact on firm value.

Although this technique has been underutilized in business and finance research, there are notable applications in the literature. For example, Conyon and He (2017) examined the relationship between firm performance and boardroom gender diversity in US firms. They found that the presence of women directors disproportionately positively affected high-performing firms compared to low-performing ones. This finding illustrates how quantile regression reveals nonhomogeneous effects that standard regression methods might overlook. Similarly, Huarng and Yu (2014) employed a novel quantile information criterion (NQIC) to assess variable predictability, demonstrating how quantile regression provides richer insights and broader interpretative value than conventional mean regression. They argue that managers gain more actionable insights for decision-making through the nuanced understanding this technique provides.

The quantile regression method used in this study follows Machado and Santos Silva (2019), whose approach improves traditional quantile methods (e.g., bootstrap) by effectively handling panel data and accounting for individual effects. This advanced estimator ensures robust and precise quantile estimates, overcoming challenges inherent to standard regression techniques.

4 | Results

4.1 | Descriptive Statistics

Table 1 presents the construction and descriptive statistics of the variables. Several measures of environmental impact-adjusted firm value exhibit average values above unity (e.g., *EIAFV*1, *EIAFV*2, *EIAFV*4, and *EIAFV*6), suggesting a positive market perception. *EIAFV*3, the firm's market capitalization, adjusted by its environmental impact, shows an average value of 85.7% of its total assets. This figure reflects the extent to which a company's environmental impact reduces the market value of its stock. Similarly, *EIAFV*5 reveals that the average environmental impact amounts to 7.1% of total assets, indicating the scale of environmental damage relative to firm size. These observations emphasize the necessity of including potential negative environmental impacts when measuring firm value to comprehensively reflect the value generated by corporate activities.

The descriptive statistics also reveal that the average firm in the sample finances 26.9% of its investments with debt (*Lev*). Additionally, on average, more than 30% of total assets are fixed assets (*Tangible*).

The *ZScore*, which measures default risk, demonstrates that most firms in the sample operate within a safety zone with a low likelihood of bankruptcy. According to Altman (1968), a score below 1.81 signals a high bankruptcy risk, whereas a score above 2.99 indicates financial stability. The sample's average *ZScore* of 12.82 indicates a robust financial position, as higher scores correspond to lower bankruptcy risk.

Regarding investment in new physical assets, companies in the sample allocate approximately 5% of total assets to capital expenditures (*CapEx*), as reflected by the capital expenditure ratio. Similarly, research and development expenses account for about 1.7% of a firm's revenues.[11]

Table 2 presents the correlation matrix, showing no extreme correlations among the variables, except in one case: between *CapEx* and *Tangible*, where correlations slightly exceed 0.5. These moderate correlations suggest potential multicollinearity issues. However, the uncentered VIF test confirms that multicollinearity is not a concern, as all VIF values fall below the critical threshold of 4 according to O'Brien (2007). The table also shows a positive and statistically significant correlation between the monetized environmental impact metric (*EIAFV*5) and all other measures of environmental impact-adjusted firm value (*EIAFV*1 to *EIAFV*4 and *EIAFV*6). This suggests that as firms reduce their environmental externalities—reflected in higher *EIAFV*5 values—their adjusted firm value increases. This positive association stems from the construction of *EIAFV*5, which is designed to rise as a company's environmental impact declines. This variable takes negative values most of the cases and in just a few cases the value is positive, meaning that a company's operations do not produce a negative externality but a positive effect on the environment.

4.2 | Multivariate Analysis

4.2.1 | Linear and Nonlinear Relationship Between Leverage and Environmental Impact-Adjusted Firm Value

The multivariate analysis summarized in Table 3 examines the linear relationship between leverage and environmental impact-adjusted firm value. The first five models, which include alternative measures of *EIAFV*, show a positive and statistically significant relationship with the *Lev* variable after controlling for company size (*Size*), asset tangibility (*Tangible*), profitability (*ROA*), default risk (*ZScore*), capital expenditures (*CapEx*), and research and development expenses (*RDSales*). This finding suggests that firm value also rises as financial debt relative to total assets increases. For instance, in Model 1, a one-standard deviation increase in leverage (0.149) leads to an increase in *EIAFV*1 by 0.345, equivalent to 24.09% of its mean value, *ceteris*

TABLE 2 | Correlation matrix.

	EIAFV1	EIAFV2	EIAFV3	EIAFV4	EIAFV5	EIAFV6	Lev	Size	Tangible	ROA	ZScore	CAPEX	RDSales
EIAFV1	1.000												
EIAFV2	0.985***	1.000											
EIAFV3	0.976***	0.982***	1.000										
EIAFV4	0.757***	0.727***	0.685***	1.000									
EIAFV5	0.242***	0.232***	0.243***	0.188***	1.000								
EIAFV6	0.910***	0.928***	0.901***	0.676***	0.219***	1.000							
Lev	−0.055***	−0.006	−0.196***	0.144***	−0.081***	0.049***	1.000						
Size	−0.102***	−0.131***	−0.162***	−0.035***	0.001	−0.103***	0.178***	1.000					
Tangible	−0.114***	−0.085***	−0.103***	−0.074***	−0.235***	−0.055***	0.101***	−0.003	1.000				
ROA	0.485***	0.490***	0.525***	0.309***	0.003	0.471***	−0.236***	−0.058***	−0.069***	1.000			
ZScore	0.732***	0.768***	0.839***	0.379***	0.078***	0.685***	−0.450***	−0.248***	−0.053***	0.527***	1.000		
CAPEX	0.022**	0.033***	0.029***	0.002	−0.130***	0.046***	0.0158	0.0104	0.535***	0.084***	0.058***	1.000	
R&DSales	0.206***	0.212***	0.238***	0.122***	0.127***	0.171***	−0.162***	0.073***	−0.134***	0.044***	0.251***	−0.009	1.000
R&DSalesIndiccator	0.004	0.006	0.041***	−0.034***	0.029***	−0.021*	−0.184***	0.011	0.036***	0.004	0.112***	0.077***	0.537***

Note: This table reports the pairwise Pearson correlations between variables used in the following study. We noticed that our different measures of firm values are strongly correlated, suggesting that they tend to capture the same underlying dimension of a firm's value.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

TABLE 3 | Panel data linear regression model.

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	**EIAFV1**	**EIAFV2**	**EIAFV3**	**EIAFV4**	**EIAFV6**	**EIAFV5**
Lev	2.314***	2.592***	1.596***	9.856***	1.964***	0.026*
	(24.174)	(31.531)	(19.394)	(17.888)	(18.107)	(1.889)
Size	0.027*	0.015	0.015	−0.041	−0.004	0.004*
	(1.747)	(1.150)	(1.101)	(−0.501)	(−0.206)	(1.682)
Tangible	−0.123*	−0.117*	−0.123*	−0.298	0.019	−0.053***
	(−1.652)	(−1.843)	(−1.934)	(−0.753)	(0.218)	(−4.078)
ROA	0.434***	0.282***	0.271***	2.046***	1.192***	−0.005
	(4.482)	(3.323)	(3.198)	(4.121)	(10.070)	(−0.462)
ZScore	0.074***	0.076***	0.076***	0.163***	0.052***	0.000
	(69.321)	(76.042)	(76.077)	(32.204)	(37.735)	(1.445)
CAPEX	0.366**	0.283**	0.277**	2.291***	0.369**	0.003
	(2.507)	(2.167)	(2.120)	(3.041)	(2.198)	(0.137)
RDSales	3.188***	3.183***	3.153***	10.413***	4.856***	0.396***
	(4.311)	(4.923)	(4.869)	(2.580)	(4.927)	(3.386)
RDSalesIndicator	−0.162***	−0.125**	−0.121**	−0.326	−0.187***	−0.018**
	(−2.691)	(−2.456)	(−2.378)	(−1.049)	(−2.833)	(−2.023)
Constant	−0.727**	−0.869***	−0.855***	−1.767	−0.193	−0.140**
	(−2.087)	(−2.877)	(−2.826)	(−0.967)	(−0.455)	(−2.320)
Observations	14,238	14,238	14,238	14,237	13,572	14,238
Number of iden	2086	2086	2086	2086	2086	2086
Industry dummy	YES	YES	YES	YES	YES	YES
Country dummy	YES	YES	YES	YES	YES	YES
Year dummy	YES	YES	YES	YES	YES	YES
Instruments	271	271	271	271	271	271
Avrg. obs. per group	6.826	6.825	6.826	6.825	6.826	6.825
AR(1)	−6.009	−5.644	−5.646	−1.074	−10.45	−2.112
p value	0.000	0.000	0.000	0.283	0.000	0.225
AR(2)	−1.534	−1.615	−1.621	0.372	−4.353	−0.138
p value	0.125	0.106	0.105	0.710	0.201	0.347
Hansen	430.3	452	452.3	336	438.6	312.4
F test	797.6	998.1	942.9	167.6	316.1	5.909

