HOW DIFFERENT AND HOW ALIKE? CLUSTER ANALYSIS APPLIED TO GREENHOUSE GAS EMISSIONS INVENTORY DATA FROM COMPANIES LISTED ON THE BRAZILIAN STOCK EXCHANGE

Juliana Costa Ribeiro Prates[1]
Aline Souza Magalhães[2]
Thierry Molnar Prates[3]
Bruna Camargos Avelino[4]

ABSTRACT

Purpose: The purpose of this investigation is to understand how companies listed on the B3 that disclose emissions inventories in Brazil are similar or different, based on quantitative variables related to GHG (Greenhouse Gas) emissions intensity, company size, net operating revenue, the potential for investments in new technologies, communication, and socio-environmental responsibility.

Theoretical framework: Theoretical framework addresses corporate social responsibility (RSE) and the economic foundations of Regulation.

Method/design/approach: We used a multivariate cluster analysis technique on a sample of 31 companies listed on the Brazilian stock exchange that disclosed emissions inventories over the period 2012 to 2019.

Results and conclusion: The results showed that companies like Petrobras (cluster 4), as well as JBS, Vale, Ultrapar, and CBD (cluster 3), besides emitting more GHGs, are also larger companies, with higher revenues, committed to communication and socio-environmental responsibility. In addition, they incentivize their executives through higher monetary incentives. Because they have such distinct characteristics from other companies, these companies or sectors could be driven by incentives other than traditional regulation.

Research implications: The results suggest that large companies have, in some cases, anticipated regulation as they have incorporated environmental programs within their long-term strategies. In contrast, increased regulation may put pressure on smaller companies to adapt.

Originality/value: Our findings contribute to the literature by highlighting the characteristics of these companies that voluntarily disclose emissions inventories in Brazil. Furthermore, we indicate how they are similar or different according to financial, environmental, and social performance criteria.

Keywords: Emissions Inventories, Greenhouse Gas Emissions, Regulation, Cluster Analysis.

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[1] Universidade Federal de Minas Gerais (UFMG). Belo Horizonte, Minas Gerais, Brasil.
 E-mail: julianacrprates@gmail.com Orcid: https://orcid.org/0000-0003-1289-3937
[2] Universidade Federal de Minas Gerais (UFMG). Belo Horizonte, Minas Gerais, Brasil.
E-mail: alinesm@cedeplar.ufmg.br Orcid: https://orcid.org/0000-0003-3349-5372
[3] Universidade Federal Rural do Rio de Janeiro (UFRRJ). Seropédica, Rio de Janeiro, Brasil.
E-mail: thierry_prates@hotmail.com Orcid: https://orcid.org/0000-0003-4070-1605
[4] Universidade Federal de Minas Gerais (UFMG). Belo Horizonte, Minas Gerais, Brasil.
 E-mail: bcavelino@gmail.com Orcid: https://orcid.org/0000-0001-8958-8725

QUÃO DIFERENTES E QUÃO IGUAIS? ANÁLISE DE CLUSTER APLICADA AOS DADOS DE INVENTÁRIO DE EMISSÕES DE GASES DE EFEITO ESTUFA DE EMPRESAS LISTADAS NA BOLSA DE VALORES BRASILEIRA

RESUMO

Objetivo: Compreender de que forma as empresas listadas na bolsa de valores brasileira que divulgam inventários de emissões no Brasil se assemelham ou se distinguem, com base em variáveis quantitativas relacionadas à intensidade de emissões de GEE (Gases de Efeito Estufa), tamanho da empresa, receita operacional líquida, potencial para investimentos em novas tecnologias, comunicação e responsabilidade socioambiental.

Estrutura teórica: O referencial teórico aborda a responsabilidade social corporativa (RSE) e aos fundamentos econômicos da Regulação.

Método/desenho/abordagem: Utilizamos uma técnica de análise multivariada de cluster em uma amostra de 31 empresas listadas na bolsa de valores brasileira que divulgaram inventários de emissões no período de 2012 a 2019.

Resultados e conclusão: Os resultados mostraram que empresas como a Petrobras (cluster 4), assim como a JBS, Vale, Ultrapar e CBD (cluster 3), além de emitirem mais GEEs, são também empresas maiores, com maiores receitas, comprometidas com a comunicação e a responsabilidade socioambiental. Além disso, elas incentivam seus executivos através de maiores incentivos monetários. Por terem características tão distintas de outras empresas, estas empresas ou setores poderiam ser impulsionados por outros estímulos que não a regulamentação tradicional.

Implicações da pesquisa: Os resultados sugerem que as grandes empresas têm, em alguns casos, se antecipado a regulação, já que incorporaram programas ambientais dentro de suas estratégias de longo prazo. Em contraste, o aumento da regulação pode pressionar as empresas menores a se adaptarem.

Originalidade/valor: Os resultados contribuem para a literatura ao destacar as características dessas empresas que voluntariamente divulgam inventários de emissões no Brasil. Além disso, indicamos como elas são semelhantes ou diferentes de acordo com critérios financeiros, ambientais e de desempenho social.

Palavras-chave: Inventários de Emissões, Gases de Efeito Estufa, Regulamentação, Análise de Cluster.

1 INTRODUCTION

Since Kyoto Protocol, in 1997, the world carbon markets institutionalization took a relevant step forward. Developing countries, particularly Brazil, even though without the requirement to set goals for emission decrease of pollutant gases, have been able to participate in a lucrative new market, benefiting from the Clean Development Mechanism (CDM). An Important feature of this treaty allowed the purchasing of credits derived from projects which reduce greenhouse gas emissions (GHG) from non-participating countries (Uderman, 2010).

Therefore, the pursuit of cleaner energy has placed Brazil as an alternative investment option for developed countries demanding carbon credits. The idea is that these markets are beneficial both for buyers and sellers. On the one hand, it helps buyers to meet developed countries' emission targets, thereby reducing the high switching costs of existing production processes (Prates, 2019). On the other hand, sellers may establish revenue sources, improving companies' performance, as long as the implementation cost of carbon emission reduction processes does not surpass the revenues generated by trading the credits.

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Furthermore, this market provides a better reputation for companies' commitment to social and environmental responsibility, attracting investments by linking their brands with sustainability, adding product value, differentiating them, and boosting competitiveness (Alvarez, 2012; Matsumura, Prakash, & Vera-Munoz, 2013; Cheng & Liu, 2018; Karassin & Bar-Haim, 2019).

