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Article

Is Green Profitable? A Look at Carbon Efficiency and Returns in Brazil's Stock Market (B3)

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Abstract: This study explores the correlation between carbon emissions and financial performance in 73 companies in the Brazilian stock market(B3) and B3's Efficient Carbon Index (ICO2) in 2021. Linear regression models were used to analyze the impact of carbon emissions (EMC) on Profit per share (LPA), return on assets (ROA), and return on equity (ROE) while taking into account debt (END). We employed descriptive statistical methods to carry out this study and used ordinary least squares (OLS) and generalized least squares (GLS) estimation models. The econometric analysis software Gretl was used for linear regression analysis. The study found that, on average, companies with higher CO2 emissions had better financial performance in terms of EPS and ROE. However, the relationship between carbon emissions and financial performance is complicated, and the results should be interpreted cautiously, considering the study's limitations. This study aims to explore the correlation between carbon emissions and financial performance in 73 companies listed in B3's Efficient Carbon Index (ICO2) in 2021. Linear regression models were used to analyze the impact of carbon emissions (EMC) on Profit per share (LPA), return on assets (ROA), and return on equity (ROE) while taking into account debt (END). We employed descriptive statistical methods to carry out this study and used ordinary least squares (OLS) and generalized least squares (GLS) estimation models. The econometric analysis software Gretl was used for linear regression analysis. The study found that, on average, companies with higher CO2 emissions had better financial performance in terms of EPS and ROE. However, the relationship between carbon emissions and financial performance is complicated, and the results should be interpreted cautiously, considering the study's limitations.

Keywords: carbon emissions; financial performance; carbon efficient index; corporate sustainability

1. Introduction

Planet Earth finds itself at a crucial moment where the growing scarcity of natural resources is a global challenge. In this context, companies' environmental responsibility is central, as their environmental impacts are considerable and require immediate attention. Population growth and dependence on fossil fuels drive climate change, with greenhouse gas (GHG) emissions as the leading causes of the problem related to climate change. This scenario requires a paradigm shift, where sustainability becomes a fundamental pillar for the development of companies.

To encourage companies to adopt sustainable practices, the stock exchange (B3) created the Carbon Efficient Index (ICO2), which monitors the GHG emissions of listed companies. Companies that join the index must meet a series of environmental criteria, such as reducing GHG emissions, efficient use of natural resources, and adoption of sustainable practices. ICO2 is an essential instrument for promoting sustainability in the business sector. Companies that join the index can improve their image and become more competitive in the market (Ximenes et al.,2021). Strengthening the company's reputation as a responsible agent committed to sustainability can attract more conscious consumers and investors. At the same time, its strategic positioning in the market can meet the growing demands for environmentally responsible products and services.

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The environmental issue has been a hotly debated topic since the 1970s when it began to be treated with more importance. In 1972, the United Nations Conference on the Human Environment in Stockholm proposed the creation of environmental management instruments to promote a new type of development. As a result of this conference, the United Nations Environment Program (UNEP) was created. UNEP's current priorities are the environmental aspects of disasters and conflicts, ecosystem management, environmental governance, harmful substances, resource efficiency, and climate change (Schaller, 2020). In this context, pressure on companies, whether through governments or society itself, has increased and demanded increasingly sustainable solutions in the means of production and consumption in order to reduce environmental impacts.

The notion of development has changed over time, according to society's experience. In the past, development was associated only with economic growth, and companies were evaluated only by their revenue. However, growing concern about the environment led to a change in the development concept, which now includes sustainability (Mendonça et al. 2019). Today, a company's performance encompasses both economic, environmental, and social aspects.

There is still no consensus in academic literature on the impact of greenhouse gas (GHG) emissions on companies' financial performance. Some research suggests that low emissions can benefit financial performance, as it conveys to society an idea of business commitment to sustainability. Other research has found no relationship between GHG emissions and financial performance. Still, other research suggests that the impact of GHG emissions on financial performance may depend on the sector in which it operates and the country in question, whether developed or emerging. Thus, much disagreement exists about the relationship between carbon performance and financial performance (Meng et al., 2023).