Note: Columns include different specifications for the dependent variables and the corresponding independent variables as described in Table 1. *EIAFV1* is calculated as (market capitalization + total liabilities + environmental impact)/total assets; *EIAFV2* is calculated as (market capitalization + total debt + environmental impact)/total assets; *EIAFV3* is calculated as (market capitalization + environmental impact)/total assets; *EIAFV4* is calculated as (market capitalization + environmental impact)/total equity; *EIAFV5* is calculated as environmental impact/total assets; *EIAFV6* is calculated as (market capitalization + debt including preferred stocks and minority interest − cash and short-term investments + environmental impact)/total assets. The estimation method is based on the generalized method of moments with robust standard errors (GMM-SE) and t-statistics are in parentheses. Industry, country, and year dummies are included in all specifications. Instruments refer to the number of instruments used in the system GMM. Arellano–Bond AR(1) and AR(2) is an autocorrelation test of first and second order, respectively, using residuals in differences, asymptotically distributes as an N(0.1) and under the null hypothesis of no autocorrelation. Although AR(1) is expected in first differences, it does not invalidate the results. Hansen test is a contrast of overidentifying restrictions or whether the instruments, as a group, appear exogenous, asymptotically distributed as a X^2 and robust to heteroskedasticity. Endogenous variables were instrumentalized with up to 3 years lagged according to Jara et al. (2008), and the number of instruments were kept below the number of cross-sections as suggested by Roodman (2009). *F* test contrasts the joint nullity of the estimated parameters.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

paribus.[12] This represents an economically significant result. Similar findings are observed across the other four models, with all estimated parameters statistically significant at the 1% confidence level, confirming the robustness of our measure of firm value.

In contrast, the last model in Table 3 does not measure firm value but monetizes environmental impact as a share of total assets. Here, by construction, the way to read the variable is that it increases in value as environmental damage decreases. The estimated coefficient of 0.026 for *Lev* is significant at the 10% level (p value = 0.059), indicating that higher leverage is associated with lower environmental impact. This suggests creditors monitor corporate operations, granting loans to firms with more sustainable practices and lower negative environmental impacts. This observation aligns with earlier findings where adjusted firm value increases through the dual mechanisms of debt as a monitoring tool and tax deductions on interest payments (Botta and Colombo 2022). In this respect Khanchel and Lassoued (2022) find strong evidence that environmental disclosure is negatively associated with the cost of capital, implying that higher leverage degree due to low cost of capital is possible for companies with low environmental impact.

Regarding the control variables, little evidence is found to suggest that firm size (*Size*) significantly affects adjusted firm value, as observed in the first model. Likewise, the last model, which measures monetized environmental impact (*EIAFV*5), shows that larger firms tend to have lower monetized environmental impacts. This could be attributed to larger firms facing stricter regulatory constraints and accounting with the necessary capital to invest in sustainable projects that reduce their environmental footprint.

The results also show that physical assets (*Tangible*) are not a significant source of firm value, as evidenced by the negative estimated coefficients in the first three models. In contrast, profitability (*ROA*) has a positive and statistically significant effect on adjusted firm value, consistent with existing literature that associates profitability with higher firm value. Similarly, lower default risk, reflected by higher *ZScore*, is associated with increased firm value across various *EIAFV* metrics. Capital expenditure (*CapEx*) is also positively correlated with improvements in adjusted firm value, as shown in the first 5 models of the table. Furthermore, research and development expenses (*RDSales*) significantly influence multiple metrics of adjusted firm value. On the one hand, investment in intangible assets, such as research and development, enhances firm value, as evidenced in the first five models. On the other hand, it also reduces the monetized environmental impact (*EIAFV*5), as demonstrated in the last model.

The results further suggest that monetized environmental impact decreases as firms rely more on debt but increases with higher asset tangibility. In other words, companies operating with a greater proportion of physical capital relative to total assets tend to cause a more significant negative environmental impact.

The subsequent part of the analysis explores the nonlinear relationship between leverage and adjusted firm value, as presented in Table 4. The key parameters are the coefficients for *Lev* and Lev^2. In the first five models, *Lev* has a positive and statistically significant coefficient, while Lev^2 has a negative and statistically significant coefficient—except in Model 4 in which the coefficient of the squared variable is not significant. This establishes a non-monotonic, inverse U-shaped relationship between leverage and adjusted firm value. The firm value increases with leverage up to an optimal point, beyond which further increases in leverage lead to value erosion. This result aligns with the trade-off theory, which posits that firms initially benefit from tax deductions and creditor monitoring at low debt levels. However, default risk and financial distress costs at higher debt levels outweigh these benefits, reducing firm value.

The Lind–Mehlum test, applied to identify the extreme point of leverage where *EIAFV*1 is maximized, indicates that the optimal leverage ratio (*Lev*) is 61.3%. The null hypothesis of a monotonic or U-shaped relationship is rejected at the 1% confidence level (p value = 0.000). The Fieller confidence intervals further confirm that, with 95% confidence, this extreme point lies between a debt level of 54.70% and 72.20% of total assets. The analysis also reveals that the average slope at the lower bound is positive (4.644), while it is negative (−2.508) at the upper bound, with both slopes statistically significant. This analysis provides robustness to the nonlinear relationship between *EIAFV*1 and *Lev*.

Model 4, which uses *EIAFV*4 (market capitalization minus environmental impact divided by total equity) as the dependent variable, does not exhibit the expected umbrella-shaped relationship with *Lev*. The extreme point lies outside the observed range of *Lev*, making the test results trivial in this case. Nevertheless, the other models (2, 3, and 5) in the table provide consistent results. For instance, the optimal leverage ratios for maximizing *EIAFV*2, *EIAFV*3, and *EIAFV*6 are 64.40%, 51.20%, and 49.20%, respectively, lending robustness to our findings, as exhibited at the bottom of the table.

Figure 2 provides a graphical representation of Model 1 from Table 4, illustrating the relationship between *Lev* and *EIAFV*1. The plot shows that most firms in the sample operate at leverage levels below the optimal range, indicating significant potential for these firms to use debt more effectively to maximize their adjusted firm value.

The sixth model in Table 4 examines the relationship between leverage and monetized environmental impact *EIAFV*5, which increases in value as the environmental harm decreases. A U-shaped relationship is observed (p value = 0.014), as shown in Figure 3, where the null hypothesis is a monotone or inverse U-shaped relationship. At debt levels below 27.70% of total assets, an increase in debt correlates with greater environmental harm, reflecting higher external damages caused by the firm's activities. Beyond this threshold, however, higher leverage reduces negative environmental impacts. These findings suggest that most firms operate at or near this critical threshold (as the average leverage ratio, *Lev*, is 26.90%, according to Table 1), indicating considerable potential for reducing environmental damage through strategic debt structuring. The benefits arise from creditor scrutiny and tax deductions, further reinforcing

TABLE 4 | Panel data nonlinear regression model.

