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Eco-efficiency and financial performance in Latin American countries: An environmental intensity approach

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ABSTRACT

This research contributes to the literature by empirically demonstrating the economic effect of listed companies' eco-efficiency in Brazil, Chile, Colombia, and Mexico through an environmental intensity approach. We find evidence of a positive relationship between eco-efficiency and financial performance; that is, a lower CO_2 emission-to-sales ratio increases Tobin's *q*, with a stronger impact on those companies with the highest financial performance, mainly those in Brazil and Chile, with lower impacts in Colombia. On the other hand, Mexico shows no such relationship. These results can help investors understand the effect of eco-efficiency on Tobin's *q* not only at the median but also in the different quantiles. Moreover, our findings help fill the gap in the literature on eco-efficiency at the micro level in Latin American countries.

1. Introduction

Since the adoption of the 1997 Kyoto Protocol, businesses have shown a growing interest in reducing pollution. The creation of the Chicago Climate Exchange (Hoffman, 2005) is an example of how companies, financial markets and governments have combined strategies to reduce the impact of climate change. In this way, corporations, in their process of continuous adaptation to meet the demands of public investors, have replaced their compliance strategies with commitments to environmental responsibility (Perez-Calderon et al., 2011). Additionally, Fu et al. (2020) mention that investors often pursue social goals beyond private financial objectives and find no evidence of a performance cost for ethical portfolios. Gao et al. (2020) find that in emerging markets, responsible investment can bring portfolio benefits to investors and that these gains improve on days with heavy air pollution.

The concept of eco-efficiency was first described by Schaltegger and Sturm (1989) and then widely publicized by Schmidheiny (1992) and the World Business Council for Sustainable Development (WBCSD). Since then, it has been received as the leading strategic topic in global business in relation to the commitments and activities to be managed in sustainable development. The WBCSD (2000) describes eco-efficiency as "being achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle to a level at least

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in line with the Earth's estimated carrying capacity."

The academy commonly focuses on the formal definition of eco-efficiency, considering cost and value as economic categories as well as categories within the International Standards of Accounting and Reporting (ISAR) under United Nations (UN) coordination through the System of National Accounts (ISWGNA, 1993). However, the conventional accounting model is not able to assess an enterprise's environmental performance and the impact of that performance on financial performance (UN, 2004). Environmental approaches such as life-cycle assessment, developed by international standards organizations and the Society for Environmental Toxicology and Chemistry (SETAC), are more detailed than those from the accounting and management fields but have not yet led to broad acceptance of specific methods for assessing eco-efficiency (Huppes and Ishikawa, 2005).

In this regard, eco-efficiency can be measured with a production value approach in two ways. The first approach is as a ratio of some measure of economic value added to some measure of environmental impact: the higher this ratio is, the more efficient the environmental performance. On the other hand, the inverse relationship, known as eco-intensity—an environmental measure divided by an economic value, with a lower indicator meaning better eco-efficiency—is also a possible measure. However, the number of measurement possibilities associated with the concept hints at one of its problems: quantification (Ehrenfeld, 2005).

The notions of eco-efficiency and its relationship with financial performance are still new in Latin America in business and academia (Fernández-Viñé et al., 2010). In contrast, developed countries have focused on environmental public policies to sustain companies' value and improve market efficiency and business models (Konar and Cohen, 2001; Al-Najjar and Anfimiadou, 2012).

The originality of this research lies in its empirical demonstration of the economic effect of listed firms' eco-efficiency. We contribute to the ongoing debate on the relationship between eco-efficiency and financial performance through an environmental intensity approach; that is, we evaluate whether a lower CO_2 emission-to-sales ratio increases Tobin's q. We provide a solid microeconomic understanding of how environmental sustainability as measured by eco-efficiency affects the value of a firm. To this end, 102 publicly listed firms were selected from the financial markets of Chile, Colombia, Brazil, and Mexico. The methodology of this study involves the use of the quantile regression method originally proposed by Koenker and Bassett (1978) and Koenker and Hallock (2001).

This paper is organized into five sections. Section two presents the theoretical framework for eco-efficiency and a review of the studies on the relationship between financial performance and eco-efficiency. In section three, we present the data and methods. Finally, sections four and five present the study's results and conclusions, respectively.

2. Theoretical background

2.1. Theory of eco-efficiency

Efficiency generally refers to producing the maximum number of outputs with the fewest inputs. However, eco-efficiency in the context of environmental management has a slightly different meaning; for example, carbon emissions are an undesired output (Zvezdov and Schaltegger, 2015). In this instance, the theory of eco-efficiency proposed by Porter and van der Linde (1995) states that it is possible for companies to maximize their efficiency by reducing costs and creating value while also minimizing their environmental impact.