The growing concern about environmental sustainability and climate change highlights the need to understand the relationship between carbon emissions and companies' financial performance. This study aims to investigate this complex relationship in the context of B3's Carbon Efficient Index (ICO2), seeking to determine whether companies with higher CO2 emissions perform better or worse than those with lower emissions. This study contributes to corporate sustainability and finance literature by providing empirical evidence of the relationship between carbon emissions and financial performance in the Brazilian context. This information is relevant for companies, investors, and public policymakers. This study provides a solid foundation for future research and contributes to the debate on the role of companies in mitigating climate change.

The work's structure consists of an introduction, literature review and hypotheses, methodology, analysis of results, and final considerations.

2. Literature Review and Hypotheses

2.1. Carbon Emissions and Financial Performance

While the topic of low-carbon development is gaining increasing attention due to global warming, there is still much disagreement about the relationship between carbon performance and financial performance (Meng et al., 2023).

Several studies present consistent evidence that there is a positive relationship between environmental performance and company financial performance. Lewandowski (2017) analyzed the relationship between environmental performance and company financial performance in terms of reducing carbon emissions and adapting to climate change. The author concluded that companies that adopt sustainable practices have low carbon emissions. As a result, companies obtain competitive advantages and greater profits, while companies that do not care about the environment and have high carbon emissions suffer economic and reputational losses.

Desai et al. (2022) also examined the impact of carbon emissions on companies' financial performance. For the authors, carbon emissions significantly negatively impact financial performance measures. Although carbon efficiency is closely related to resource efficiency, it also has

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distinct impacts on financial performance, particularly in reducing systematic risk (Trinks et al., 2020).

Sectoral studies were also carried out. In a recent study, Sampaio (2022) analyzed how climate performance affects the financial performance of banks in 42 countries with different levels of development. He found a positive and statistically significant association between climate performance and banks' ROA (return on assets), but only in developed countries. This result suggests that banks that care about the climate have a financial advantage. Amorim (2023) states that sustainability can benefit textile companies that adopt it financially. A study compared two companies in the textile sector that implemented sustainability strategies with others that did not. The study found that sustainable companies saw a significant increase in their profits, returns on equity, and investment. Sustainability can be a competitive differentiator for textile companies, as they can attract more investors and consumers.

The study by Gonçalves (2020) examined the influence of investments in environmental management on the financial performance of companies in the mining sector, using Vale, Petrobras, and Natura as a sample from 2008 to 2012. The results indicated that companies that invested in environmental management presented good financial results in both profitability and growth. These results suggest that investments in environmental management can contribute to increasing companies' financial performance. This can be attributed to several factors, such as reducing costs, increasing productivity, and improving the company's reputation among *stakeholders*. Cruz (2020) analyzed the impact of adhering to B3's Carbon Efficient Index (ICO2) on the economic-financial performance of 13 companies linked to agribusiness in Brazil. The results showed that companies that joined ICO2 had a reduction in short-term debt and a high capacity to finance their working capital needs. However, a profitability drop and an average term increase were also observed.

Soares et al. (2019) investigated the relationship between companies' characteristics and their greenhouse gas (GHG) emissions levels. The sample included 140 publicly traded Brazilian companies, with data covering 2015 to 2019. The results showed that the company's sector is the most important characteristic for determining the level of GHG emissions. Companies in more energy-intensive sectors like oil and gas had higher emissions. Reducing greenhouse gases leads to an increase in financial performance in the entire sample and clean industries, while it has no significant effects on financial performance in dirty industries (Iwata and Okada, 2011).

Castilho (2021) analyzed the relationship between climate change adaptation and mitigation strategies (EAMMC) and corporate financial performance in Brazil. The results reveal a positive and significant relationship between the EAMMC and the financial performance of companies, suggesting that implementing strategies to deal with climate change by companies can generate many benefits, both social and environmental as well as economic. Faria (2023) indicates that sustainability practices positively affect companies' economic and financial performance. This effect is explained by turnover but not by personnel costs.