Variables	(1) EIAFV1	(2) EIAFV2	(3) EIAFV3	(4) EIAFV4	(5) EIAFV6	(6) EIAFV5	(7) FV1
Lev	4.644***	4.868***	3.877***	9.993***	4.995***	−0.220**	4.781***
	(14.632)	(17.290)	(13.734)	(5.752)	(12.644)	(−2.191)	(15.770)
Lev^2	−3.787***	−3.781***	−3.783***	−0.322	−5.072***	0.396**	−4.260***
	(−7.666)	(−8.611)	(−8.601)	(−0.109)	(−8.064)	(2.538)	(−9.036)
Size	0.012	−0.000	−0.001	−0.033	−0.026	0.021***	0.002
	(0.800)	(−0.029)	(−0.106)	(−0.406)	(−1.390)	(3.779)	(0.143)
Tangible	−0.113	−0.093	−0.102*	−0.267	0.105	−0.038*	0.018
	(−1.600)	(−1.536)	(−1.683)	(−0.664)	(1.184)	(−1.728)	(0.285)
ROA	0.441***	0.283***	0.273***	2.053***	1.102***	−0.081*	0.393***
	(4.753)	(3.483)	(3.360)	(4.086)	(9.554)	(−1.672)	(4.640)
ZScore	0.075***	0.077***	0.077***	0.162***	0.054***	0.000	0.075***
	(72.117)	(78.840)	(78.921)	(32.014)	(37.919)	(0.467)	(79.163)
CAPEX	0.208	0.121	0.112	2.366***	0.414**	−0.007	0.281**
	(1.489)	(0.987)	(0.909)	(3.102)	(2.557)	(−0.161)	(2.219)
RDSales	2.913***	2.780***	2.722***	11.742***	4.192***	0.279	1.804***
	(3.977)	(4.352)	(4.254)	(2.856)	(4.243)	(0.952)	(2.754)
RDSalesIndicator	−0.108*	−0.078	−0.073	−0.393	−0.148**	−0.043**	−0.092*
	(−1.859)	(−1.604)	(−1.491)	(−1.241)	(−2.245)	(−2.200)	(−1.764)
Constant	−0.686**	−0.796***	−0.774***	−1.937	−0.078	−0.485***	−0.411
	(−2.062)	(−2.761)	(−2.682)	(−1.053)	(−0.183)	(−3.874)	(−1.348)
Observations	14,238	14,238	14,238	14,237	13,572	14,238	14,238
Number of iden	2086	2086	2086	2086	1986	2086	2086
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Instruments	271	271	271	271	271	271	271
Avrg. obs. per group	6.826	6.826	6.826	6.825	6.834	6.826	6.826
AR(1)	−6.349	−6.116	−6.125	−1.075	−10.42	−2.240	−6.033
p value	0.000	0.000	0.085	0.282	0.000	0.244	0.000
AR(2)	−1.575	−1.600	−1.422	0.370	−1.339	−1.166	−1.326
p value	0.115	0.289	0.184	0.711	0.166	0.125	0.185
Hansen	435	456.2	457.5	339.6	424.1	149.2	449.6
F test	644.5	789.1	773.4	132	244.8	3.671	766.6
Extreme point	0.613	0.644	0.512	15.530	0.492	0.277	0.561
H0: Monotone or U shape (*p* value)	0.000	0.000	0.000	Trivial Rjct	0.000	0.014	0.000
95% Fieller	0.547	0.578	0.498	—	0.450	0.103	0.512
95% Fieller	0.722	0.746	0.577	—	0.559	0.369	0.635

(Continues)

TABLE 4 | (Continued)

Variables	(1) EIAFV1	(2) EIAFV2	(3) EIAFV3	(4) EIAFV4	(5) EIAFV6	(6) EIAFV5	(7) FV1
Slope lower bound	4.644	4.868	3.877	—	4.995	−0.220	4.781
p value	0.000	0.000	0.000	—	0.000	0.143	0.000
Slope upper bound	−2.508	−2.274	−3.269	—	−4.585	0.529	−3.265
p value	0.000	0.000	0.000	—	0.000	0.004	0.000

Note: Columns include different specifications for the dependent variables and the corresponding independent variables as described in Table 1. *EIAFV1* is calculated as (market capitalization + total liabilities + environmental impact)/total assets; *EIAFV2* is calculated as (market capitalization + total debt + environmental impact)/total assets; *EIAFV3* is calculated as (market capitalization + environmental impact)/total assets; *EIAFV4* is calculated as (market capitalization + environmental impact)/total equity; *EIAFV5* is calculated as environmental impact/total assets; *EIAFV6* is calculated as (market capitalization + debt including preferred stocks & minority interest—cash and short-term investments + environmental impact)/total assets; *FV1* is calculated as (market capitalization + total debt) /Total Assets. The estimation method is based on the generalized method of moments with robust standard errors (GMM-SE) and t-statistics are in parentheses. Industry, country, and year dummies are included in all specifications. Instruments refer to the number of instruments used in the system GMM. Arellano–Bond AR(1) and AR(2) is an autocorrelation test of first and second order, respectively, using residuals in differences, asymptotically distributes as an N(0.1) and under the null hypothesis of no autocorrelation. Although AR(1) is expected in first differences, it does not invalidate the results. Hansen test is a contrast of overidentifying restrictions or whether the instruments, as a group, appear exogenous, asymptotically distributed as a X^2 and robust to heteroskedasticity. Endogenous variables were instrumentalized with up to 3 years lagged according to Jara et al. (2008), and the number of instruments were kept below the number of cross-sections as suggested by Roodman (2009). *F*-test contrasts the joint nullity of the estimated parameters. Nonlinearity of *Lev* is assessed with the Lind–Mehlum test that provides the exact test of the presence of a Monotone or U-shaped (or inverse U-shaped) relationship on an interval. The Fieller (1954) confidence interval was used to find the interval for the extreme point. Slopes in lower and upper bounds of *Lev* are reported as well as the testing of the null hypothesis that such slopes individually are equal to 0.

***$p < 0.01$.

**$p < 0.05$.

*$p < 0.1$.

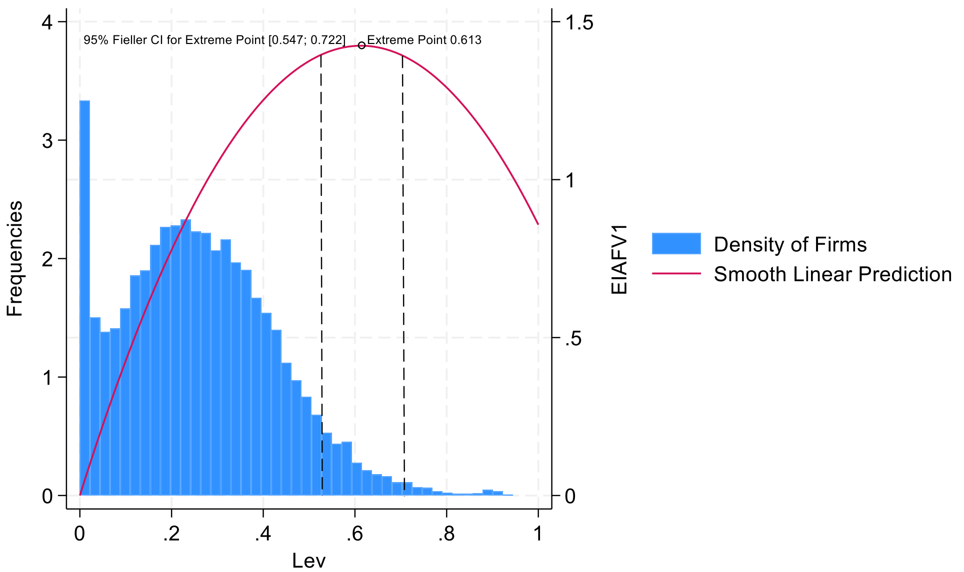

FIGURE 2 | First model in Table 4. The figure illustrates the graphical representation of the first model in Table 4. *EIAFV1* is determined as (market capitalization + total liabilities + environmental impact)/total assets. *Lev* is determined as total financial debt/total assets. The figure includes the histogram of *Lev* variable, the smoothed linear prediction of the first model in Table 4, the extreme point of *Lev* at which *EIAFV1* is maximized, and the Fieller (1954) confidence interval at 95% confidence level.

the linear modelling explains partially the relationship between leverage and firm value.