Schaltegger and Wagner (2005) mention that eco-efficiency is a multidimensional concept that is related to each specific analytical context; thus, mathematically, an unlimited number of combinations of economic and environmental measures have been applied (Galal et al., 2021). Additionally, Huppes and Ishikawa (2005) point out that eco-efficiency metrics have been used in different ways, considering four types according to the order of inversion of the variables and which of two approaches is used: 1) the production value approach, which focuses on environmental intensity (an environmental measure divided by an economic measure) or environmental productivity (an economic measure divided by an environmental measure) and 2) the environmental improvements approach, which focuses on environmental cost-effectiveness (an environmental measure divided by an economic measure) or environmental improvement cost (an economic measure divided by an environmental measure).

The eco-efficiency metric that we use is an environmental intensity metric, i.e., environmental impact (CO_2) per unit of production value (sales). A decrease in the CO_2-to-sales ratio implies a lower environmental intensity of the firm or, in other words, an improvement in its eco-efficiency. Recently, similar micro-level studies on emerging markets, such as Sudha (2020), have analyzed eco-efficiency as measured through an environmental intensity approach, such as the relationship between energy and water consumption and sales, among other eco-intensity metrics.

2.2. Eco-efficiency and financial performance

In the last two decades, several studies have analyzed the relationship between eco-efficiency and financial performance and obtained different results. Some of them have found that when companies integrate eco-efficiency into their operations, better financial performance is achieved. For example, Derwall et al. (2004) observe higher Sharpe ratios in a portfolio analysis when the eco-efficiency of U.S. companies is presented. Moreover, Pogutz and Russo (2009) suggest a positive relationship among environmental strategies by examining greenhouse gas (GHG) emissions and financial performance over the short term for companies listed in the Global Fortune 500 Index.

In contrast, other researchers have argued that strategies and actions that improve environmental performance conflict with financial objectives since emission reduction generates costs and diverts resources from other strategic investments (Lothe et al., 1999). For instance, Hassel et al. (2005) conclude that positive environmental performance has a negative impact on stock price yields and, in turn, on long-term financial returns and argue that investors consider environmental activities to be implemented at the expense of an increase in future gains.

Mixed or unclear results have also been observed in the literature; for example, Lucato et al. (2017) note that it is not possible to identify a statistically significant relationship between environmental performance as measured by their eco-efficiency indicator and financial performance for small and medium-sized enterprises (SMEs) in the textile sector of Brazil. Nevertheless, Lucato et al. (2017) suggest expanding the analysis to include larger companies and other sectors, since the aforementioned study was conducted through a survey of textile manufacturing SMEs located in a specific geographic area and the major textile companies were not considered. In addition, Orlitzky et al. (2003) find that despite evidence for a positive relationship between companies' environmental and financial performance, it remains unclear whether pollution prevention influences firms' financial results or whether high-performing companies can sustain environmental gains.

To this end, studies taking a micro financial approach commonly analyze the effects of eco-efficiency or other environmental measures on the financial performance of firms. To measure financial performance, an accounting metric, a market metric or a combination of both may be employed. In this vein, Ohlson (1995) proposes a model to assess the effect of accounting and non-accounting information on the market value of firms. Generally, either market capitalization or Tobin's q is used as a proxy to measure market value, as in Dowell et al. (2000); Guenster et al. (2011) and Matsumura et al. (2014), who incorporate an environmental metric as nonaccounting information that investors can use as relevant information in valuing firms. Based on these models and the eco-efficiency intensity approach in the present study, the first hypothesis that we propose is the following:

H1. The eco-efficiency of Latin American firms positively affects firm value.

2.3. Eco-efficiency in emerging markets

Since previous studies have focused mainly on developed countries, emerging country studies have been of interest in academic research. As a result, ecological modernization theory (EMT) has arisen to analyze "how contemporary industrialized economies deal with environmental crises" (Mol et al., 2000). This theory suggests that industrialization, technological development, economic growth, and capitalism are key drivers of a country's ecological sustainability (York and Rosa, 2003). In this regard, Twerefou et al. (2017) examine the impact of economic growth and globalization on environmental quality and sustainability for 36 sub-Saharan African countries using panel data. Their study reveals a positive relationship between economic growth in emerging economies and environmental sustainability.

Emerging countries represent approximately half of global gross domestic product (GDP) and two-thirds of the world's population, according to the IMF (2017). Huber (2008) concludes that these countries contribute to global resource consumption and emissions given their lower level of eco-efficiency and their higher environmental intensity. Thus, this study also aims to determine whether eco-efficiency has an impact on the value of companies in emerging Latin American countries. To assess whether the country where each eco-efficient firm analyzed is located has an impact on the firm's market value, we propose a second hypothesis based on EMT:

H2. The effect of Latin American firms' eco-efficiency on firm market value varies depending on the firms' country of origin.