Prates (2023) highlighted that the Brazilian capital market does not penalize the voluntary disclosure of carbon emissions. On the contrary, companies that disclose their emissions data, even if they are polluting, obtain a reduction in their cost of capital. This result can be explained by the signaling theory, which points out that the disclosure of relevant information can be seen as a positive signal by issuers. In the case of carbon emissions, disclosure can be interpreted as a sign that the company is concerned about the environment and is committed to reducing its environmental impacts.

Thus, the relationship between ESG practices and corporate financial performance, focusing on the role of environmental commitment, has been of interest to academic studies. The results show that ESG practices positively influence financial performance, primarily environmental and corporate governance practices. CO2 emissions, on the other hand, deteriorate financial performance (Neves, 2022). Siddique et al. (2020) argue that companies with better carbon performance are more likely to disclose information about their carbon emissions. This can be explained by companies committed to sustainability being more likely to be transparent about their environmental practices.

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Aswani et al. (2024) highlight that companies in the USA with high levels of carbon emissions and significant changes in these emissions tend to obtain higher stock returns.

The study also identified that companies have been seeking to be more efficient over the years but that it is still difficult to find mention of ICO2 in annual and sustainability reports. Companies that were part of B3's Carbon Efficient Index (ICO2) performed better in the Ibovespa Index (Da Silva, 2022).

Based on the information previously cited in the literature review, the following hypotheses are inferred:

H1: *Companies with better financial performance have lower carbon emissions.*

H1a: *Companies with better financial performance, measured by EPS, have lower carbon emissions.*

H1b: *Companies with better financial performance, measured by ROE, have lower carbon emissions*

H1c: *Companies with better financial performance, measured by ROA, have lower carbon emissions*

2.1. Green Innovation and Financial Performance

A study by Li et al. (2023) investigated the impact of green innovation on the construction sector in China. The results showed that green innovation has a positive effect on reducing carbon emissions in the construction sector in China. However, this effect is heterogeneous and depends on several factors, including the region, the innovation element, and the type of development. Results from a panel threshold model showed a significant non-linear relationship between green innovation and carbon emissions when the intensity of environmental regulation is used as a threshold variable. This suggests that green innovation may effectively reduce carbon emissions in environments with strong environmental regulations.

According to Yuan et al. (2023), green innovation influences carbon emissions performance in Chinese cities differently. The study used data from 218 cities from 2007 to 2013 and classified green innovation into four categories: product innovation, process innovation, organizational innovation, and marketing innovation. The results indicated that green innovation has an overall positive impact on carbon emissions performance. However, this impact varies according to the type of innovation and the type of city. Green innovation can contribute to the reduction of carbon emissions by reducing the energy intensity of consumption, by favoring the transition to cleaner industries, by increasing the energy and environmental efficiency of cities and by strengthening the environmental management capacity of local governments.

Thus, green technologies positively impact the efficiency of carbon emissions. In global warming, the search for efficiency is essential for countries and organizations, and green technological innovation is essential for environmental protection and energy conservation. Green technologies can help reduce carbon emissions, improve energy efficiency, and promote industrial modernization (Zhang & Liu, 2022). Töbelmann and Wendler (2020) examined the effects of environmental innovation on carbon dioxide emissions in European Union countries between 1992 and 2014. The study found that environmental innovation contributed to reducing emissions, but this effect is small compared to increased economic activity. Furthermore, the effect of innovation differs between countries, with less developed economies showing a higher level of heterogeneity. In this sense, Shan et al. (2021) showed that green technological innovation and renewable energy negatively affect carbon dioxide emissions, while energy consumption, population, and per capita income positively affect carbon dioxide emissions.

It is necessary to invest in long-term policies to maximize the effect of green technological innovation. (Shao et al., 2021). According to the authors, green technological innovation reduces CO2 emissions in the short and long term. However, the effect is more significant in the long term, with a 10% reduction in CO2 emissions compared to 5% in the short term. These results suggest that green technological innovation is vital for reducing CO2 emissions. A study by Guo et al. (2021) analyzed how green innovation and investment in the energy industry affect China's CO2 emissions. The

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results indicated that green innovation and investment in the energy industry are essential for reducing CO2 emissions in the long term.

Paramati and Huang (2021) argue that green technology requires significant R&D investments to develop new technologies that are more energy-efficient and less polluting. A well-functioning financial market is essential for improving technological progress as it provides capital for R&D investments.