The last model reported in Table 4 uses the traditional, unadjusted Tobin's *Q* as the dependent variable (*FV1*), defined as the sum of market capitalization and corporate debt divided by total assets. This model is compared with the first one in the table, which employs the firm value measure adjusted for environmental impact (*EIAFV1*). The results show that both models exhibit an inverted U-shaped relationship between firm value and leverage. However, the optimal leverage point differs: it occurs at 56.10% in the unadjusted model versus 61.30% in the environmentally adjusted one. This suggests that incorporating environmental impact shifts the optimal debt level upward. This particular finding indicates that, at low to moderate levels of debt, shareholders are incentivized to engage in environmental risk-taking by reducing environmental compliance-related expenditures. However, as leverage increases, creditors begin to view environmental risks as a serious threat to their claims and respond by enforcing stricter covenants and higher environmental standards, as suggested by Albuquerque et al. (2019). As a result, firms are encouraged to finance more sustainable

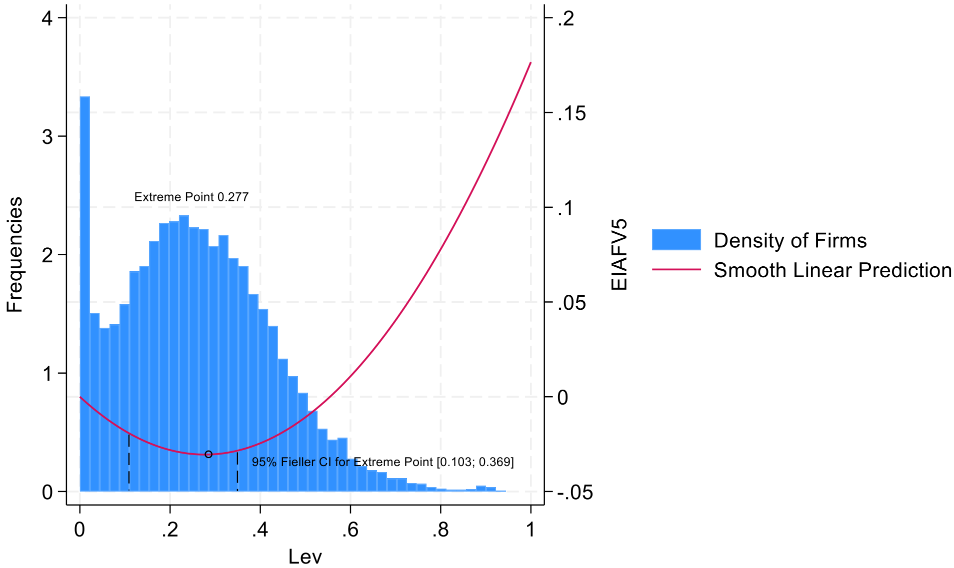

FIGURE 3 | Sixth model in Table 4. The figure illustrates the graphical representation of the sixth model in Table 4. *EIAFV5* is determined as environmental impact/total assets. *Lev* is determined as total financial debt/total assets. The figure includes the histogram of *Lev* variable, the smoothed linear prediction of the sixth model in Table 4, the extreme point of *Lev* at which *EIAFV5* is minimized, and the Fieller (1954) confidence interval at 95% confidence level.

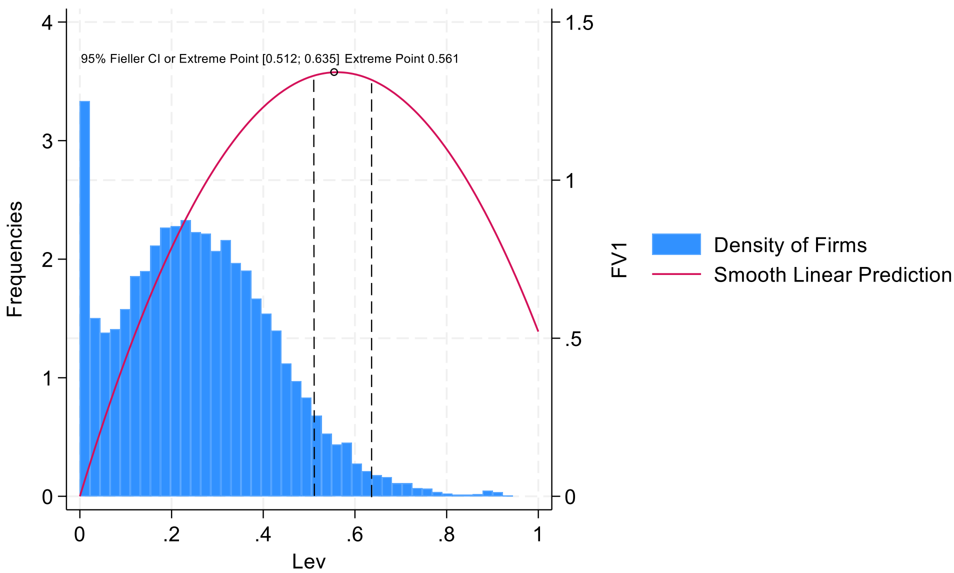

FIGURE 4 | Seventh model in Table 4. The figure illustrates the graphical representation of the seventh model in Table 4. *FV1* is the unadjusted Tobin's *Q* defined as the sum of market capitalization and corporate debt divided by total assets. *Lev* is determined as total financial debt/total assets. The figure includes the histogram of *Lev* variable, the smoothed linear prediction of the seventh model in Table 4, the extreme point of *Lev* at which *FV1* is maximized, and the Fieller (1954) confidence interval at 95% confidence level.

projects, which enhances their value and increases their capacity to borrow further, provided the environmental costs remain low. Figure 4 shows a graphical representation of the last model reported in Table 4.

4.2.2 | Quantile Panel Regressions

We employed a novel quantile panel regression approach developed by Machado and Santos Silva (2019) to further investigate the relationship between leverage and environmental impact-adjusted firm value. This method allows us to examine how leverage affects firm value across different points in the distribution of the dependent variable, which is particularly valuable when the variable is not normally distributed. As shown in Table 1, all measures of impact-adjusted firm value exhibit significant deviations from normality, indicated by skewness values different from 0 and kurtosis values well above 3. Although not reported for brevity, normality tests were conducted and consistently rejected the null hypothesis of normality across all variables.

For comparison, we also estimated the pooled regressions. Unlike quantile panel regressions, pooled regressions focus only on the relationship between independent variables and the

TABLE 5 | Panel quantile regressions.

	Panel A						Panel B					
	Pool	(1)	(2)	(3)	(4)	(5)	Pool	(6)	(7)	(8)	(9)	(10)
Variables	**EIAFV1**	**EIAFV1Q10**	**EIAFV1Q25**	**EIAFV1Q50**	**EIAFV1Q75**	**EIAFV1Q90**	**EIAFV6**	**EIAFV6Q10**	**EIAFV6Q25**	**EIAFV6Q50**	**EIAFV6Q75**	**EIAFV6Q90**
Lev	1.845***	1.790***	1.873***	1.988***	2.108***	2.194***	2.363***	1.668***	1.753***	1.875***	2.004***	2.097***
	(60.844)	(5.938)	(8.336)	(15.557)	(25.277)	(16.869)	(69.907)	(9.932)	(16.331)	(10.805)	(6.200)	(4.777)
Size	0.025***	−0.066	−0.056	−0.042	−0.027	−0.017	0.009***	−0.017	−0.004	0.015	0.035	0.050
	(8.698)	(−1.038)	(−1.180)	(−1.563)	(−1.573)	(−0.627)	(2.879)	(−0.433)	(−0.158)	(0.359)	(0.454)	(0.472)
Tangible	−0.332***	−0.106	−0.085	−0.056	−0.025	−0.003	−0.166***	0.092	0.112	0.141	0.171	0.193
	(−14.990)	(−0.424)	(−0.454)	(−0.523)	(−0.360)	(−0.027)	(−6.650)	(0.649)	(1.235)	(0.957)	(0.624)	(0.518)
ROA	2.274***	0.799	0.761**	0.708***	0.653***	0.613***	2.446***	1.244***	1.286***	1.345***	1.408**	1.454*
	(22.461)	(1.574)	(2.010)	(3.291)	(4.653)	(2.800)	(21.749)	(4.105)	(6.639)	(4.296)	(2.414)	(1.835)
ZScore	0.056***	0.050***	0.054***	0.059***	0.065***	0.068***	0.055***	0.038***	0.042***	0.047***	0.053***	0.057***
	(116.812)	(11.461)	(16.513)	(31.682)	(52.737)	(35.981)	(102.560)	(14.168)	(24.271)	(16.949)	(10.202)	(8.087)
CAPEX	0.400***	0.845	0.794*	0.723***	0.648***	0.595**	0.296**	0.884**	0.826***	0.743*	0.656	0.592
	(3.108)	(1.335)	(1.682)	(2.694)	(3.707)	(2.179)	(2.073)	(2.310)	(3.377)	(1.880)	(0.890)	(0.592)
RDSales	1.556***	−0.412	−0.543	−0.724	−0.912**	−1.048	1.354***	−0.265	−0.303	−0.356	−0.412	−0.453
	(11.710)	(−0.263)	(−0.465)	(−1.090)	(−2.107)	(−1.551)	(9.330)	(−0.265)	(−0.473)	(−0.344)	(−0.214)	(−0.173)
RDSalesIndicator	−0.098***	0.002	0.001	0.000	−0.001	−0.001	−0.111***	−0.001	−0.002	−0.003	−0.004	−0.005
	(−10.011)	(0.023)	(0.020)	(0.009)	(−0.028)	(−0.037)	(−10.304)	(−0.025)	(−0.067)	(−0.065)	(−0.049)	(−0.043)
Constant	−0.361***						−0.578***					
	(−5.406)						(−7.778)					
Observations	14,403	14,403	14,403	14,403	14,403	14,403	13,572	13,572	13,572	13,572	13,572	13,572
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.643						0.600					