3. Data and methods

3.1. Sample

We analyzed data from 2010 to 2017 for a sample of 102 listed firms (see Table 1): 47 firms from Brazil, 18 from Chile, 12 from Colombia, and 25 from Mexico. Ten sectors were considered (real estate, energy, finance, industrial, materials, noncommodity consumer products, consumer staples, health care/pharmaceuticals, telecommunication/information technology, and public utilities). To select the sample, we considered the same listed companies that reported their CO_2 emissions during each of these years. The firms in the sample represent 56 % of the total Latin American market capitalization.

Table 1
Sectoral composition of the sample.

Sector	Brazil	Chile	Colombia	Mexico	Total
Real estate	1	1			2
Energy	3	1	1		5
Finance	6	2	1	5	14
Industrial	5	1	1	3	10
Materials	8	3	4	5	20
Noncommodity consumer products	6	1		3	10
Consumer staples	6	3	1	7	17
Health care/pharmaceuticals	2				2
Telecommunications/information technology	2	1	1	1	5
Public utilities	8	5	3	1	17
Total sample	47	18	12	25	102
% Market capitalization [1]	54%	38%	61%	98 %	

[1] Capitalization of the companies in the sample divided by the total market capitalization of the country in 2016.
Source: S&P Capital IQ database.

Table 2
Economic and greenhouse gas emissions statistics by country.

Country	GDP in trillions of USD	Capitalization/GDP	CO_2 emissions per capita
Brazil	1.80	46%	2.59
Chile	0.25	106%	4.69
Colombia	0.28	39%	1.76
Mexico	1.08	36%	3.87
Latin America[1] & the Caribbean[2]	6.00	37%	2.92

[1] The Latin American countries considered are Argentina, Belize, Bolivia, Brazil, Costa Rica, Chile, Colombia, Ecuador, El Salvador, Guatemala, French Guiana, Guyana, Honduras, Mexico, Nicaragua, Paraguay, Panama, Peru, Suriname, Uruguay, and Venezuela.
[2] The Caribbean countries considered are Antigua & Barbuda, Aruba, Bahamas, Barbados, Cayman Islands, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Puerto Rico, Saint Barthélemy, St. Kitts & Nevis, St. Lucia, St. Vincent & the Grenadines, Trinidad & Tobago, Turks & Caicos Islands, and the Virgin Islands.
Source: World Bank development indicators for 2016 (https://data.worldbank.org/indicator/CM.MKT.LCAP.GD.ZS).

Table 2 shows the economic importance of these countries in Latin America. The countries represent the largest economies in the region. Their GDP represents 57 % of the total GDP of all Latin American and Caribbean countries. The stock market capitalization-to-GDP ratio is used to determine whether an overall market is undervalued or overvalued in comparison to an average. Table 2 shows this ratio compared to the average capitalization-to-GDP ratio in Latin American and Caribbean countries. It is important to highlight that the Brazilian, Colombian, and Mexican valuation ratios fall between 30 % and 50 % and that these markets can thus be said to be undervalued. This represents an opportunity to grow investment in the region. Furthermore, the market capitalization of these four countries is also the largest in Latin America, representing 89 % of the regional total. On the other hand, the Carbon Dioxide Information Analysis Center reports that Mexico and Brazil belong to the list of the 20 highest fossil fuel-derived CO_2-emitting countries: in 2008, they together accounted for approximately 53 % of total regional emissions (Boden et al., 2017) and, in 2016, for 65 % (Le Quéré et al., 2016). In contrast, Chile and Colombia have shown their environmental concern through sustainability indices developed in their markets.

3.2. Empirical eco-efficiency model

Ohlson (1995) proposes a model to assess whether the information that a company discloses is relevant for market investors. To measure market value, Tobin's *q* is commonly used and is also a good indicator in emerging economies (Sarkar and Sarkar, 2012). The model uses the market value of equity (Tobin's *q*) as a function of accounting and nonaccounting information. As a proxy for accounting earnings, Russo and Pogutz (2009) use the ratio of earnings before interest and taxes (EBIT) to sales, and Kumar and Shetty (2018) consider an environmental indicator for nonaccounting information. Thus, the model used to test H_1, that is, whether eco-efficiency positively affects firm value, is expressed as follows:

$$Tq_{it} = \beta o + \beta_1 EcoEff_{it} + \beta_2 EBITDA\_S_{it} + \beta_3 \ln\_Assets_{it} + \beta_4 Debt\_E_{it} + e_{it} \quad (1)$$

where

Tq_{it} = Tobin's *q*, calculated as the sum of capital, debt and preferred shares divided by the replacement value of property, plants and equipment and the short-term assets of company *i* in period *t*.

$EcoEff_{it}$ = the index, base 100, for the relationship between the intensity of CO_2 emissions per unit of sales reported in dollars for firm *i* in period *t*.

$EBITDA\_S_{it}$ = total earnings before interest, taxes, depreciation, and amortization divided by the total sales of firm *i* in period *t*.