Based on the information mentioned above, the following hypothesis is inferred:

H2: *Companies with more incredible innovation have lower carbon emissions.*

3. Methodology and Data Analysis

This investigation seeks to verify the specific hypotheses established in the previous section. This study aims to investigate this complex relationship in the context of B3's Carbon Efficient Index (ICO2), seeking to determine whether companies with higher CO2 emissions perform better or worse than those with lower emissions.

3.1. Variables and Descriptive Statistics

For the study, 73 companies listed on the Brazilian stock exchange (B3), which make up the B3 Carbon Efficient Index (ICO2 B3), were considered. The data used refers to the year 2021. The variables include revenue, CO2 emission, ROE (Return on Capital), ROA (Return on Assets), EPS (Profit per share), Debt (END) (Liabilities/assets), and INO (innovation) ranking by PWC and Jornal Valor Econômico with the 150 most innovative companies in 2021.

The chosen indicators are described in Table 1, with a description of the variables below:

Table 1. Description of variables.

VARIABLE	ACRONYM	DESCRIPTION	SCALE	SOURCE
1. Recipe	RCT	These are all resources arising from the sale of goods or the provision of services over a certain period.	Monetary (R$ million)	stock Exchange
2. Total Emissions (tCO2e)	EMC	Number of tons of carbon dioxide equivalent emitted in the base year.	Numeric (tons)	stock Exchange
3. Return on Equity	ROE	It measures the ability of a business to add value to itself using its resources. (Ratio between net profit/Net Equity).	%	Statusinvest
4. Return on Assets	ROA	Measures the profitability and total profit capacity of an asset within an organization. (Ratio between net profit/total assets x 100).	%	Statusinvest
5. Earnings per Share	LPA	It represents the portion of the company's net Profit generated that belongs to each share it owns (the Ratio between net Profit and the number of shares traded on the stock exchange).	Numeric	Statusinvest

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5. Debt	END	It measures a company's degree of financial leverage by comparing its assets with its total short and long debts (Liabilities/Assets Ratio).	%	Statusinvest
6. Innovation	INO	Valor Innovation Brazil 2021 Award from PWC and Jornal Valor Econômico Ranking among the 150 most innovative companies in 2021	1-150	PWC and Valor Econômico

3.2. Descriptive Statistics

Table 2 presents some descriptive statistics on the variables used in the empirical analysis. The data makes it possible to highlight some relevant aspects.

Table 2. Statistical description of variables.

Variable	Average	Median	Standard deviation	Minimum	Maximum
Revenue (R$ million)	49686	19763	86918	992.3	567400
Total Emissions (Ton)	2331000	460700	7635000	595	61750000
ROE%	22.60	16.49	28.82	-34.30	177.8
ROA%	5,189	5,090	9,092	-50.14	23.60
EPS%	2,453	1,380	3,132	-3,340	17.54
Debt	0.6882	0.6800	0.3320	0.00	2.46
Innovation	31.27	0.00	43.03	0.00	149

The Revenue variable (RCT) of the 73 companies present on the Brazilian stock exchange for 2021, which are part of B3's carbon efficient index, has an average value of 49.686 million. The median is 19.763 million and has a standard deviation of 86.918 million. The company with the lowest revenue value is Iguatemi, with a value of 992.3 thousand, and the company with the highest value is Petrobras, with 567.45 million. Furthermore, the other companies with the best positions in the ranking were JBS (361.41 million), Itaú (203.25 million), and Raízen (199.38 million).

The total emissions variable reveals which companies are the biggest emitters of CO2 into the atmosphere: those that pollute the most. This variable has an average value of 2.33 million tons. The median is 460.7 thousand tons, with a standard deviation of 7.63 million tons. The company that emits the least carbon is Ez Tec Empreendimentos e Participações SA, with 595 tons, and the company with the largest emission is Petrobras, with 61.75 million tons of CO2. In addition to these, we can highlight other companies that emit the most, such as Companhia Siderúrgica Nacional (13.87 million), Gerdau (12.08 million), and Braskem (11.14 million).