Note: Columns from (1) to (5) and from (6) to (10) are considered dependent variables in the 10th, 25th, 50th, 75th, and 90th quantiles of *EIAFV1* (Panel A) and *EIAFV6* (Panel B), respectively. Columns marked as Pool reported the pooled estimation for *EIAFV1* and *EIAFV6*. *t* Tests are shown in parenthesis. Industry, country, and year dummies are included in all models. All estimations but Pool are based on panel quantile regressions according to Machado and Santos Silva (2019)'s approach.
***$p<0.01$.
**$p<0.05$.
*$p<0.1$.

conditional mean of the dependent variable. Moreover, they do not account for unobservable individual heterogeneity across firms, making pooled models more susceptible to biased results. The findings from these analyses are presented in Table 5. Panels A and B use *EIAFV*1 and *EIAFV*6 as dependent variables, respectively, and report results for these variables' 10th, 25th, 50th, 75th, and 90th quantiles.

Across all quantiles and both panels, the *Lev* variable exhibits a statistically significant coefficient at the 95% confidence level. Furthermore, these coefficients increase progressively from the 10th to the 90th quantile. For example, in Panel A, the coefficient for *Lev* rises from 1.790 at the 10th quantile to 2.194 at the 90th quantile of *EIAFV*1. This is a particularly appealing result, as it demonstrates that the effect of leverage on firm value is not uniform across the distribution. Instead, firm value responds more strongly to marginal increases in leverage at higher levels of adjusted firm value compared to lower levels.

When compared to the pooled regression results in the first column of Panel A, the limitations of the pooled model become evident. The pooled regression indicates that *Lev* has a marginal effect of 1.845 on the conditional mean of *EIAFV*1. However, this average effect fails to capture the variations in leverage's impact across different quantiles, emphasizing the limitations of pooled models in identifying patterns outside the central tendencies of the dependent variable's distribution.

Figure 5, Panel A, offers a graphical representation of these results. It illustrates the behavior of *Lev*'s impact on *EIAFV*1 across different quantiles. The dark blue line represents the estimated impact of *Lev*, showing a clear upward trend as the quantiles of the dependent variable increase. The light blue shaded region denotes the confidence intervals, which are consistently above 0, confirming the statistical significance of *Lev* at all quantiles of *EIAFV*1. Additionally, the continuous black line represents the pooled regression result, capturing the conditional mean impact of *Lev* on *EIAFV*1 at 1.845, as previously discussed. The graph further highlights the advantages of quantile regression, which provides richer insights into the heterogeneity of leverage's effects compared to the pooled model.

The findings also extend to other control variables. Particularly, a company's default risk (*ZScore*) has the most significant impact on firms with relatively high environmental-adjusted firm value. In these cases, when default risk decreases, firms with higher adjusted firm value experience a greater increase in firm value than firms with lower adjusted firm value.

Panel B of Table 5 and Panel B of Figure 4 are included to ensure the robustness of the results. While there is some loss of significance for certain control variables at specific quantiles (e.g., *ROA* and *CapEx*), the main findings concerning the impact of *Lev* the adjusted firm value remains qualitatively and quantitatively consistent with those observed in Panel A of the table.

4.2.3 | Nonlinear Relationship Between Leverage and Environmental Impact-Adjusted Firm Value Controlled by Contextual Variables

The final part of the robustness analysis introduces contextual variables at the country level. While country-level, time-invariant effects were already accounted for in the baseline estimations, concerns remain regarding time-varying, country-specific dynamics that could influence firm valuation. This issue has been raised in prior literature, including O'Connor (2011), Saona and San Martín (2018), and more recently by Cai et al. (2024). To address this, we re-estimate the core model presented in Table 4 by introducing a set of country-level financial development indicators that may shape the environmental impact-adjusted firm value. These variables include market capitalization as a percentage of the country's GDP (*MktCapGDP*); banks' net interest margin (*BankNIM*); the bank lending-deposit spread (*Spread*); a banking crisis dummy (*BankCrisis*), which equals 1 during a banking crisis and 0 otherwise; and the stock market return year-on-year in percentage terms (*StockMktReturn*). Results from the augmented Model 1 are presented in Table 6, while estimates for the other models, omitted for brevity, remain qualitatively and quantitatively consistent with those in Table 4.

A significant reduction in the number of observations is observed in Table 6 compared to Table 4. This is primarily due

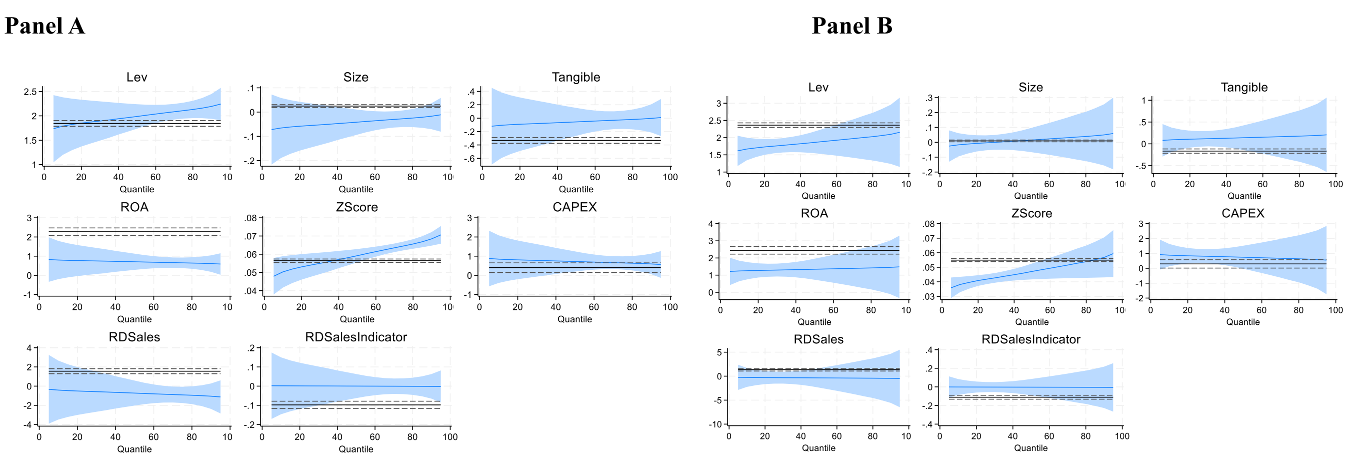

FIGURE 5 | Models for Table 5. The figure illustrates the graphical representation of Panels A and B reported in Table 5. For each variable, the dark blue line represents the estimated impact of the variable on the measure of EIAFV. The light blue region denotes the confidence intervals, the black color lines represent the pooled regression results, whereas the dashed lines indicate their confidence intervals.

TABLE 6 | Panel data nonlinear regression model with contextual variables.