$\ln\_Assets_{it}$ = the natural logarithm of the assets of company *i* in period *t*.

$Debt\_E_{it}$ = the total debt divided by the equity of company *i* in period *t*.

Based on Dowell et al. (2000); King and Lenox (2001) and Konar and Cohen (2001), we use Tobin's *q* as our dependent variable. This metric represents the firm's market value, obtained as the sum of the investments of common shareholders in the firm, of preferred shares, and of debt. The latter includes short- and long-term financing. On the other hand, the replacement value of the assets of the company at time *t* is the sum of property, plants and equipment minus accumulated reserves for depreciation and amortization, as well as short-term assets represented by cash and other liquid assets sold or consumed within a year of the firm's operating cycle.

For the independent variables, we select the emission intensity of CO_2 per unit of sales as our measure of eco-efficiency (Dechow et al., 2010). This variable is calculated using the data disclosed in the environmental reports provided by Bloomberg in the ESG indicators of the companies under study. The GHG emissions, measured through carbon dioxide, are the sum of the annual use of energy, electricity, fuel, gas, heating, and urban cooling. These emissions are standardized relative to total sales (Dowell et al., 2000). It should be noted that the coefficient on this indicator must be negative for a firm to be considered eco-efficient; i.e., a ratio greater than 1 implies high CO_2 emissions per unit sold, which in turn implies that the company's level of eco-efficiency is poor. Due to the large distance between the minimum and maximum values of the series, we build a base-100 index for this eco-efficiency measurement (*EcoEff*), where the base period includes the observations with the highest CO_2-to-sales ratio. When *EcoEff* is close to 100, then the firm has low levels of eco-efficiency; the opposite holds when *EcoEff* is close to zero.

We also include total earnings before interest, taxes, depreciation, and amortization by total sales (*EBITDA_S*) as a control variable; this variable represents the profitability ratio of the company based on its sales margin, which determines the operating flow ratio for each unit sold (Russo and Pogutz, 2009). Furthermore, in line with King and Lenox (2001), the size of the company as determined by the natural logarithm of its assets is also included (ln_*Assets*). Finally, to account for the financial structure of the firm and to control for any potential effect of leverage, the total debt divided by the equity of the company (*Debt_E*) is also included, as in King and Lenox (2001) and Russo and Pogutz (2009).

On the other hand, to assess whether the country of origin for each firm in the sample also influences the firm's market value, 3 dichotomous variables for Brazil, Chile, and Mexico are created, with Colombia excluded for comparison to avoid multicollinearity. However, to test the impact of eco-efficiency jointly with the country effect, the two variables are interacted. Thus, Eq. (2) allows us to compare changes in the parameter values of the fundamental variables, including the country effects, as in Guenster et al. (2011). However, unlike the model presented by Guenster et al. (2011), who analyze the differences in eco-efficiency between high- and low-eco-efficiency firms, Eq. (2) tests the difference in eco-efficiency across countries (H_2):

$$Tq_{it} = \beta o + \beta_1 EcoEff_{it} + \beta_2 EBITDA\_S_{it} + \beta_3 \ln\_Assets_{it} + \beta_4 Debt\_E_{it} + \beta_5 EcoEff_{it}*Mexico_{it} + \beta_6 Ecoeff_{it}*Brazil_{it} + \beta_7 EcoEff_{it}*Chile_{it} + e_{it} \quad (2)$$

where

$EcoEff_{it}*Mexico_{it}$ = the eco-efficiency index of Mexican firms.

$Ecoeff_{it}*Brazil_{it}$ = the eco-efficiency index of Brazilian firms.

$EcoEff_{it}*Chile_{it}$ = the eco-efficiency index of Chilean firms.

As in Eq. (1), β_1, β_5, β_6, and β_7 are expected to be negative and statistically significant; i.e., greater eco-efficiency is expected to improve firm value.

3.3. Data

Table 3 shows the descriptive statistics for the 102 firms from 2010 to 2017 in the countries under study. Information about the eco-efficiency ratio and financial performance of the listed Latin American firms is taken from Bloomberg financial data. The skewness and kurtosis coefficients are calculated to characterize the position and degree of concentration in the data and the data variability. Notably, high kurtosis values indicate the presence of outliers and suggest nonnormality of the series. The sample includes firms of different sizes in terms of market volatility; thus, the market value of the firms as measured by Tobin's *q* follows a leptokurtic distribution.

The correlations between the independent variables are calculated to detect possible multicollinearity among the variables. The values in Table 4 are relatively small, which indicates a low correlation between the variables; i.e., there is no evidence of

Table 3
Descriptive statistics.