The dependent variable, return on equity (ROE), is an essential financial indicator that measures a company's ability to generate value through its initial resources. In other words, it shows how much Profit is generated from the capital invested. It presents an average value of 22.60%, a median of

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16.49% standard deviation, and an average of 28.82%. The company with the lowest value is Gol Linhas Aéreas Inteligentes SA, with -34.30%; this result means that the company is spending more than it receives, recording a loss. The company with the highest value is BRASKEM SA, with 177.8%. The other companies with the best results in return on equity are Marfrig Global Foods SA (110.85%), Minerva (91.55%), and Companhia Siderúrgica Nacional (60.34%).

The dependent variable return on assets (ROA) is an essential financial indicator that indicates what percentage of assets should return profitability to the business. It indicates whether companies know how to use their assets to generate Profit. The average return on assets of companies in the B3 carbon efficient index is 5.18%, and the median is 5.09%. It has a standard deviation of about an average of 9.09%. It points to Gol Linhas Aéreas Inteligentes SA as the company with the lowest value of -50.14%. The company with the highest value was CSN Mineração SA, with a maximum of 23.60%. The other companies with the best results in return on assets are Usiminas (22.97%), Gerdau SA (20.99%), and Companhia Siderúrgica Nacional (15.44%). CSN Mineração SA is the organization that best uses its assets to generate profits and is achieving a good return on investments in its assets. However, when a company presents a negative ROA, it means that the assets it acquired are not profitable for the business.

The dependent variable, Earnings per Share (EPS), has an average of 2.453, a median of 1.38, and a standard deviation of 3.132. Azul SA presented the lowest value of -3.34, which indicates that the organization suffered losses during the period analyzed. Braskem presented the maximum value of 17.54, indicating that it is the company that presents the highest net Profit for each share it owns.

The variable, indebtedness (END), measures a company's financial leverage; the liability/asset ratio measures it. High financial leverage can indicate risk, indicating that the company is more dependent on external financing to finance its operations. Portfolio data shows a mean of 0.68, a median of 0.68, standard deviation of 0.33. The company with the lowest value is Tim, which is 0.00; this could mean two possibilities: the company does not need third-party capital to finance its operations, or the company has sufficient net worth to cover all its debts. The highest debt value was with Gol Linhas Aéreas Inteligentes SA, with 2.46. This means that for every R$1.00 in assets, the company has R$2.46 in liabilities. In other words, the company has more liabilities than assets, which indicates high financial leverage. Other companies with high leverage are Azul SA (1.99), Bradesco (1.07), and Minerva SA (0.97).

Finally, the innovation variable (INOV) ranking by PWC and Jornal Valor Econômico among the 150 companies was the most innovative in 2021. The research evaluates, consistently and systematically, the innovation practices of companies operating in Brazil in different economic activities. Participating companies must have at least 5% private participation in their capital and have a net revenue in Brazil above R$500 million in one of the last two fiscal years.

The creation of the ranking is based on five pillars of the innovation chain: intention to innovate, effort to carry out innovation, results obtained, market assessment, and generation of knowledge. The objective is to analyze how each of these pillars is built-in companies located in Brazil and how this is reflected in the innovation practices of each participant. Based on a model specially developed for the Brazilian environment and qualitative and quantitative indicators, the research highlights companies that adopt the best innovation management, their investments in the local market, and the results achieved. The average of this variable was 31.27%, with a median of 0, a standard deviation of 43.03, a minimum of 0, and a maximum of 149. The best-placed company was EMBRAER, in the 1st position, followed by WEG in the 2nd position, and the last place was BANCO DO BRASIL, in the 149th position.

5. Model and Estimation Method

If linearity assumptions and correct model specifications are met, the OLS (Ordinary Least Squares) or least squares method can be used to estimate our cross-section models, *as indicated below*. However, if hypothesis violations are detected, such as a violation of homoscedasticity, alternative

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estimation methods, such as the GLS (Generalized Least Squares) or robust errors, must be applied, as they are more efficient in the occurrence of heteroscedasticity.