Variables	(1) EIAFV1	(3) EIAFV1	(4) EIAFV1	(7) EIAFV1	(8) EIAFV1
Lev	4.936***	4.652***	4.283***	5.103***	4.479***
	(13.368)	(13.769)	(18.774)	(9.213)	(14.029)
Lev^2	−4.586***	−3.679***	−3.737***	−4.816***	−3.439***
	(−7.844)	(−7.106)	(−11.066)	(−5.137)	(−7.086)
Size	−0.057***	0.007	−0.014	0.024	−0.015
	(−2.860)	(0.413)	(−0.867)	(1.203)	(−0.933)
Tangible	−0.070	−0.025	−0.405***	−0.252**	−0.017
	(−0.847)	(−0.300)	(−5.395)	(−2.484)	(−0.238)
ROA	0.629***	0.526***	0.889***	0.809***	0.433***
	(5.674)	(5.354)	(8.877)	(4.941)	(4.745)
ZScore	0.069***	0.074***	0.061***	0.072***	0.074***
	(47.454)	(67.359)	(58.035)	(47.805)	(62.043)
CAPEX	0.472***	0.332**	0.159	0.199	0.381**
	(2.688)	(2.232)	(1.005)	(1.001)	(2.407)
RDSales	4.245***	3.470***	3.259***	1.732*	3.735***
	(5.342)	(4.242)	(4.377)	(1.698)	(5.142)
RDSalesIndicator	−0.131**	−0.131**	−0.181***	0.010	−0.169***
	(−2.224)	(−2.126)	(−4.061)	(0.134)	(−3.195)
MktCapGDP	0.001***				
	(6.594)				
BankNIM		−0.023*			
		(−1.900)			
Spread			−0.001		
			(−0.419)		
BankCrisis				−0.089***	
				(−4.380)	
StockMktReturn					0.001***
					(5.454)
Constant	0.818*	−0.561	0.231	−0.947**	−0.069
	(1.808)	(−1.576)	(0.631)	(−2.135)	(−0.189)
Observations	10,287	13,731	4884	9023	12,836
Number of iden	1855	2003	899	1893	1834
Industry dummy	Yes	Yes	Yes	Yes	Yes
Country dummy	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes
Instruments	226	271	226	151	271
Avrg. obs. per group	5.546	6.855	5.433	4.767	6.999

(Continues)

TABLE 6 | (Continued)

Variables	(1) EIAFV1	(3) EIAFV1	(4) EIAFV1	(7) EIAFV1	(8) EIAFV1
AR(1)	−4.948	−6.525	−3.958	−3.707	−6.180
p value	0.000	0.144	0.000	0.230	0.000
AR(2)	−1.038	−1.462	0.688	−1.200	−1.321
p value	0.299	0.678	0.492	0.210	0.186
Hansen	276.7	425.6	269.9	183.4	408.9
F-test	2396	2843	2135	2447	2955
Extreme point	0.538	0.632	0.573	0.530	0.651
H0: Monotone or U shape (*p* value)	0.000	0.000	0.000	0.001	0.001
95% Fieller	0.485	0.558	0.527	0.458	0.574
95% Fieller	0.623	0.759	0.636	0.685	0.784
Slope lower bound	4.936	4.652	4.283	5.103	4.479
p value	0.000	0.000	0.000	0.000	0.000
Slope upper bound	−3.726	−2.296	−2.776	−3.993	−2.016
p value	0.000	0.000	0.000	0.001	0.001

Note: Columns include different specifications for *EIAFV*1 as dependent variable, the firm-specific as well as the country-specific variables described in Table 1. The estimation method is based on the generalized method of moments with robust standard errors (GMM-SE) and t-statistics are in parentheses. Industry, country, and year dummies are included in all specifications. Instruments refer to the number of instruments used in the system GMM. Arellano-Bond AR(1) and AR(2) is an autocorrelation test of first and second order, respectively, using residuals in differences, asymptotically distributes as an N(0.1) and under the null hypothesis of no autocorrelation. Although AR(1) is expected in first differences, it does not invalidate the results. Hansen test is a contrast of overidentifying restrictions or whether the instruments, as a group, appear exogenous, asymptotically distributed as a X^2 and robust to heteroskedasticity. Endogenous variables were instrumentalized with up to 3 years lagged according to Jara et al. (2008), and the number of instruments were kept below the number of cross-sections as suggested by Roodman (2009). F-test contrasts the joint nullity of the estimated parameters. Nonlinearity of *Lev* is assessed with the Lind–Mehlum test that provides the exact test of the presence of a Monotone or U-shaped (or inverse U-shaped) relationship on an interval. The Fieller (1954) confidence interval was used to find the interval for the extreme point. Slopes in lower and upper bounds of *Lev* are reported as well as the testing of the null hypothesis that such slopes individually are equal to 0.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

to the unavailability of data for the newly introduced variables across countries. Despite this limitation, the statistical significance of the key variables of interest remains unchanged. For instance, the *Lev* and Lev^2 variables remain statistically significant across all the models, with positive and negative estimated coefficients, respectively. Furthermore, the Lind–Melhum test consistently confirms the presence of an inverted U-shape (umbrella-shaped) relationship between *Lev* and *EIAVF*1 across all five models, reinforcing the main research hypothesis. The leverage point at which the adjusted firm value is maximized corresponds to 58.48% of total assets, calculated as the average estimate across the five regressions shown at the bottom of Table 6. This result is comparable to those reported in Table 4.

As for the time-varying country-level variables, the analysis reveals important insights. Variables associated with the development of capital markets, such as the market capitalization as a share of GDP (*MktCapGDP*) and stock market return (*StockMktReturn*), are statistically significant and positively influence adjusted firm value. These findings suggest that greater capital market development enables firms to capitalize on favourable market conditions and reduce friction to enhance firm value. Conversely, variables linked to the banking system, such as banks´ net interest margin (*BankNIM*), show a negative effect on adjusted firm value, implying that wider interest margins—often indicative of inefficiency or market power—may erode firm value through increased borrowing costs. This finding is consistent with O'Connor (2011), who argued that excessive banking sector deepening may reduce market capitalization through inefficiencies and firm overexpansion.

Similarly, although not statistically significant, the bank lending deposit spread (*Spread*) shows a negative trend, suggesting that less competitive banking environments are associated with lower firm valuations. Additionally, the banking crisis variable (*BankCrisis*) indicates that during banking crises, adjusted firm value is approximately 8.9% lower than in noncrisis periods.

To further validate the relevance of contextual variables, we perform an additional robustness test by segmenting the sample based on the Environmental Policy Stringency Index (EPS), as reported by the OECD. This index reflects the intensity of environmental regulations by country and year, placing an explicit or implicit price on environmentally harmful behavior.[13] Table 7 presents results for the five countries with the highest average EPS (Switzerland, Japan, Finland, Denmark) and those with the lowest (Brazil, New Zealand, Indonesia, Israel, South Africa) included in the sample. Despite similar patterns across both

TABLE 7 | Panel data nonlinear regression model with sample separated by environmental policy stringency (EPS) and period of analysis.

Variables	High EPS EIAFV1	Low EPS EIAFV1	2008–2015 EIAFV1	2016–2022 EIAFV1
Lev	5.407***	5.923***	4.792***	4.415***
	(41.987)	(66.438)	(7.439)	(10.582)
Lev^2	−5.216***	−5.436***	−4.348***	−3.230***
	(−23.765)	(−38.404)	(−3.943)	(−5.116)
Size	−0.072***	−0.039***	0.046	0.009
	(−7.526)	(−4.408)	(1.410)	(0.422)
Tangible	−0.427***	0.283***	−0.298**	−0.113
	(−7.769)	(5.537)	(−2.329)	(−1.126)
ROA	0.159**	0.865***	0.557***	0.376***
	(2.548)	(11.618)	(3.069)	(3.085)
ZScore	0.065***	0.074***	0.074***	0.077***
	(122.932)	(134.064)	(41.046)	(60.536)
CAPEX	0.627***	−0.097	0.235	−0.069
	(7.900)	(−1.446)	(1.058)	(−0.321)
RDSales	−3.245***	−4.313***	0.564	3.337***
	(−12.060)	(−23.783)	(0.484)	(2.981)
RDSalesIndicator	0.017	−0.514***	0.116	−0.259***
	(1.014)	(−34.940)	(1.433)	(−2.920)
Constant	1.424***	0.097	−1.429**	−0.570
	(6.443)	(0.528)	(−2.016)	(−1.208)
Observations	3821	584	6992	8489
Number of iden	446	88	1633	1972
Industry dummy	Yes	Yes	Yes	Yes
Country dummy	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes
Instruments	271	271	121	176
Avrg. obs. per group	8.567	6.636	4.282	4.305
AR(1)	−4.077	−2.369	−3.261	−5.895
p value	0.005	0.331	0.001	0.355
AR(2)	−1.899	−0.971	−1.121	−0.924
p value	0.0576	0.0179	0.262	0.374
Hansen	299.6	80.78	157.1	297.7
F-test	2316	17,437	209.4	451
Extreme point	0.518	0.545	0.551	0.684
H0: Monotone or U shape (*p* value)	0.000	0.000	0.000	0.018
95% Fieller	0.497	0.529	0.457	0.577
95% Fieller	0.543	0.562	0.822	0.917