However, although carbon credits may represent a potential market niche for Brazil, generating additional revenue through environmental services exports, in its current design they are often considered as a license to pollute. This argument relies on the argument that the failure to comply with the determined reduction targets would be eliminated by acquiring carbon credits as compensation, avoiding possible legal penalties.

This behavior tends to reinforce Gneezy and Rustichini's (2000) arguments where the penalty for failure to comply with targets is perceived as an incentive for non-desirable behavior. However, from the regulation perspective, which is the mother of all socio-environmental innovations, it is possible to establish a common baseline, able to significantly reduce competition problems caused by the costs versus benefits of environmental efforts in companies (Prates, 2010; Karassin & Bar-Haim, 2019).

Most of the existing studies used an *ex-post* approach when exploring the impacts of regulation from the regulatory framework with the National Policy on Climate Change (PNMC, law 11.187/2009). The intention was to identify changes and evaluate possible scenarios on environmental externalities. Our study expands this knowledge by seeking to identify the characteristics of companies that choose to proactively control and disclose GHG emissions. That is, they anticipate regulation by disclosing this data. We emphasize that in Brazil, there are few companies that choose to conduct and disclose emission inventories (Magalhaes, 2013; Prates, 2019).

The purpose of this investigation is to understand how companies listed on the B3 that disclose emissions inventories in Brazil are similar or different, based on quantitative variables related to GHG (Greenhouse Gas) emissions intensity, company size, net operating revenue, the potential for investments in new technologies, communication, and socio-environmental responsibility. The research contributes to the literature to highlight the characteristics of these companies, seeking to understand how firms that voluntarily disclose emissions inventories in Brazil are similar or different according to financial, environmental, and social performance criteria.

We chose to use the clustering technique of companies that perform the disclosure (evidencing) of carbon emissions inventories and sort them according to the similarity in characteristics of pollution potential, industry sector, size, net operating revenue, investment potential in new technologies and adaptation of low carbon production process, communication, and socio-environmental responsibility.

The study's relevance lies in providing information to guide regulatory policy toward the decrease of GHG emissions, considering the firm's characteristics, such as investment potential in new technologies and their behavior regarding emission mitigation policies. The results reveal that large firms, to some extent, have already anticipated regulation, by implementing environmental management systems, labels, standardization, and/or technological innovation policies. In turn, regulatory tightening may force smaller firms to be more compliant.

The article is organized in five parts, including this introduction and final considerations. Part two, the theoretical framework, raises the key theories related to the environment, environmental policy, carbon market, and environmental regulation. Subsequently, in part three, we describe the data and introduce the cluster analysis methodology as well as the employed variables. In the fourth section, the statistical findings from the cluster analysis are addressed. At the end, the concluding remarks are given.

2 THEORETICAL FRAMEWORK

Theoretical framework explores two relevant topics: i) Current corporate dynamics and its relationship with environmental issues and, ii) Environmental policy instruments and regulation. Together, both allow the establishment of analytical bases for the discussion of our findings.

2.1 Corporate Dynamics and Environmental Issues

In the so-called Eco-Industrial Revolution, environmental preservation actions have changed not just the corporate profile in consumers' eyes, but also the way companies produce and discard residues, often directly impacting their profit margins (Costa, 2005; Cheng & Liu, 2018). Companies' environmental, social, and governance (ESG) engagement has been growing and reflects a concern that is being addressed as a competitiveness mechanism, a development and survival strategy for companies in business. However, this concern with the environment is rarely raised by environmental awareness alone, rather it emerges in response to market demands (Costa, 2005; Alvarez, 2012; Matsumura et al., 2013; Cheng & Liu, 2018; Peng, Tu, Elahi, & Wei, 2018).

The adoption of mechanisms that foster organizational change or environmental technology often implies high costs, taking place in the context of strong regulation or serious scarcity of a given natural resource. In addition, the escalating natural resources demand comes from an intensively diversified universe, due to global interconnectedness, but the theme is being more and more discussed as global ecological awareness has grown.

In Brazil, the environmental laws can be described as modern, but there is a challenge in the enforcement, for a lack of human and material resources, especially concerning smaller companies (Prates, 2006), in this sense, only bigger companies would be motivated to get involved with environmental issues. Note that these firms are the ones responsible for eco-efficient growth in Brazil (Marcovitch, 2014; Prates, 2019).

According to Lustosa (2003), the determinants of environmental investment are: i) environmental regulation - incentives for companies to become less aggressive and take measures to reduce environmental problems; ii) pressures from final and intermediate consumers - have substantially increased with the rise of environmental awareness, but still shows huge differences between rich and poor countries iii) Stakeholders pressure - civil society, congressmen, resident populations around a business that produces negative environmental externalities, Non-Governmental Organizations (NGOs) and environmentalists. iv) Investors pressure - risk of financial liabilities deriving from environmental violations.

Costa (2005) emphasizes some of the reasons given for this growing corporate interest in the environment, highlighting seven points: i) the continuity of companies, which is related to the need for technologies that enable the sustainable generation of basic resources for the maintenance of some important sectors of the economy, such as, for example, energy and cellulose. ii) market opportunities: an example of a market generated from environmental preservation actions is the sale of CO_2 absorption quotas; iii) competitiveness: consumers are beginning to prefer environmentally friendly products; iv) market continuity: the increasingly tighter environmental standards have contributed to less prepared companies not being able to survive in the market; v) financial market: new regulations and a climate of aggressive legal disputes, making an environmental health certificate vital to secure investments and financing for new projects in a wide range of productive sectors; vi) legal and criminal liability: new environmental protection laws have required several companies to adapt their technology, otherwise their implementation or expansion will become unfeasible; and finally, vii) globalized information: broader access to information by all firms in the market.

Based on the different corporate motivations in caring for finite natural resources, we discuss some environmental policies and regulations that seek to internalize harmful aspects or effects in corporate routine.

2.2 Environmental Policy Instruments and Regulation

GHG emission reduction policies are founded upon the idea of conserving a public good globally, whose benefits extend to everyone. However, a recurring argument is made that the process costs of mitigating negative externalities are transferred only to the ones who pay for these actions, and the benefits resulting from these measures will only be felt in the future, inhibiting efficient policies in the present (Baumol & Oates, 1971; Daly, 1992; Magalhães & Domingues; 2013).