Gretl was used in econometric research; it has a wide variety of estimators based on ordinary least squares, maximum likelihood, and the generalized method of moments and can be used to analyze different types of data, such as time series, *cross-section*, and panel data.

A log-log model specification was assumed to present better results. In the log-log model, the estimated coefficients represent elasticities and show the absolute variation of the dependent variable as a function of an absolute variation of the explanatory variable. Follow the model specifications (1).

Model (1):

$$lnLPA = \alpha_0 + +\alpha_1 lnEMC_i + u_i \quad (1)$$

The dependent variable of the model (1), EPS (Earnings per Share) (Eq. 1), is an indicator that shows how the portion of the company's Profit is allocated to each outstanding share of that company on the stock exchange. This is a very important metric for both company managers and investors. It is calculated by dividing the company's net Profit by the total number of shares it has. Estimating Equation (1), it is expected to negatively correlate with Total Emissions (EMC).

Model (2):

$$\boldsymbol{lnROE = \alpha_0 + \alpha_1 lnEMC_i + \alpha_2 lnEND_i + u_i} \quad (2)$$

The dependent variable of the model (2), ROE (Return on Net Equity) (Eq. 2), is a financial indicator that measures a company's profitability, considering its net worth. In other words, ROE shows how much the company earns in relation to the money its shareholders invested. It is calculated by multiplying net Profit by net worth x 100.). A **negative correlation is expected between ROA** and debt (END) and total emissions (EMC).

Model (3):

$$\boldsymbol{lnROA = \alpha_0 + \alpha_1 lnEMC_i + \alpha_2 lnEND_i + u_i} \quad (3)$$

The dependent variable of the model (3), ROA (Return on Asset) (Eq. 3), Return on Asset (ROA) is an essential measure for investors as it indicates how a company is using its resources to generate profits. A high ROA indicates that the company is being efficient in its operations and is generating significant profits. Estimating Equation (3), it is expected that there will be a **positive correlation** between ROE and the following variables: revenue (RCT), Emissions (EMC), and Innovation (INOV). We expect a **negative correlation** with debt (END).

6. Analysis and Discussion of Results

Table 3 presents the regression results for the dependent variables EPS, ROE, and ROA. In general, the results are satisfactory in terms of the quality of fit and statistical significance of the coefficients.

Table 3. Estimation results from Equation (2). LPA, ROE, ROA.

Variables	Model (1) (OLS - LPA)	Model (2) (OLS - ROE)	Model (3) (OLS - ROA)	Model (4) (GLS-ROA)
Const	−2,77400 (***)	1.53608(**)	−2,07166(***)	−1,65847(**)
	0.0032	0.0292	0,0071	0,0220
lnEND	*	0.816199(**)	-1.03905(***)	−0,968122 (***)
		0.0194	0.0063	<0,0001
lnEMC	0.144946 (**)	0.131659(**)	0.244978(***)	0.214346(***)

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	0.0270	0.0116	<0.0001	0.0001
R-squared (R^2)	0.189893	0.188451	0.277580	0.342811
F- Stat	F(2, 64) 7.500947	F(2, 64)	F(2, 64) = 12.29555	F(2, 64) =16.69223
Joint	p-value (F)	7.430765	p-value = 0.000030	p-value =
significance	0.001184	p-value (F)		0.00000147
		0.001253		
Heteroscedasti	LM = 0.959872	LM = 2.30403	LM = 16.3592	*
city	p-value =	p-value =	p-value =	
(White's test)	0.965737	0.805674	0.00588989	
				*
Specification	F(2, 62) =2.20619	F(2, 62) = 2.79145	F(2, 62) = 1.37022	
(Ramsey reset)	p -value = 0.118693	p -value = 0.0690561	p -value = 0.261637	
Comments (#)	73	73	73	73

Notes: ***, **, * indicate that the coefficients are statistically significant at the 1%, 5%, and 10% levels, respectively; p-values of the coefficient significance are underneath the estimates; (#) due to missing data, the initial set of countries reduced significantly.

The RESET test did not reject the null hypothesis that models 1 and 2 have adequate specifications. Model 3, however, presents heteroscedasticity, as White's test indicates. To correct heteroscedasticity in model 3, the GLS (*Generalized Least Squares*). GLS is more efficient in heteroscedasticity, resulting in more accurate estimates, as in Model 4.