Statistics	*Tq* [1]	*EcoEff* [2]	*EBITDA_S* [3]	ln_*Assets* [4]	*Debt_E* [5]
Mean	1.64	5.20	26.36	11.59	135.13
Std. Dev.	0.95	14.11	18.60	2.74	187.97
Skewness	3.13	4.52	0.75	0.73	6.51
Kurtosis	18.39	25.83	3.75	2.62	76.67

[1] *Tq* is Tobin's *q*, which represents the market value of company *i* in period *t*.
[2] *EcoEff* is the index, base 100, of the relationship between the intensity of CO_2 emissions per unit of sales, reported in dollars, of company *i* in period *t*.
[3] *EBITDA_S* is the EBITDA margin and measures the cash flow per unit sold, reported in dollars, of company *i* in period *t*.
[4] ln_*Assets* is the natural logarithm of the assets of company *i* in period *t*.
[5] *Debt_E* is the leverage of company *i* in period *t*.
Source: Own elaboration using data from Bloomberg.

Table 4
Correlation coefficients between the independent variables in the model.

Variable	*EcoEff* [1]	*EBITDA_S* [2]	ln_*Assets* [3]	*Debt_E* [4]
EcoEff[1]	1.00			
EBITDA_S[2]	0.1384	1.00		
Ln_Assets[3]	−0.2992	0.1278	1.00	
Debt_E[4]	−0.0422	−0.1904	−0.185	1.00

[1] *EcoEff* is the index, base 100, of the relationship between the intensity of CO_2 emissions per unit of sales, reported in dollars, of company *i* in period *t*.
[2] *EBITDA_S* is the EBITDA margin and measures the cash flow per unit sold, reported in dollars, of company *i* in period *t*.
[3] ln_*Assets* is the natural logarithm of the assets of company *i* in period *t*.
[4] *Debt_E* is the leverage of company *i* in period *t*.
Source: Own elaboration with data from Bloomberg.

multicollinearity in the series. For instance, Table 4 shows a negative correlation coefficient between the CO_2-to-sales ratio (*EcoEff*) and size (*ln_Assets*); that is, a lower level of pollution per unit of sales is associated with larger companies, although this association is small (−0.29).

3.4. Quantile regression method

The sample includes firms of different sizes and from different markets, which influences the distribution of the data. In particular, the dependent variable follows a leptokurtic and asymmetric distribution. Therefore, an ordinary least squares (OLS) regression would not be an appropriate method to estimate the market value of the firms, as it may generate inefficient and biased regression coefficients given the nonnormality of the distribution of Tobin's *q*. On the other hand, since it is possible for companies to create value by minimizing their environmental impact, as indicated by the eco-efficiency theory mentioned previously, the effect of eco-efficiency on market value may differ for different values of Tobin's *q*; i.e., this impact could be different for companies that are valued more highly by investors than for those with a lower market value given the environmental disclosure of the companies, especially if the values of Tobin's *q* are not symmetrically distributed and outliers are more likely to be present. In this instance, while the central effects from OLS estimations could provide interesting summary statistics of the impact of eco-efficiency, they would fail to describe its full distributional impact since eco-efficiency may affect both the central and tail quantiles of the distribution of Tobin's *q* in a different way. For these reasons, an alternative estimation method is necessary.

Quantile regression, originally introduced by Koenker and Bassett (1978), is a statistical tool for estimating conditional quantile models and could provide a deeper understanding of the contribution of eco-efficiency to heterogeneity in the analysis of Tobin's *q* values in the sample. Koenker and Hallock (2001) emphasize the advantages of quantile estimation over OLS, highlighting cases where noncompliance with certain assumptions leads to more reliable results. According to Buchinsky (1995), the information available usually accommodates heavy restrictions on the basic assumptions of a linear regression model. In this regard, quantile regression techniques could provide a more complete image of the relationship between Tobin's *q* and eco-efficiency since this method accounts for extreme events in the tails of the conditional distribution of the dependent variable. Quantile regressions have been applied in corporate social responsibility analyses such as Oware and Mallikarjunappa (2021), among other financial cases.

In addition, Chernozhukov and Hansen (2008) develop an instrumental variable quantile regression method, and Harding and Lamarche (2009) improve this technique by including fixed effects for cases in which the endogenous variables are correlated with the individual effects that influence the dependent variable. The endogenous variables are unobserved factors that may impact the dependent variable and are correlated with the explanatory variables; however, in our sample, eco-efficiency is considered an exogenous and uncorrelated variable given the previously mentioned results in Table 3. Thus, to examine the impact of eco-efficiency at different quantiles of the conditional distribution of Tobin's *q*, we use the quantile regression method described in Koenker and Hallock (2001), who point out ways to expand the application of this tool in different empirical economic analyses. The method is explained briefly as follows. Assume that there is a linear specification for the conditional quantiles of *Y*; then,

$$Y_t = x_t\beta + u_t \tag{3}$$

where Y_t is the dependent variable, x_t is the independent variable, β is the coefficient that needs to be estimated, and u_t is the residual term. The goal of a quantile regression model is therefore to estimate β for different conditional quantile functions. Assume that the conditional mean of Y is $\mu(X) = X'\beta$; then, the ordinary least squares approach that is used to estimate β minimizes $\sum_{t=1}^{n}(Y_t-\mu)^2$; that is,