The common microeconomic argument which defines the role of regulation is that rules are meant to fix market failures. Energy efficiency standards, when carefully implemented, can strengthen policies via cost-efficient market mechanisms. Regarding environmental policy and regulation, the purpose is to ensure that external pollution costs are fully absorbed by the polluters behind it. For many years, industry's environmental cleanup needs were ignored by most nations trying to slow down regulatory enthusiasm that arose in the 1960s/70s following several scientific papers and books predicting depletion of resources (Boulding, 1966; Georgescu-Roegen, 1970; Baumol & Oates, 1971; Meadows et al., 1972). The core rationale behind this idea was that production adjustment costs would exceed by far the benefits, and that technology was not sufficiently developed to fulfill these requirements satisfactorily and cheaply.

Brazil was the first country to sign the Climate Change Convention, which resulted from the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 and proposed to participate voluntarily through Clean Development Mechanism (CDM) initiatives. It was expected that either via carbon market or carbon taxation, Brazil could have a high potential to assure and enable compliance with voluntary emission targets defined by the National Policy on Climate Change (PNMC, law 11.187/2009). The increasing popularization of trading emissions has led to the emergence of a range of carbon markets over the past decade.

However, the emphasis has been concentrated primarily on deforestation control and regulatory measures and incentives (Brazil, 2010). So far, the PNMC has not considered such mechanisms, and enforcement has not yet occurred. Under this scenario, the PNMC's chance of success is even lower, and the costs (of verification and monitoring) may be high or zero (if it is not happening) (Magalhães, 2013).

Regulation moved slower until the 1990s, especially in developing countries. In the mid-1990s, the environment came back to the industry's central agenda, with the Rio 1992 Earth Summit and researchers such as Michael Porter. Some papers by this researcher pointed out that the conflict concerning environmental protection and economic competitiveness would be a false trade-off for many industrial activities (Porter, 2006; Porter & Linde 1995a; Porter & Linde 1995b). The so-called "Porter Hypothesis" would show evidence that many competitive firms are able to innovate more effectively by responding to a regulatory stimulus. The hypothesis itself would not prove that firms could always innovate to reduce environmental impact cost-effectively, but it would denote that there are considerable opportunities to abate pollution through innovations in redesigning products, processes, and methods of operation. Thus, the picture has started to change more quickly.

Environmental solutions employed by companies can be divided into two main categories: End of Pipe Solutions (EOP) and Pollution Prevention (PP). The first one, which was more typical at the beginning of environmental regulation, merely provided a solution to remediate pollution that already occurred, such as filters for gas and particulate pollution and effluent treatment plants. The second group of solutions, and much more effective, is the entire

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change in the production process, applying more efficient technologies, which can avoid pollution before it occurs, such as input changes, waste recovery, water reuse and self-cleaning cycles, etc. These PP solutions are perfectly in line with Porter's hypothesis, by significantly reducing the utilization of inputs, water and energy, therefore transforming production to be more efficient, economical and clean (Prates, 2006).

Concerning regulatory aspects, policies to enforce targets and emissions tend to be uniform for different sources. In practice, however, emissions control means, and costs differ across sectors and companies, often considerably. Indeed, there can be considerable differences between costs of reducing GHG emissions - some companies for example might be able to install pollution control equipment more cheaply than others. Regulation that requires an identical level of abatement from all polluters is neither the most efficient nor the least costly way to achieve a desired reduction in total pollution (Behr, Witte, Hoxtell, & Man, 2009). In this respect, market-based approaches have been discussed extensively, such as carbon taxation and cap-and-trade policies (Chelly, Nouira, Hadj-Alouane, & Frein, 2021).

There are three main categories of environmental policy instruments that intend to internalize externalities (Kemp, Smith, & Becher, 2000). The first one is Command and Control, and it happens when government intervention is direct and objective. This is the so-called direct regulation, which establishes rules, standards, and procedures that must be followed by polluting agents, as well as fines and penalties in response to non-compliance. Table 1 shows their typology.

Table 1. Typology and Instruments of Environmental Policy

Command and Control	**Economic Instruments**	**Communication Instruments**
- Product control or ban	- Fees and tariffs	- Provision of information
- Process Control	- Subsidies	- Agreements
- Bannig or restriction of activities	- Certification of tradable emissions	- Networking
-Technological specifications	- Deposit return systems	- Environmental management system
-Control of the use of natural resources		- Environmental labels
-Pollution standards for specific sources		- Environmental marketing

Source: Kemp, Smith, and Becher (2000)

The second category is economic instruments. These are considered to be important economic incentives and drivers for responsible behavior. Market mechanisms have two main appeals. Firstly, they enable companies and individuals to voluntarily choose to reduce GHG emissions since there are minimal costs to doing so, reaching a given level of pollution control at less cost than enforcing the regulation. Secondly, market-based instruments provide a continuous incentive for developing less polluting products and processes, while regulations tend to encourage only the minimum compliance required (Baumol & Oates, 1998; Peng et al., 2018; Lewis & Tietenberg, 2019).

A different market mechanism is carbon emission taxation, where the administrative authority establishes the tax rates and firms may incur price increases and/or reduced profits. In this regard, market forces spontaneously work in a cost-effective (cost-minimizing) way to reduce emissions. Markets such as the Danish, Finnish, Swedish, Dutch, and Norwegian markets were the first ones to adopt carbon emissions taxes (Magalhães, 2013).

Arguably, although environmental taxes have the potential to minimize compliance costs for firms, as a result, consumers will pay a share of the tax costs. Therefore, the minimum cost comes from the point that a common tax given to all polluters leads to different emission

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abatement rates determined by the individual marginal costs of reducing pollution. Polluters with high marginal cost will tend to pay the tax rather than reduce emissions.

The central concept underlying the measure is that carbon taxes work as a continuous incentive for adopting clean technologies. Standards tend to favor moves to available technologies. But unless standards are continually reviewed and adapted to achieve better technologies, there is little incentive for polluters to go beyond the regulated standard. Much national and international research points to potential GHG mitigation effects of introducing policies based on carbon taxation (Silva Freitas, Santana Ribeiro, Souza, & Hewings, 2016; Ohlendorf, Jakob, Minx, Schröder, & Steckel, 2021; Chelly, Nouira, Hadj-Alouane, & Frein, 2021).

The carbon market is one mechanism perceived as having the potential to reduce GHG emissions and encourage sustainable development in the long term. Thus, an emission reduction mechanism could be a lower cost resource for organizations, from a short-term traditional return point of view, and become an investment with financial and economic return opportunities in the medium and long term, besides enabling the company to increase the global market competitive advantages (Hopwood, Unerman, & Fries, 2010).