The GLS model for ROE presents an R—*R-squared* of 0.34, indicating that the explanatory variables explain 34% of the ROE variability the explanatory variables explain. The F statistic validates the joint significance of the coefficients.

The results of the estimates of the models used are described in Table 3.

Interpreting the marginal impacts of the explanatory variables, we can predict, on average, that a 1% increase in CO2 emissions is expected to be 0. 144946% increase in Earnings per share (LPA) (model 1) of the selected companies, with a (p-value=0.0270) (significant at 5%), that is, there is a high chance (greater than 95%) that this effect is accurate and that CO2 emissions are influencing companies' EPS. This model 1 explains only 18.99% (R- *squared)* of the variability in earnings per share depending on emissions, which means that other factors, besides CO2 emissions, influence companies' earnings per share. The results **do not confirm hypothesis H1a,** which states that companies with better financial performance, measured by EPS, have lower carbon emissions, according to model 1.

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In the analysis of equation 2, where ROE is the dependent variable. For model 2, a 1% increase in debt is associated with an average increase of 0.816199% in ROE. On average, companies with higher CO2 emissions tend to have a higher ROE. On average, a 1% increase (in tons) in CO2 emissions is associated with a 0.131659% increase in ROE. This model 2 explains only 18.85% of the variability in ROE, which means that other factors, besides debt and CO2 emissions, influence companies' ROE. The results do not confirm hypothesis H1b, which states that companies with better financial performance, measured by ROE, have lower carbon emissions.

Analyzing model 3, referring to equation 3, indicates a positive relationship between CO2 emissions and companies' Return on Assets (ROA). On average, a 1% increase in CO2 emissions is associated with a 0.214346% increase in Return on Assets. There is a negative relationship between debt and Return on Assets. A 1% increase in debt is associated with a 0.968122% decrease in Return on Assets, on average. The model explains 34.28% (R- *squared*) of the variability in Return on Assets, which means that other factors, besides CO2 emissions and debt, influence companies' ROA. The results do not confirm the H1c hypothesis, which states that companies with better financial performance, measured by ROA, have lower carbon emissions.

Hypothesis 2, which states that companies with greater innovation have lower carbon emissions, cannot be tested due to the lack of statistical significance about the other variables. This result can be attributed to the fact that not all selected companies, which are part of the efficient carbon index, are also present in the PWC and Valor Econômico newspaper rankings. This intersection between groups of companies may have influenced the statistical results.

6.1. Discussion of Results

Analyzing the empirical results of the research, we found that other authors also found similar results.

Soares et al. (2019) investigated the relationship between companies' characteristics and their greenhouse gas (GHG) emissions levels. The sample included 140 publicly traded Brazilian companies, with data covering 2015 to 2019. The results showed that the company's sector is the most important characteristic for determining the level of GHG emissions. Companies in more energy-intensive sectors, such as oil and gas, had higher emissions associated with better financial performance. Meng et al. (2023) state that the complex relationship between carbon and finance is influenced by several factors, such as the type of industry, regulation and policies of the sector and country, and moment of analysis (whether short or long-term). In the Brazilian scenario, the largest emitter is Petrobras, which produces 61.75 million tons of CO2. In addition to these, we can highlight other companies that emit the most, such as Companhia Siderúrgica Nacional (13.87 million), Gerdau (12.08 million), and Braskem (11.14 million). These companies fall within the oil, gas, mining, and steel sectors. These companies stand out for their high ROE and ROA. In Brazil, companies in energy-intensive sectors, such as oil and gas, have the highest GHG emissions and, historically, the best financial performances. In this sense, waste emissions generally do not significantly affect financial performance.

Aswani et al. (2024) highlight that academic literature generally uses unsized emissions (gross emissions), while practice uses emissions intensity (emissions per unit of production). Unscaled emissions correlate with stock returns, but emissions intensity does not. It is argued that for individual companies, emissions intensity is the most appropriate measure to assess carbon performance.