(Continues)

TABLE 7 | (Continued)

Variables	High EPS EIAFV1	Low EPS EIAFV1	2008–2015 EIAFV1	2016–2022 EIAFV1
Slope lower bound	5.407	5.923	4.792	4.415
p-value	0.000	0.000	0.000	0.000
Slope Upper bound	−4.445	−4.345	−3.420	−1.685
p-value	0.000	0.000	0.010	0.018

Note: Columns include different specifications for *EIAFV*1 as dependent variable, the firm-specific as well as the country-specific variables described in Table 1. The estimation method is based on the generalized method of moments with robust standard errors (GMM-SE) and t-statistics are in parentheses. Industry, country, and year dummies are included in all specifications. Instruments refer to the number of instruments used in the system GMM. Arellano-Bond AR(1) and AR(2) is an autocorrelation test of first and second order, respectively, using residuals in differences, asymptotically distributes as an N(0.1) and under the null hypothesis of no autocorrelation. Although AR(1) is expected in first differences, it does not invalidate the results. Hansen test is a contrast of overidentifying restrictions or whether the instruments, as a group, appear exogenous, asymptotically distributed as a X^2 and robust to heteroskedasticity. Endogenous variables were instrumentalized with up to 3 years lagged according to Jara et al. (2008), and the number of instruments were kept below the number of cross sections as suggested by Roodman (2009). *F*-test contrasts the joint nullity of the estimated parameters. Nonlinearity of *Lev* is assessed with the Lind–Mehlum test that provides the exact test of the presence of a Monotone or U-shaped (or inverse U-shaped) relationship on an interval. The Fieller (1954) confidence interval was used to find the interval for the extreme point. Slopes in lower and upper bounds of *Lev* are reported as well as the testing of the null hypothesis that such slopes individually are equal to 0.
***$p < 0.01$.
**$p < 0.05$.
*$p < 0.1$.

groups, a key difference emerges in the estimated leverage point at which firm value is maximized: 51.8% for high-EPS countries versus 54.5% for low-EPS countries. This divergence suggests that the trade-off between debt and value creation is moderated by environmental policy conditions, reinforcing the need to control for institutional context in the analysis.

Table 7 also explores time variation by splitting the sample into two periods: 2008–2015 and 2016–2022. In both sub-periods, the inverted U-shaped relationship remains intact. However, the optimal leverage point increases from 55.1% in the earlier period to 68.4% in the latter, suggesting that firms have become more resilient to leverage over time, potentially due to regulatory changes, improved risk management, or more robust financial markets. These temporal differences support the appropriateness of our panel data approach to capture evolving dynamics.

Although omitted from the tables for space considerations, the results remain robust across different timeframes, such as the pre-2020 period to exclude COVID-19 effects, and across industry classifications, following Saona and Muro (2023), who categorized firms into primary, secondary, and tertiary sectors and distinguished between high- and low-impact industries. These robustness checks yield qualitative and quantitative results consistent with those presented in earlier tables. We also added the ESG score as a control variable to control for third omitted variables, potentially producing endogeneity. From such analysis using *EIAVF*1 the inclusion of ESG as a control variable does not change the sign and significant level of *Lev* and Lev^2. The ESG score coefficient equals −0.115 with a p value > 0.1. The statistical insignificance of the ESG coefficient may stem from several conceptual and methodological factors. First, ESG scores are subject to substantial measurement inconsistencies across rating agencies, as there is no standardized methodology or taxonomy for assessing environmental, social, and governance dimensions. This lack of uniformity introduces measurement error and reduces the comparability and reliability of ESG indicators across firms, time, and countries. Second, ESG ratings are primarily constructed from qualitative assessments rather than purely quantitative data, which may weaken their statistical relationship with financial metrics derived from quantitative models. Third, the aggregation of the three pillars—environmental, social, and governance—into a single composite index can obscure divergent effects among them, since the pillars may move in different or even opposing directions. In addition, ESG data coverage remains limited, particularly for smaller firms and earlier years, which diminishes sample size and the power of statistical inference. Measurement error inherent in the composite ESG metric also inflates standard errors, further reducing coefficient significance. Finally, in the present specification, the environmental component of ESG overlaps conceptually with the dependent variable. When estimated using the GMM framework, this overlap weakens the linear association between ESG and the dependent variable, contributing to the observed insignificance. Future research may address these limitations by disentangling the environmental pillar from the ESG composite and exploring alternative, more granular indicators better aligned with environmental performance and firm value dynamics. Consistent results with our main findings are also observed using disaggregated ESG scores.

In summary, the inclusion of time-varying, country-level financial variables enhances the precision and relevance of our model. Despite some data limitations, our findings remain robust, reinforcing the view that both firm-specific and contextual factors jointly shape environmental value creation. Rejecting the inclusion of country-level variables would risk overlooking critical systemic influences on firm behavior and valuation in a multi-country context.

5 | Conclusions

Our paper aims to bridge the gap between the literature on the capital structure puzzle and sustainable finance by incorporating environmental impact into the definition of firm value.

Building on the trade-off theory of capital structure, we verified a nonlinear, inverted U-shaped relationship between leverage and *EIAFV*. The latter increases with leverage up to an optimal point, approximately 58%–61% of total assets, after which higher leverage leads to value erosion due to rising default risk and financial distress costs. In addition, our findings reveal that higher leverage is associated with lower environmental impact. Specifically, adjusting firm value for environmental impact shifts the optimal debt level upward, suggesting that as leverage rises beyond moderate levels, creditors mitigate default risk by imposing stricter environmental standards and covenants on borrowers.

Quantile regression analysis highlights that the impact of leverage varies across the distribution of *EIAFV*, with stronger effects observed at higher quantiles. Contextual country-level variables, such as capital market development, positively influence *EIAFV*, while banking system inefficiencies, like higher net interest margins and banking crises, negatively affect it, aligned with Botta (2020)'s argument that crises generate underinvestment problems arising from debt overhang, which prevent companies to pursue profitable investment opportunities.

Our pioneering approach, based on a more integrative methodology to measure firm value and incorporate the interests of different stakeholders, is well suited to be applied to multiple institutional contexts and research areas. For instance, the proposed study might be examined concerning specific countries to derive more specific conclusions for each institutional context. Hence, in countries with higher attention to environmental issues, debt is expected to have a more predominant role in monitoring corporate operations. In addition, the study offers considerable insights into researching the impact of other strategic corporate decisions, including other corporate financial policies and investment decisions, on the expanded value measure.

The joint analysis of leverage and *EIAFV* could have significant implications for managers, investors, creditors, and policymakers. The study provides a valuable tool for corporate managers to understand how different environmental impacts can be integrated into decision-making to maximize firm value responsibly. In addition, the proposed framework can enable managers to increase or decrease leverage to maximize firm value while complying with environmental constraints. Second, the study is also a valuable tool for investors to transparently understand the firm value net of environmental impacts so that results can be compared and evaluated within market and industry classifications, therefore favoring investment decisions. Third, the results also suggest implications for creditors, who can monitor corporate operations, granting loans to firms with more sustainable practices and lower negative environmental impact. This observation is in line with previous findings that firm value increases due to the dual mechanism of debt acting as an external governance mechanism to monitor corporate operations (Tascón et al. 2021) and through tax deductions on interest payments (Lin and Chang 2011). Finally, the study also has implications for policymakers to develop policies to incentivize corporate sustainable practices and social responsibility while enabling firms to maximize their value responsibly.