According to the World Bank, the voluntary carbon market (which comprises firms not required to offset emissions), moved US$320 million in 2019 - equivalent to 1% of the regulated market, driven by public policies and encompassing commitments made by countries in the United Nations. The expectation now is that, with ESG demand increasing worldwide, this market will surpass $300 billion by 2050 (Valor, 2021).

The literature presents different possibilities that may contribute to reducing GHG emissions. Among them are carbon taxation (Silva Freitas et al., 2016; Criqui, Jaccard, & Sterner, 2019; Ghazouani, Xia, Ben Jebli, & Shahzad, 2020), manager incentives (Eccles, Ioannou, Li, & Serafeim, 2012; Dögl & Behnam, 2015; Prates, 2019) regulation (Kemp et al., 2000; Behr et al., 2009; Peng et al., 2018; Cheng & Liu, 2018; Karassin & Bar-Haim, 2019; Wang, Liao & Li, 2021), carbon market (Magalhaes, 2013; Basse Mama & Mandaroux, 2022), investments in clean energy (Uderman, 2010, Hussain, et al., 2022) and changes in the manufacturing process (Porter and Linde, 1995a). Such proposals have advantages and disadvantages and require, above all, an effective cost-benefit analysis indicating the feasibility to adopt them considering the Brazilian market's peculiarities.

Finally, communication tools, such as disclosure of financial and non-financial information, aim primarily to raise awareness and inform agents, to create markets for environmental products, and promote a corporate image and reputation culture that enhances the value of products (D'Amico, Coluccia, Fontana, & Solimene, 2016; Cheng & Liu, 2018; Brook & Oikonomou, 2018; Naranjo Tuesta, Crespo Soler, & Ripoll Feliu, 2020). ESG, for example, stands for Environmental, Social and Governance, and it is a set of principles and practices focused on environmental, social, and corporate governance issues. For Hernandez, Strine, Lindsay, and Main (2020), investors recognize that ESG factors can influence long-term business performance and expect these factors to be integrated into company strategy and disclosed in public reports, indicating the quality of corporate governance.

Therefore, this term is becoming more and more prominent, mainly due to the financial market's greater engagement with sustainability issues, which has led not only the declared profits in financial balance sheets, but even the ESG practices adoption to start being accounted for in risk analysis and investment decisions by shareholders and market agents. However, the term still raises many doubts and criticisms about the real objective and practice effectiveness, which have little effect on production and consumption relations. Moreover, another criticism lies in the extent to which "green marketing" is consistent with the effective practices adopted by these firms (Hernandez et al., 2020).

Despite the growing demand and increasing social awareness around climate issues, only 31 Brazilian non-financial companies listed on the Brazilian stock exchange conducted

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GHG emissions inventory through an accredited agency (GHG Protocol) during the period. Emissions inventory disclosures are voluntary, which hinders access to other data in a reliable way. However, the sample we wish to explore includes companies from a variety of sectors and can provide important information about the characteristics of firms that decide to make them public.

3 METHODOLOGY

This study is classified as descriptive, documental, and quantitative in its approach (Saunders, Lewis, & Thornhill, 2016). We apply the cluster method to analyze the similarities and dissimilarities among Brazilian companies that disclose emissions inventories. The time horizon analyzed covers 2012 to 2019, given the availability of publicly released and available emissions inventory data. We started with a total of 246 observations, reduced to 207 given that some companies did not disclose emissions inventories in some years.

3.1 Research Data

The sample is composed of 31 companies from diverse sectors of the economy, listed on B3 that disclose executive compensation data and GHG emissions inventories in the years analyzed. These companies are part of the Brazilian GHG Protocol Program (FGV, 2021), whose emissions inventories are voluntarily disclosed online on the mentioned platform.

The largest share in the sample comes from the Electric Power sector (19.4%). The Cyclical Trade, Pulp and Paper, Telecommunications, Transportation, and Oil, Gas, and Biofuels segments each participate with 9.7% in the total sample. The remaining 32% includes Processed Food (6.45%), Health (6.44%), Non-Cyclical Trade (3.2%), Water and Sanitation (3.2%), Civil Construction (3.2%), Manufacturing (3.2%), Mining (3.2%), and Chemicals and Petrochemicals (3.2%).

3.2 Research Variables

In this study, we analyze data on GHG emissions in tons (Carb), net operating revenue (Revenue), total assets (Atot), total executive compensation (Remtot), each company's ESG score and the companies' long-term onerous liabilities. The ESG variable was included as a proxy for the Communication and Environmental Responsibility instrument and the Invteclp variable as a proxy for the market instrument related to the investment potential in new technologies. Both were discussed in the theoretical framework and are specified in Table 2.

Table 2. Research variables dimensions

Proxy	Description	Type	Database
Carb	GHG emissions in tons – Emission Intensity	Quantitative variable in tons of emissions/year	GHG Protocol
Remtot	Total compensation of the firm's statutory management – Monetary Incentives	Quantitative variable in Reais/year	Reference Forms
Receita	Net Operating Revenues – Operational Performance	Quantitative variable in thousands of Reais/year	Economática
Atot	Total Assets – Firm Size	Quantitative variable in thousands of Reais/year	Economática
ESG	ESG Score – Communication and Socio-environmental Responsibility	ESG score/year	Thomas Reuters

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Invteclp	Long-term loans and financing – Potential investments in technologies	Quantitative variable in Economática thousands of Reais/year

Source: Research data (2021)

The pollution intensity emitted is measured through the variable Carb in tons (Kim, et. al., 2015). The Total Compensation variable considers the total compensation paid to the executives, given that Prates (2019) identified that both fixed and non-fixed incentives are able to influence emissions reduction in the Brazilian market. The Revenue variable represents the company's performance from its main operations, which are more directly tied to carbon emissions. Total assets are a proxy for firm size (Jung, Herbohn, & Clarkson, 2014), and investments in new technologies were measured through the proxy of long-term onerous liabilities (Bryant, Griffin, & Perry, 2020).

The ESG variable is a proxy used to measure the communication between the company and the community, regarding the entities' socio-environmental responsibility. This variable presents each company's score for ESG targets, with a maximum score of 100 points. For this variable, the average score of the last two years was considered, when the company did not disclose the ESG score until the data collection date (namely: Aes Brasil, Cesp, Cosan, Grupo Fleury, Sanepar, Whirlpool).