$$\min_{\beta \epsilon \mathrm{R}} \sum_{t=1}^{n}(Y_t - X'\beta)^2 \tag{4}$$

Solving the linear specification of Eq. (4) gives an estimation of the median (2nd quantile or 50th percentile) function. We chose τ to denote the other quantile values. Then, the conditional quantile function can also be expressed as:

$$Q_Y(\tau|X) = X'\beta(\tau) \tag{5}$$

Therefore, to estimate the conditional quantile functions, that is, $\widehat{\beta}(\tau)$, we need to solve the following equation:

$$\min_{\beta \epsilon \mathrm{R}} \sum_{t=1}^{n}\rho_\tau(Y_t - X'\beta) \tag{6}$$

where ρ_τ is a weighting function and, for any $\tau\epsilon(0,1)$, is expressed as follows:

$$\rho_\tau\,(u_i) = \begin{cases} \tau u_i \text{ if } u_i \geq 0) \\ (1-\tau)u_i \text{ if } u_i < 0 \end{cases}, \text{where } u_i = Y_t - X'\beta \tag{7}$$

By combining Eqs. (6) and (7), we obtain the estimator $\widehat{\beta}(\tau)$ by solving the weighted minimization problem:

$$\min_{\beta \epsilon \mathrm{R}} \left[\tau \sum_{Y_t \geq X'\beta} |Y_t - X'\beta| + (1-\tau)\sum_{Y_t < X'\beta} |Y_t - X'\beta|\right] \tag{8}$$

Thus, $X'\hat{\beta}$ approximates the τth conditional quantile of Y. The minimization problem can be solved by using the linear programming method proposed by Koenker and Orey (1987).

4. Results

Table 5 shows the results for Eq. (1) when we estimate quantile regressions for the 25th, 50th and 75th percentiles. The results for the model show that the effect of the fundamental variable *EcoEff* is negative and statistically significant. The inverse relationship between *EcoEff* and Tobin's q means that lower CO_2 emissions per unit of sales lead to higher market value. However, the effect of eco-efficiency on the market value of the firms is greater among the firms whose Tobin's q is highest (75th percentile) than among those whose Tobin's q is lowest; that is, investors are willing to pay more for shares in eco-efficient companies with a higher market value relative to book value (75th percentile) than for shares in companies for which this economic value is lower (25th percentile).

Russo and Pogutz (2009) find that a firm can improve its eco-efficiency by decreasing its production of GHG emissions per production unit. A decrease in the eco-efficiency ratio has a powerful implication: in this case, the denominator formed by sales exhibits

Table 5
Quantile regression estimation results.

Variable	25th percentile		50th percentile		75th percentile	
EcoEff [1]	−0.0024**	(-2.30)	−0.0085*	(-1.68)	−0.0132***	(-3.04)
EBITDA_S [2]	0.0082***	(5.38)	0.0145***	(2.82)	0.1783***	(5.72)
ln_*Assets* [3]	−0.7402***	(-8.88)	−0.1240***	(-3.40)	−0.1373***	(-4.23)
Debt_E [4]	0.0001**	(2.13)	−0.0000	(-0.01)	−0.0002	(-1.34)
Cons [5]	1.7418***	(15.39)	2.5620***	(5.65)	3.1651***	(8.10)
R^2	0.0784[6]		0.1008[6]		0.161[6]	

*** p value <0.01.
** p value <0.05.
* p value <0.10, Student's t value in parentheses.
[1] *EcoEff* is the index, base 100, of the relationship between the intensity of CO_2 emissions per unit of sales, reported in dollars, of company i in period t.
[2] *EBITDA_S* is the EBITDA margin and measures the cash flow per unit sold, reported in dollars, of company i in period t.
[3] ln_*Assets* is the natural logarithm of the assets of company i in period t.
[4] *Debt_E* is the leverage of company i in period t.
[5] Cons represents the constant or intercept of the quartile analysis, where the dependent variable is company i's Tobin's q in period t.
[6] Pseudo R^2.
Source: Own elaboration with data from Bloomberg.

Table 6
Quantile regression estimation results with country effects.