Despite its contributions, this study is not without limitations. Our proposed metric for environmental-adjusted firm value relies heavily on data availability. Many firms still lack comprehensive environmental reporting, particularly regarding Scope 3 emissions, which often represent a significant portion of a company's environmental footprint. To address this gap, the methodology uses machine learning imputation techniques to estimate missing data—an approach that inevitably introduces some uncertainty into the valuation process.[14] Likewise, another limitation involves the assessment of biodiversity impacts. Due to the inherent difficulty in assigning monetary values to biodiversity loss, the impact-weighted accounts (IWA) methodology currently excludes this factor from its calculations. As a result, the environmental impact is likely underestimated, especially for firms operating in sectors such as agriculture, forestry, and land development. We acknowledge that these limitations may subsequently introduce a certain degree of bias in the precise monetization of a firm's environmental impact of our firm value metric.

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Endnotes

[1] See also the World Economic Forum 2024 at https://www.weforum.org/publications/global-risks-report-2024/.

[2] "Impact is defined as the change in an outcome. An outcome is the result of an action or event which is an aspect of social, environmental or economic well-being" Freiberg et al. (2021). Corporate Environmental Impact: Measurement, Data and Information. In H. B. School (Ed.), *Harvard Business School Accounting & Management Unit Working Paper* (Vol. 20–098, pp. 1–42).

[3] For a more comprehensive review, see Section 2.

[4] The Impact-Weighted Accounts (IWA) methodology for the Corporate Environmental Impact developed by Harvard Business School "seeks to understand how to appropriately place an economic value upon the social, environmental, and managerial contributions, as well as the cost, of corporates to society as a function of capital consumption. IWA's Corporate Environmental Impact methodology provides a framework for quantitatively assessing the economic cost in monetary units of corporate capital resource consumption" Velez Caicedo (2022). *Practitioner Guide to Calculating Corporate Environmental Impact* [Practitioner Guide]. Harvard Business School.

[5] For a detailed review on trade-off and pecking order hypothesis see, among others, Frank and Goyal (2008). Trade-Off and Pecking Order Theories of Debt. In B. E. Eckbo (Ed.), *Handbook of Empirical Corporate Finance* (Vol. 2, pp. 135–202). Elsevier. 10.1016/B978-0-444-53265-7.50004-4.

[6] https://ifvi.org/wp-content/uploads/2023/10/Practitioner-Guide-To-Calculating-Corporate-Environmental-Impact.pdf

[7] The sample includes firms headquartered in small jurisdictions such as Gibraltar (0.03%), the Isle of Man (0.11%), and the Cayman Islands (1.29%). Although these territories are not sovereign states and represent a negligible portion of the dataset, they were retained to preserve the completeness of the sample. The inclusion of these observations does not affect the validity of the results, as the econometric specification incorporates country fixed effects that account for cross-country heterogeneity and mitigate potential biases arising from jurisdictional characteristics. Moreover, robustness checks excluding these firms—204 observation out of 14,238, representing a 1.43% of the total sample—produced virtually identical results, confirming that their presence does not materially influence the findings.

[8] The data is available at https://www.worldbank.org/en/publication/gfdr/data/global-financial-development-database.

[9] Winsorization at different thresholds was applied depending on the distributional properties of each variable. This choice was driven by the varying degree of outlier presence: some variables exhibited only minor outliers, while others contained more extreme values that substantially skewed their distribution. By adjusting the threshold to the specific characteristics of each variable, we aimed to minimize distortion of the data while still reducing the influence of outliers. Importantly, we verified that this variation in winsorization did not materially affect our main results, which remained robust across specifications.

[10] D'Agostino K^2 test checks skewness and kurtosis separately first, and then runs a joint test of the null hypothesis that skewness is zero and the kurtosis is 3, which would be consistent with normality.

[11] It is important to note that, by construction, missing values of research and development expenses are recoded as zero in the dataset, which reduces the actual, unobservable mean value of this variable.

[12] Such impact was computed as the standard deviation of *Lev* (0.149 as shown in Table 1) multiplied by the estimated coefficient of leverage ratio *Lev* (2.314 as shown in Table 3) and divided by the mean of *EIAFV*1 variable (1.431 as shown in Table 1).

[13] This index is based on the degree of stringency of 13 environmental policy instruments, primarily related to climate and air pollution. The index ranges from 0 (not stringent) to 6 (highest degree of stringency) and covers 40 countries for the period 1990–2020. Further information about this index can be found here https://sft-framework.unctad.org/key-performance-indicator/environment-environmental-policy-stringency-index.

[14] The sample used in this study was not significantly affected by uncertainty in the valuation process, as the proportion of imputed data amounted to only 6.14% according to the IWA methodology, corresponding to 577 observations. To address potential concerns in this regard, estimations were replicated using non-imputed data, yielding results that were virtually identical to those reported in this study.

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Appendix

TABLE A1 | Distribution of the sample by country.

Country	Frequency	Percent	Cumulative
Argentina	11	0.08	0.08
Australia	579	4.07	4.14
Austria	111	0.78	4.92
Bahrain	3	0.02	4.94
Belgium	77	0.54	5.49
Bermuda	108	0.76	6.24
Brazil	149	1.05	7.29
Canada	368	2.58	9.88
Cayman Islands	184	1.29	11.17
Chile	59	0.41	11.58
China	160	1.12	12.71
Colombia	40	0.28	12.99
Croatia	9	0.06	13.05
Cyprus	2	0.01	13.06
Czechia	9	0.06	13.13
Denmark	70	0.49	13.62
Finland	175	1.23	14.85
France	610	4.28	19.13
Germany	473	3.32	22.46
Gibraltar	4	0.03	22.48
Greece	34	0.24	22.72
Hong Kong	213	1.5	24.22
Hungary	24	0.17	24.39
India	180	1.26	25.65
Indonesia	31	0.22	25.87
Ireland	118	0.83	26.7
Isle of Man	16	0.11	26.81
Israel	18	0.13	26.94
Italy	194	1.36	28.3
Japan	2628	18.46	46.76
Jersey	40	0.28	47.04
Kuwait	14	0.1	47.14
Liberia	9	0.06	47.2
Luxembourg	34	0.24	47.44
Malaysia	102	0.72	48.16
Malta	7	0.05	48.21
Mexico	198	1.39	49.6
Morocco	1	0.01	49.6

(Continues)

TABLE A1 | (Continued)

Country	Frequency	Percent	Cumulative
Netherlands	215	1.51	51.11
New Zealand	32	0.22	51.34
Norway	113	0.79	52.13
Oman	3	0.02	52.15
Pakistan	6	0.04	52.19
Papua New Guinea	2	0.01	52.21
Peru	2	0.01	52.22
Philippines	76	0.53	52.76
Poland	30	0.21	52.97
Portugal	54	0.38	53.35
Qatar	5	0.04	53.38
Romania	11	0.08	53.46
Russia	73	0.51	53.97
Saudi Arabia	10	0.07	54.04
Singapore	115	0.81	54.85
Slovenia	3	0.02	54.87
South Africa	386	2.71	57.58
South Korea	390	2.74	60.32
Spain	207	1.45	61.78
Sri Lanka	15	0.11	61.88
Sweden	296	2.08	63.96
Switzerland	338	2.37	66.33
Taiwan	1099	7.72	74.05
Thailand	121	0.85	74.9
Turkey	66	0.46	75.37
United Arab Emirates	15	0.11	75.47
United Kingdom	1324	9.3	84.77
United States	2168	15.23	100
Total	14,237	100	

Note: The table shows the total number of firms' countries included in the study, indicating their frequency, percentage, and cumulative percentage.

TABLE A2 | Distribution of the sample by year.

Year	Frequency	Percent	Cumulative
2010	790	5.55	5.55
2011	826	5.80	11.35
2012	918	6.45	17.8
2013	1005	7.06	24.86
2014	1087	7.63	32.49
2015	1123	7.89	40.38
2016	1243	8.73	49.11
2017	1271	8.93	58.03
2018	1256	8.82	66.86
2019	1291	9.07	75.92
2020	1317	9.25	85.17
2021	1291	9.07	94.24
2022	820	5.76	100.00
Total	14,238	100	

Note: The table shows the distribution of the sample by year, indicating its frequency, percentage, and cumulative percentage.