Since the variables are measured in different units of measurement, which can influence cluster formation, we used the procedure of standardizing the variables by the Zscore method (with zero mean and standard deviation = 1).

3.3 Cluster Analysis

To meet the research objective, which is to understand how companies that disclose emission inventories in Brazil are similar or differentiated by means of quantitative financial, environmental, and social performance variables, thus describing the determining characteristics of this grouping, we chose to use the multivariate cluster analysis. The expectation is that by segregating the companies into groups, it is possible to identify similarities among individuals in the same group and dissimilarities between groups.

Cluster analysis is a statistical technique used to classify elements into groups so that elements within the same cluster are very similar, and the elements in different clusters are distinct from each other (Mingoti, 2007). This methodology aims to form relatively homogeneous groups (clusters) of a given variable. Given a set of n individuals for which there is information about the form of p variables, the clustering method allocates individuals according to the available information, so that the individuals in a group are as similar as possible and different from the elements of the remaining groups (Mingoti, 2007).

We adopted Ward's method (1963), which provides the grouping of the data with the smallest possible variance between the vectors that make up each group and the group average vector. Clustering occurs in two parts. Initially, there is a group for each vector in the database and the internal error and variance are zero, because each vector that makes up each group is itself the mean vector of the group. Then, the clusters are grouped in a way that causes the smallest increase in the internal group error. The distance measured between two clusters is the sum of the squared distances between the two.

Thus, the method enables the identification of similarities among companies that publicly disclose GHG emission inventories in relation to economic and financial performance, social and environmental performance, and governance characteristics. After grouping the companies, ANOVA variance tests were applied to ensure analysis robustness regarding the existence (or not) of variance equality between the clusters formed. The expectation is that the null hypothesis of equality is rejected, indicating dissimilarity among the clusters formed. For

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the grouping process and cluster number definition, the Callinski and Duda-Hart tests were applied, and presented in the next topic.

4 RESULTS AND DISCUSSION

This section presents the clustering analysis results in two phases: i) definition of the number of clusters, and ii) presentation of descriptive statistics per cluster created. The results will be discussed throughout and at the end of this topic.

4.1 Setting the Number of Clusters for the Analysis

We applied two tests for defining the number of clusters for the analyses, the Calinski and Harabasz test (1974) and the Duda, Hart and Stork test (2001). The first can be used in hierarchical and non-hierarchical level analyses and provides the pseudo-F, which indicates that the higher the value, the more distinct the cluster is. Therefore, the bigger the better. In this case, the test indicated the grouping of the data into two clusters (pseudo-F144.84).

Duda-Hart (2001) test can be used in hierarchical level analyses and provides the pseudo-T, which indicates that the smaller the value, the more distinct the cluster is. Therefore, the smaller, the better. Duda Hart's test indicated that four clusters should be used in the analyses (pseudo-Tsquared 63.69).

Petrobras, however, is alone in one cluster, which reveals that the use of two clusters would be insufficient to fulfill the purpose of this study. Table 3 shows the number of clusters formed, the observations/year frequency in each one, and the explanation percentage of the individual and accumulated variance.

Table 3 – Clustering from the GHG emissions inventories disclosed

Cluster	Freq.	Percent	Cum.	Companies
1	110	53,14	53,14	Aes, BRF, CCR, Cemig, CPFL, EDP energias, Ecorodovias, Eletrobrás, Fleury, Klabin, Lojas Renner, MRV, Natura, Sanepar, Tim, Whirlpool and Gol.
2	64	30,92	84,06	Braskem, Cesp, Fibria, Hypera, Oi, Suzano, Lojas Americanas and Cosan
3	30	14,49	98,55	JBS, Ultrapar, Vale, Telefônica and CBD
4	3	1,45	100,0	Petrobrás
Total	**207**	**100**		

Source: Research data (2021)

Note that Cluster 1 is the largest in relation to the others and has 110 observations. The second has 64 observations, the third has 30 and the fourth has only three. As the analysis considered a period of eight years, it is possible that the observations regroup over the years, in different clusters according to the inherent characteristics in each variable through the companies' performance in each year. In Figure 1 we provide a visual analysis (by a dendrogram) of how the firms are organized by cluster.

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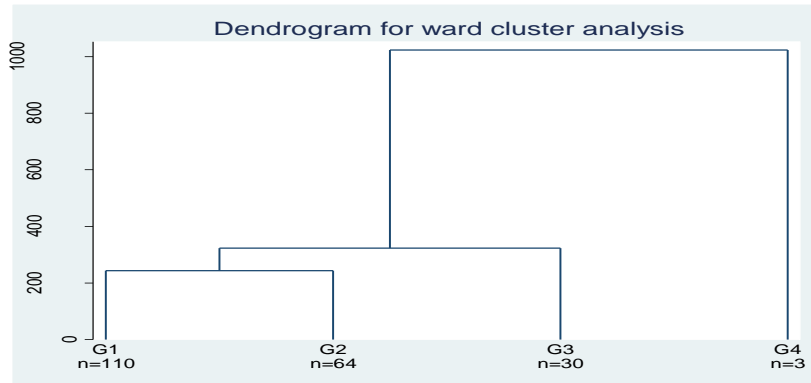
Figure 1: Dendrogram
Source: Research data

Through graphical analysis it was possible to visualize the clustering process step by step, as well as the distance levels of the clusters formed. The decision point of the final clustering is where the distance values change considerably. It can be seen that Petrobras presents very distinct characteristics from the other companies analyzed. Therefore, the use of two clusters would not be sufficient since the other entities would be considered in a single cluster. To further deepen the database, we started to analyze the observations per cluster each year. Table 4 details the observations ranking for each year analyzed.

Table 4 – Observations by Cluster and year

Cluster	2012	2013	2014	2015	2016	2017	2018	2019	Total
1	12	12	18	16	17	18	6	11	**110**
2	13	14	6	9	7	8	3	4	**64**
3	3	3	5	5	6	3	1	4	**30**
4	0	0	0	0	1	1	0	1	**3**
Total	28	29	29	30	31	30	10	20	**207**

Source: Research data (2021)

It is possible to verify that except for Cluster 4 (Petrobras), the others underwent changes over time. Cluster 1 initially adds 12 observations in 2012 and ends 2019 with 11. In 2012, Cluster 2 adds 13 observations. Among the others, it is the one that undergoes the most changes over time, reaching 2019 with four observations only. The third cluster maintained some observations pattern over time, with an average of 3.7 observations.