Variable	25th percentile		50th percentile		75th percentile	
EcoEff [1]	−0.0035*	(-1.80)	−0.0092***	(-3.72)	−0.0150***	(-4.71)
EBITDA_S [2]	0.0070***	(2.81)	0.0178***	(6.66)	0.0219***	(5.24)
ln_*assets* [3]	−0.0539***	(-4.99)	−0.1122***	(-6.22)	−0.1671***	(-4.31)
Debt_E [4]	0.0002	(1.10)	0.0001	(0.75)	−0.0000	(-0.21)
*Mexico*EcoEff* [5]	−0.0137	(-0.42)	−0.0604	(-1.57)	−0.0919	(-1.62)
*Brazil*EcoEff* [6]	−0.0498***	(-3.95)	−0.1039***	(-5.61)	−0.1089***	(-3.49)
*Chile*EcoEff* [7]	−0.0378*	(-1.66)	−0.1336***	(-4.39)	−0.1865***	(-3.94)
Cons [8]	1.7312***	(9.61)	2.6604***	(11.40)	3.6148***	(7.97)
R^2 [9]	0.1329[9]		0.2108 [9]		0.249[9]	

**p value <0.05.
*** p value <0.01.
* p value <0.10.
[1] *EcoEff* is the index, base 100, of the relationship between the intensity of CO_2 emissions per unit of sales, reported in dollars, of company i in period t.
[2] *EBITDA_S* is the EBITDA margin and measures the cash flow per unit sold, reported in dollars, of company i in period t.
[3] *Ln_Assets* is the natural logarithm of the assets of company i in period t.
[4] *Debt_E* is the leverage of company i in period t.
[5] *Mexico*EcoEff* is the effect of the eco-efficiency index of Mexican firms in relation to that for Colombian firms.
[6] *Brazil*EcoEff* is the effect of the eco-efficiency index of Brazilian firms in relation to that for Colombian firms.
[7] *Chile*EcoEff* is the effect of the eco-efficiency index of Chilean firms in relation to that for Colombian firms.
[8] Cons represents the constant or intercept of the quartile analysis, where the dependent variable is company i's Tobin's q in period t.
[9] Pseudo R^2.
Source: Own elaboration with data from Bloomberg.

constant growth, and at the same time, the production of CO_2 has only small or even imperceptible changes. The negative sign represents the firm's level of eco-efficiency, which means that with a greater reduction in CO_2 emissions, the firm earns more profits (Porter and van der Linde, 1995; Konar and Cohen, 2001; Guenster et al., 2011).

The control variable *EBITDA_S* is statistically significant and is confirmed to be positively related to market value (Russo and Pogutz, 2009; Broadstock et al., 2018). The second control variable, ln*_Assets*, has a negative impact on market value; this variable is statistically significant (Konar and Cohen, 2001). The results for these two control variables are similar to those obtained by Russo and Pogutz (2009). The third control variable, *Debt_E*, has a significant positive relationship with the firm's market value only at the 25th percentile. Similarly, Al-Najjar and Anfimiadou (2012) find no evidence of a financing effect on firm value.

To determine country effects, Eq. (2) is used. The results for each of the Latin American countries are presented in Table 6. The eco-efficiency variable for Brazil and Chile relative to that for Colombia shows a negative and statistically significant relationship at the 25th, 50th, and 75th percentiles. In Mexico, there is no evidence that eco-efficiency affects Tobin's *q*. The *EBITDA_S* margin shows a positive effect on the market value for all Latin American firms.

Likewise, given the pseudo R^2 values, we note that the model fits the data for companies with high firm value (75th percentile) better than it does those for companies with lower and medium firm values (25th and 50th percentiles). These results lead us to conclude that eco-efficiency has a greater impact on large companies than on small companies.

The role of industrial sectors is fundamental to a firm's level of eco-efficiency. To examine sectoral impacts, we introduce 9 dichotomous variables into the model in Eq. (1) to account for 9 of the 10 sectors in the sample. However, there is no evidence at the micro level of sectoral effects in the impact of eco-efficiency on Tobin's *q* for the firms analyzed. It is important to remember that the sample is composed of companies that disclose their CO_2 emissions, and listed firms are not necessarily the firms that pollute. As mentioned by Puppim de Oliveira and Jabbour (2017), SMEs could be responsible for production of a significant amount of greenhouse gases, and these companies are mainly informal in nature and operate in poor socioeconomic conditions, especially in emerging markets. In this regard, Tutterow (2014) mentions that SMEs represent 90 % of companies worldwide and are reported to cause approximately 70 % of global pollution. Our results contrast with those of Moutinho et al. (2018), who find different levels of eco-efficiency by sector; however, these other studies are oriented toward the macro level. For instance, Moutinho et al. (2018) show that economic growth and carbon emissions have decreased over time in Latin America (including in Brazil, Chile, Colombia, and Mexico).

To test robustness in Eqs. (1) and (2), we substitute the dependent variable, Tobin's *q,* with performance over assets (ROA); the estimation and goodness-of-fit (R^2) test results are similar to those obtained with the original dependent variable (Tobin's *q*).

5. Conclusion

This research is motivated by the need to understand the importance to market investors of Latin American firms' initiatives to control CO_2 emissions not only from an environmental point of view but also from the perspective of financial performance. The metric used to measure the financial results in terms of the decrease in pollution levels is eco-efficiency. According to Hoffman (2005), the benefits that this concept entails have repercussions in six main areas: improvements in operations, anticipation of environmental regulations, evaluation of new sources of capital, improvements in risk management, improvements in corporate reputation, and new market and business opportunities.