On the other hand, reducing greenhouse gases increases financial performance in the entire sample and clean industries. At the same time, it has no significant effects on financial performance in dirty industries (Iwata and Okada, 2011). This corroborates our studies and highlights the need for a sectoral analysis for future research.

Aswani et al. (2024) highlight that companies in the USA with high levels of carbon emissions and significant changes in these emissions tend to obtain higher stock returns. This relationship can be explained by the high cost of equity that these companies face due to the risk of transitioning to a

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low-carbon economy. The authors state that only if the shares of companies that emit high carbon emissions are heavily undervalued will these companies have significant incentives to reduce their emissions. Investors can pressure companies to reduce their emissions through dialogue, pressure, and other forms of engagement. Therefore, markets must recognize transition risk, as companies may not make efforts to reduce their emissions, and investors may not prioritize the decarbonization of their portfolios.

We highlight the importance of green innovation for companies seeking to migrate to a low-carbon economy. Zhang & Liu (2022) demonstrate that green technologies can significantly reduce carbon emissions, positively impacting the economy and quality of life. Green technologies are essential for reducing carbon emissions, improving energy efficiency, and promoting sustainability in various sectors. Through green technological innovation, we can reduce greenhouse gas emissions, combat global warming, improve energy efficiency, optimize the use of resources and reduce costs, and promote industrial modernization, boosting the competitiveness and sustainability of productive sectors.

However, the results raise questions about whether market forces alone are enough to drive the shift towards a low-carbon economy. Some companies may choose not to invest in reducing their emissions, benefiting from higher profits and returns, even if this has long-term negative impacts on society.

In summary, thoroughly assessing the risk of transitioning to a low-carbon economy is crucial for a successful transition and a more sustainable economy.

7. Final Considerations

This study investigated the relationship between carbon emissions and the financial performance of companies listed in B3's Carbon Efficient Index (ICO2). To this end, statistical regression techniques were employed in the Gretl software to analyze econometric data.The findings of this study were consistent with prior research on the relationship between CO2 emissions and financial performance. The Ordinary Least Squares (OLS) and the Generalized Least Squares (GLS) methods were used for estimation. The study analyzed data from 73 companies on the B3 stock exchange that reported their emissions in 2021.

The study identified a positive correlation between Earnings per share (LPA) and total emissions (EMC). Specifically, it found that higher CO2 emissions corresponded to higher profits per share. Additionally, it revealed a positive relationship between Return on Equity (ROE) and Emissions (EMC) and Return on Assets (ROA) and Emissions (EMC).

The study recommends that future research focus on sectoral analysis, as different sectors may present divergent relationships between emissions and financial performance. Moreover, the study emphasizes that the characteristics of the country where companies operate should be taken into account since regulations, policies, and the economic context can impact this relationship. For example, companies in energy-intensive sectors, such as oil and gas in Brazil, have historically exhibited the highest GHG emissions and the best financial performance.

Aswani et al. (2024) highlight that the correlation between returns and emissions applies only to unscaled emissions estimated by data providers, not to unscaled emissions actually disclosed by companies. Estimated emissions differ significantly from those disclosed and show a strong correlation with the companies' financial fundamentals. This suggests that past research has primarily captured the relationship between these fundamentals and returns, not the impact of emissions.

The study highlights the need for a low-carbon economy since carbon emissions are not yet priced in the market, resulting in no penalties for companies' environmental impacts. Lack of regulation may lead to opportunistic behavior, where companies emit more carbon to maximize their short-term profits without considering the long-term social and environmental costs. However, technologies to reduce carbon emissions can be expensive, particularly for firms in carbon-intensive

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sectors, creating a disincentive to invest in decarbonization measures if there are no financial incentives to offset the costs.

The study also points out its limitations, including the need for a more accessible and comprehensive database of both dependent and independent variables of the organizations present in B3. Furthermore, the CO2 emission data (EMC) provided by B3 is limited to 2021, and the relevance and statistical reliability would increase if data from more years were analyzed. Therefore, the study recommends that future studies have a more expansive and representative sample of companies, consider the heterogeneity between sectors, analyze companies in their specific contexts, and investigate the influence of macroeconomic and regulatory factors on the relationship between emissions and financial performance.

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