Finally, Cluster 4 composed only by Petrobras, obtained observations only in 2016, 2017, and 2019, quite different from the others. This result suggests that companies are well classified in the groups. However, for a better understanding of the entities clustering, we considered the highest frequency of observations per year. Table 5 shows the frequency by company.

Table 5 – Sample Classification by Frequency

Company	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Total
AES_BRASIL	6	0	0	0	6
BRASKEM	0	7	1	0	8
BRF_SA	6	0	2	0	8
CCR_SA	7	0	0	0	7
CEMIG	6	0	0	0	6
CESP	0	6	0	0	6
CPFLENERGIAS.A.	7	0	0	0	7
CIABRAS.DISTRIBUICAO	0	0	**6**	0	6

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COSAN	3	5	**0**	0	8
EDPENERGIASDOBRASIL	6	0	0	0	6
ECORODOVIAS	7	0	0	0	7
ELETROBRAS	7	0	0	0	7
FIBRIA	0	6	0	0	6
GRUPO_FLEURY	5	2	0	0	7
HYPERA	0	5	0	0	5
JBS	0	2	**6**	0	8
KLABIN as	4	2	0	0	6
LOJAS_AMERIC	0	7	0	0	7
LOJAS_RENNER	6	2	0	0	8
MRV	7	0	0	0	7
NATURA	5	2	0	0	7
OI	0	4	3	0	7
PETROBRAS	0	0	0	**3**	3
SUZANOPAPEL	1	7	0	0	8
SANEPAR	8	0	0	0	8
TELEF_BRASIL	**2**	2	**2**	0	6
TIM_PARTICIPACOESS.A	6	1	0	0	7
ULTRAPAR	0	1	**5**	0	6
VALE	0	0	**5**	0	5
VRGLINHASAREAS	5	3	0	0	8
WHIRLPOOL	**6**	0	0	0	6
Total	110	64	30	3	207

Source: Research data (2021)

The company's classification by observation frequency shows that Cluster 1, in addition to being the largest with a total of 16 companies, is also the most diversified. Cluster 2 comprises seven companies, mostly associated with the chemical and cellulose industry sectors (Braskem, Cesp, Fibria, Hypera, Lojas Americanas, Oi, Cosan, and Suzano Papel). Cluster 3 is formed by JBS, Ultrapar, Vale, Telefônica and Cia Brasileira de Distribuição.

Lastly, Cluster 4 consists of only one firm: Petrobrás, which with only three observations over eight years has a high degree of dissimilarity in relation to the others, to the point of constituting a single cluster. To identify the dissimilarity degree in the clustering classification among companies, we begin analyzing the groups by means of descriptive statistics.

4.2 Descriptive Statistics by Cluster

In Table 6, it is possible to identify differences in the descriptive statistics between the four clusters formed. We observe that the first cluster contains the greatest diversity of companies by sector. The comparison between the means of the variables in this cluster with the others indicates four main points: i) it comprises the smallest companies in the sample; ii) it has the lowest net operating revenue; iii) it emits the least GHG (on average 1.6 million tons of GHG); and iv) in this sense, it is not surprising that they also have the lowest potential investments in technology, when compared to the other entities (5.6 million reais).

Table 6 - Descriptive statistics of quantitative variables by cluster

Panel 1: Cluster 1						
Statistics	**Obs**	**atot**	**Remtot**	**Carb**	**invteclp**	**esgscore**	**receita**
mean	110	29,1	3,4	1,651,937	5,6	66.8	12,6
Stat deviation	110	38,0	2,2	2,524,055	9,6	8.2	10,9
min	110	3,0	0,7	5,085	-	49.2	1,6
median	110	15,1	2,9	645,229	1,3	66.4	9,1
max	110	177,0	9,7	12,800,000	45,2	86.0	60,7

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Panel 2: Cluster 2						
Statistics	**Obs**	**atot**	**Remtot**	**Carb**	**invteclp**	**esgscore**	**receita**
mean	64	31,5	4,9	3,937,187	9,1	34.0	18,3
Stat deviation	64	24,2	2,6	8,630,450	11,7	17.4	20,1
min	64	2,7	0,549	4,806	-	0.0	1,5
median	64	27,8	4,9	631,073	4,7	38.9	10,1
max	64	103,0	12,5	40,800,000	52,0	58.1	92,9
Panel 3: Cluster 3						
Statistics	**Obs**	**atot**	**Remtot**	**Carb**	**invteclp**	**esgscore**	**receita**
mean	30	104,0	10,6	44,100,000	24,9	62.6	80,0
Stat deviation	30	98,7	5,1	97,700,000	29,7	13.4	50,6
min	30	15,3	2,6	162,279	-	35.9	20,1
median	30	70,3	9,4	616,081	7,8	62.4	66,6
max	30	346,0	24,2	312,000,000	103,0	84.9	205,0
Panel 4: Cluster 4						
Statistics	**Obs**	**atot**	**Remtot**	**Carb**	**invteclp**	**esgscore**	**receita**
mean	3	854,0	2,9	355,000,000	309,0	78.7	290,0
Stat deviation	3	63,6	0,49	307,000,000	63,1	1.6	11,0
min	3	805,0	2,5	297,872	237,0	76.9	283,0
median	3	832,0	2,9	523,000,000	338,0	79.3	284,0
max	3	926,0	3,4	541,000,000	353,0	80.0	302,0

Note. Variables are defined in Figure 2. Data for the variable Carb are in tons of GHG emissions. The data for total assets, total compensation, invteclp and revenues are in millions of reais. The variable esgscore variable presents the points achieved per cluster.
Source: Research data (2021)

We chose to present the analysis starting with Cluster 4, considering that it is composed only of Petrobras and has very distinct characteristics from the other companies and clusters. This cluster has the largest average size, being therefore, the largest company in the sample, as shown in Figure 2.
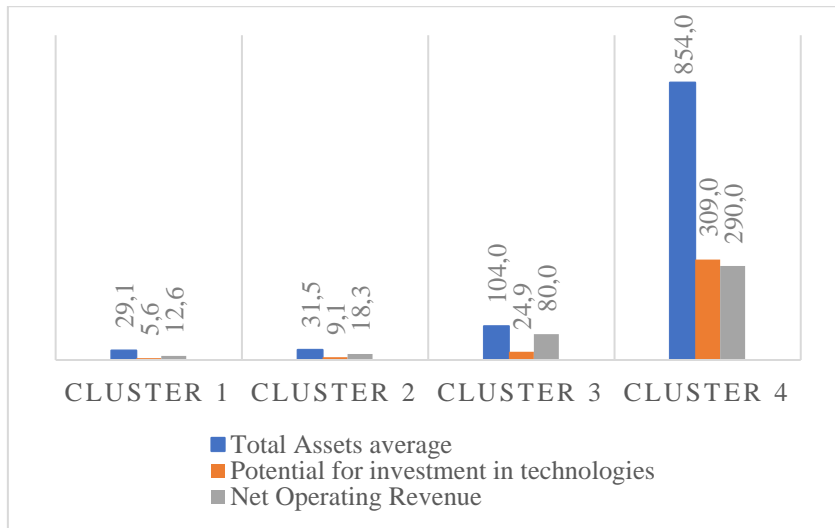