Measuring company performance in terms of emissions and consumption was the main purpose of this study, and we empirically demonstrated that the firms with the greatest environmental commitment are those that, at the same time, have high yields and receive recognition from the market when they implement this type of behavior. The results presented above coincide with those of the studies of Perez-Calderon et al. (2011); Russo and Pogutz (2009), and Al-Najjar and Anfimiadou (2012).

In this regard, the theory of eco-efficiency proposed by Porter and van der Linde (1995) was also confirmed for the Latin American firms in the sample. However, the results varied according to the country of origin of the firm; i.e., there is evidence that the eco-efficiency of Chilean and Brazilian firms has a larger effect on market value than does that of Colombian firms—and there is no evidence of an effect for Mexican firms.

The contribution of this research is relevant for three main reasons. First, there is a gap in the eco-efficiency literature on Latin America and emerging countries, as mentioned by authors such as Orsato et al. (2015). Second, a comparative analysis of countries with stock exchanges involved in sustainability initiatives is presented. Third, the effect of eco-efficiency on the market value of the firms is greater among the firms whose Tobin's *q* is highest.

For the first hypothesis, the results reveal the importance of eco-efficiency for the financial performance of public companies in the full sample. In addition, particularly when estimating the quantile regression model, we show that the financial benefits from higher eco-efficiency are greater for companies with lower CO_2 emissions per unit of sales that are in the 75th percentile of the distribution of Tobin's *q*. The evaluation of this model is consistent with the results of Perez-Calderon et al. (2011). The use of Tobin's *q* as a metric for financial performance yields the same results as in King and Lenox (2001). Theoretically, these results are in accordance with the theory of slack resources (Waddock and Graves, 1997), which states that when a firm's financial performance improves (driving it, for instance, into the 75th percentile of the sample), slack resources become available that allow the company to carry out corporate social responsibility activities and therefore further improve its eco-efficiency.

In regard to the second hypothesis, the results reveal the importance of eco-efficiency for the financial performance of public firms, with a greater impact first for large companies in Chile and second for those in Brazil. In a review of eco-efficiency in these countries, Leal (2005) makes the following arguments. In Chile, there has been a clean production policy associated with eco-efficiency indicators since 2000, and Chile is very active in defining agreements and initiatives to support preventive control. Similarly, the concept of eco-efficiency has been gaining strength in Brazil since the creation of the Brazilian Business Council for Sustainable Development, which brings together several large corporations and whose mission is to promote sustainable development in the business environment through the concept of eco-efficiency. However, it is advisable to expand these efforts to SMEs, since the study by Lucato et al. (2017) shows an ambiguous relation between eco-efficiency and financial performance in Brazilian textile manufacturing SMEs. Similarly, the Colombian Business Council for Sustainable Development (CECODES) was created as a Colombian business organization that has pioneered the promotion of eco-efficiency in the country; however, its development still has room for improvement. Finally, in Mexico, there is no official policy to promote eco-efficiency at the micro level, although various private initiatives are well regarded by the government.

Our findings reveal that Latin American firms interested in eco-efficiency have begun to consider strategies to reduce the impact of pollution and climate change on their market value. Thus, our recommendation is geared toward the strengthening of technological innovation in emerging market companies to decrease inefficiencies in the production process that represent sunk costs, as mentioned by Gimenez et al. (2015), and reduce CO_2 emissions to improve firms' eco-efficiency.

The main limitation of this study is the lack of a nonlinear effect analysis, given that the result of such an analysis would reveal the maximum eco-efficiency inversion threshold that contributes to improving market value and enabling long-term sustainability. Future research should be conducted based on this type of analysis. Furthermore, the findings of our study offer important insights into the impact of eco-efficiency at the micro level but not at the macro level, and so a deeper comparative analysis of Latin American countries could also be considered. Eco-efficiency within individual firms cannot ensure eco-efficiency at the macro level, that is, sustainable development. The logic of this observation lies in the rebound effect described by Sorrell and Dimitropoulos (2008), also called the Jevons paradox: i.e., more economical use of natural resources increases overall consumption of other resources rather than saving them. Finally, following Figge et al. (2017), new eco-efficiency metrics that reduce the gap between the micro and macro levels could be explored in future research.

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Author statement

The contributions and roles of all authors are listed as follows:

Martha del Pilar Rodríguez García - conceptualization, funding acquisition, methodology, project administration, supervision, validation.

Alicia Fernanda Galindo Manrique - conceptualization, data curation, investigation, writing - original draft, writing - review & editing.

Klender Aimer Cortez Alejandro - formal analysis, methodology, software, validation, writing - review & editing.

Alma Berenice Méndez Sáenz - investigation, writing - original draft, resources, visualization.

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