Figure 2: Total Assets average, Potential for investment in technologies and, Net Operating Revenue per cluster in millions of reais
Source: Research data (2021)

Similarly, Petrobras has the highest net operating revenue (290 million reais); as well as its financing is on average the highest with 309 million reais, which may indicate the company's interest in developing new technologies. Figure 3 shows the average emissions of each group,

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highlighting Cluster 4 (Petrobras), with an average in the three years observed of 355 million tons, well above the others.
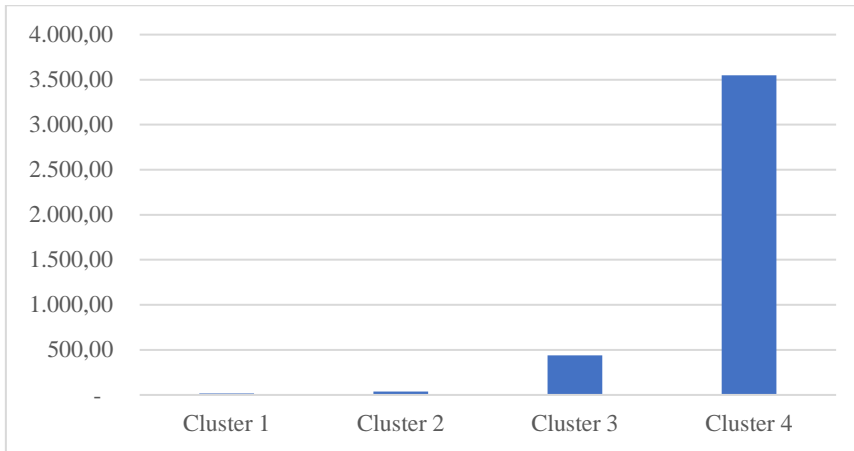

Figure 3: Average GHG emissions in tons/year per cluster
Source: Research data

The communication and socio-environmental responsibility measured by the ESG score is reported in Figure 4. Petrobras, again, presents the highest average, with 79 points, and Cluster 2, the lowest, with 34 points.
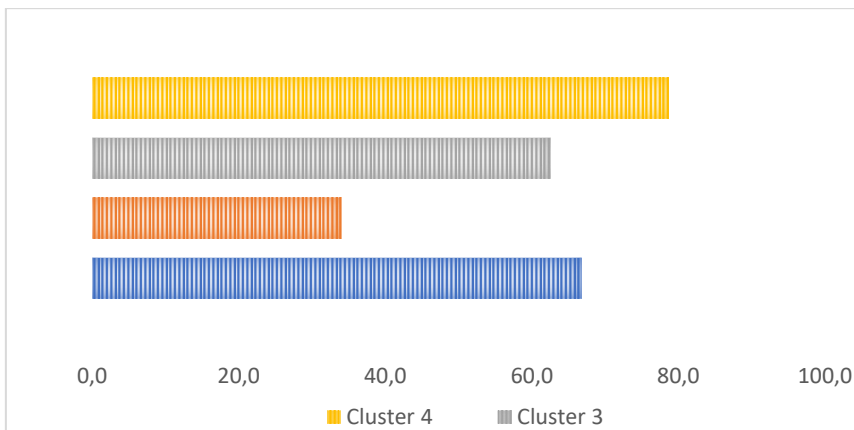
Figure 4: Average ESG score by cluster
Source: Research data (2021)

In contrast, Cluster 4 presents the lowest average monetary incentives to executives, as opposed to Cluster 3, with the highest average incentives (10.6 million reais). This cluster is composed of large companies, such as: JBS, CBD, Vale, and Ultrapar. Figure 5 details the average compensation of the statutory executive board per year.

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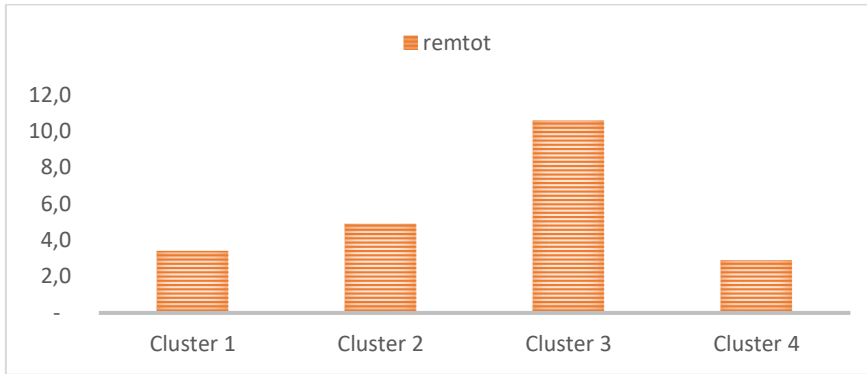
Figure 5: Average remuneration of statutory directors by cluster (in millions of reais)
Source: Research data

When it comes to GHG emissions, Cluster 3 also stands out in relation to Clusters 1 and 2, with an average of 44.1 million emissions tons. Companies that are part of this cluster are much larger in relation to the first two clusters, with average assets of around 104 million reais, the average net operating revenue of 80 million reais, and average investments of around 24.9 million reais. In communication and socio-environmental commitment, Cluster 3 had an average ESG score of around 62.6 points and a maximum of 85 points.

Cluster2 is composed, among other companies, of Braskem, Cesp, Fibria, Hypera, Oi, Suzano, Cosan, and Lojas Americanas. These companies are mostly from the pulp and chemical industry. This cluster presented, however, the lowest average ESG score (33.98 points) among the other clusters.   Lastly, Cluster 1 aggregates, in general, the smallest companies in the sample. In addition, it includes the main power companies in the country. These companies show i) lower net operating revenues; ii) lower emissions relative to other companies; iii) lower long-term investments; iv) have the second highest ESG score with an average of 66.8 points, reaching a maximum score of 86 points.

To ensure the robustness of the results achieved in the cluster analysis, a one-way analysis of variance (ANOVA) was conducted. The intent is to validate whether the values assigned to each cluster are statistically different from each other. Applying the test also allows us to analyze whether the variability between the clusters is significantly higher than the internal variability within each of them (Fávero & Belfiore, 2015). The null hypothesis is the existence of variance equality. Table 7 shows the results found by each variable analyzed.

Table 7 - Variance analysis (ANOVA)

Variable	F	Prob>F
Atot	292,65	0,0000
Remtot	47,53	0,0000
Carb	57,27	0,0000
Invteclp	355,69	0,0000
Esgscore	100,21	0,0000
Receita	190,85	0,0000

Source: Research data (2021)

The results culminate in the rejection of the null hypothesis for all variables analyzed. This implies the confirmation of distinct variance among the clusters analyzed and the dissimilarity among them, conferring robustness to our results.

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4.3 Discussion

Our results show that the larger companies, with higher revenues, are also the most polluting. On the other hand, they are more concerned with communication and social and environmental responsibility, besides granting higher monetary incentives to their executives. This finding corroborates Cheng's (2018) findings given that these companies belong to more polluting sectors and have higher public and media visibility.

Cheng and Liu (2018) analyzed highly polluting Chinese companies listed on the Shanghai and Shenzhen stock exchanges from 2012 to 2016. They found that firms' public visibility can influence firms' behavior. In this sense, firms with high levels of public attention tend to bear higher pollution costs, among other voluntary environmental actions. Thus, the social and environmental engagement of polluting companies aims, among other things, to meet demands and pressures from both stakeholders and society.

Because they present such distinct characteristics from the other companies, such firms or more polluting sectors may eventually be driven by incentives different from traditional regulation. Peng et al. (2018) evaluated the economic aspect and environmental performance associated with environmental regulation and strategies. Their results revealed that both command and control and market instruments can impact firms' reactive environmental strategy. However, the proactive environmental strategy had a significant relationship only with market incentives.

Our result is similar to that of Peng et al. (2018) in revealing that despite reactive environmental strategies to the regulatory framework, companies signal to have other incentives or proactive market strategies. In this study, firms use the proactive strategies of GHG emissions management and disclosure, as well as control investments.

It is undeniable that environmental regulation plays an important role in improving the quality of the environment, as shown by Peng et al. (2018); Karassin and Bar-Haim (2019), Wang, Liao & Li (2021) and Chelly et al. (2021). However, the regulatory contribution depends on law implementation and enforcement. Previous research shows that regulation impacts firms' environmental performance unequally. Hao, Deng, Lu, and Chen (2018) investigated the effectiveness of environmental regulation in China. Using a panel GMM data for the period 2003 to 2010 they identified that regulation is effective in reducing soot emissions, but with respect to other aspects such as effluents and sulfur dioxide it did not achieve the expected results.

In Brazil, environmental regulation exists and is considered modern. However, enforcement is quite deficient. This fact tends to reduce and even cancel the environmental engagement of smaller or unlisted companies, besides weakening the role of the State in environmental preservation issues (Prates, 2006). This fact was studied by Karassin and Bar-Haim (2019) when evaluating Israeli companies. They used three simulated scenarios: a "coercive regulator" (more punitive), a "demanding regulator" (reinforced standards), and a "permissive regulator" (less punitive and less demanding). The results showed that regulators with coercive practices reduce both the internal motivation for compliance and voluntary initiative that exceeds compliance. Thus, more lenient regulatory practices reduced the credibility of the regulatory regime's normative effect. Additionally, such practices weakened corporate motivation to improve environmental performance.

The latter scenario seems similar to that found in Brazil. Since there is no effective enforcement, the most visible companies with the greatest potential for negative environmental impact end up getting involved in sustainability issues driven by other types of incentives or pressures, such as from consumers, customers, media, society, investors, and creditors.

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5 CONCLUDING REMARKS

Each firm's and sector's characteristics are relevant aspects for any application of effective environmental policy instruments. In order to provide a better understanding of environmentally engaged firms' characteristics, this article sought to explore the data of Brazilian companies listed on B3 that perform the disclosure (evidencing) of GHG emissions inventories, by means of the multivariate cluster analysis method.

The companies' segmentation into four clusters considered characteristics related to GHG emission intensity, company size, net operating revenue, investment potential in new technologies, and lastly, communication and socio-environmental responsibility through ESG scoring. The companies were grouped by similarities between individuals, and thus it was possible to analyze aspects that can contribute to a better understanding of possible mechanisms to be explored in order to reduce GHG emissions.

The results obtained through cluster analysis show that companies like Petrobras (Cluster 4) and Cluster 3 (JBS, Vale, Ultrapar, and CBD), in addition to emitting more GHGs, are larger companies with higher revenues, more concerned with communication and socio-environmental responsibility, and encourage their executives through higher salaries. Since they have such distinct characteristics from the others, such companies or industries may eventually be driven by incentives different from traditional regulation.

In other words, the results may indicate that regulation has a more relevant impact on decisions to implement environmental management systems, labels, standardizations, and even technological vanguard in relatively smaller companies, given that large companies have in part already incorporated environmental programs within their long-term strategies that anticipate regulation. Other factors such as competitiveness strategies and reputation, for example, may be exerting a relevant influence for large companies to anticipate regulations concerning the GHG emissions reductions (Lustosa, 2003; Costa, 2005). However, in certain cases, the effectiveness of regulatory mechanisms for GHG mitigation may move initiatives to a higher level for the rest of the firms, which often move along with the regulatory framework.

This study contributes to the literature by elucidating these companies' characteristics, seeking to understand how firms that voluntarily disclose emission inventories in Brazil are similar or differentiated by financial, environmental, and social performance criteria. Our results also provide information to guide the regulatory policy of GHG emissions reduction, considering firms' specific characteristics, such as the potential for investments in new technologies and their behavior regarding emissions mitigation policies.

The main limitations of this research are related to the sample size resulting from the limited availability of companies that disclosed GHG emissions inventories. Complementary to these results, future research can explore qualitative variables in clustering, despite the methodology that minimizes variance preferred in this study for the exploratory approach to quantitative data. Aspects such as corporate governance may be relevant for a better understanding of the companies' proactive environmental performance.

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