

Challenges in Accounting for Carbon: Analysis of Accounting Policies of the World's Largest Polluters

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Received: April 15, 2024

Accepted: June 25, 2024

Online Published: August 7, 2024

doi:10.5539/ijbm.v19n5p121

URL: <https://doi.org/10.5539/ijbm.v19n5p121>

Abstract

The study's focus was on examining the accounting policies related to carbon credits of the top 100 global GHG emitters, as mentioned by Kouloukoui et al. (2019). Of these 100, only 36 gave access to the CDP questionnaire. We used the model proposed by Lovell et al. (2010) to examine carbon credit accounting choices, employing content analysis with NVivo software and statistical analysis with Stata. The financial statements (FS) and explanatory notes of 247 companies from different countries and sectors, such as oil and gas, mining, coal, transport and marine logistics, and the chemical sector, were analyzed from 2015 to 2021. Finally, nine companies provided information on the accounting treatment for carbon credits. The results indicate a predominance of classification as inventories, followed by intangible assets, measurement at cost, and liabilities accounted for by the excess carbon credits owed about existing assets at market value. We observed significant heterogeneity in accounting policies, which remained over time. The lack of standardization and consistency in reporting methods and the concealment of accounting records in this context make it challenging to compare practices, compromising the evaluation of companies' performance, the decision-making of investors and other agents, and the transparency and accountability of this market. These findings highlight the need for a more coherent and rigorous approach to accounting for carbon credits, especially considering the urgent challenges of climate change.

Keywords: carbon market, GHG emissions, climate change, carbon credit, accounting policies, carbon accounting, carbon disclosure project

1. Introduction

Concerns and narratives about climate change and its implications, such as extreme weather events, have gone beyond scientific journals given the severity of the effects on terrestrial systems, life, and the global socio-economy (Bolton et al., 2020; Sardeiro & Bilhim, 2021). In recent years, there has been no shortage of alerts, investigations, and news about the unequivocal risks of the probability of climate collapse (IPCC 2018, 2023; WEF 2022, 2023).

There is a concern about decoupling the economic growth of countries from the increase in carbon emissions, as extensive literature relates these factors (IPCC, 2021, 2022; Jaunky, 2011; Sane et al., 2022). This scenario has driven global climate governance and mobilized governments and interested institutions. The outcome has led to the formation of accords like the Kyoto Protocol and the Paris Agreement (Moore, 2019). Within this framework, enterprises play a crucial role in diminishing, alleviating, and advocating for adjustments to a carbon-neutral economy.

Interest in the accounting and financial aspects of carbon management systems has quickly grown due to the influence of production processes on emissions in the economic system (Kaplan et al., 2021; Tang, 2017; Zhang & Liu, 2020). Furthermore, GHG emission control systems have been referred to by some as carbon accounting (Stechemesser & Guenther, 2012). This accounting involves different areas of knowledge, such as national carbon inventory methods, corporate carbon control systems, GHG emission assessment at the project level, and product

life cycle evaluation (Gibassier, Omari, & Naccache, 2020). Given this challenge, this investigation aimed to understand how the world's largest polluters report accounting information on carbon credit operations. Thus, this study aimed to analyze the accounting policies adopted and reported concerning carbon credits by the world's largest polluting companies.

The rationale behind the significance of this study can be succinctly outlined in the subsequent dimensions: firstly, the socio-economic importance of research endeavors aimed at enhancing understanding of the methodologies for documenting and quantifying factors linked to GHG emissions. The ramifications of climate change manifest themselves in individuals' everyday experiences and well-being, in nations' economies, in companies' bottom lines, and exert a significant influence on marginalized communities, especially in the global south (Folke et al., 2021; Heinberg & Miller, 2023); second, the complexity of the topic is reflected in the forms of bookkeeping and measurement, especially given the absence of global standards (Kaplan et al., 2021; Omran & El-Galfy, 2014; Zhang & Liu, 2020); third, the update and comparison of this investigation with the findings of Lovell, Aguiar, Bebbington & Larrinaga (2010), a study developed to meet the interest of the Association of Chartered Certified Accountants (ACCA) and the International Emissions Trading Association (IETA) on accounting practices in use.

Regulatory changes require a deeper understanding of controls, transparency, and accountability regarding GHG emissions (Tang & Lou, 2014; Weikman & Gupta, 2021). Changes in environmental values and responsibilities lead to shifts in demands for accounting information flows and types (Hopwood, 2009).

This article employs the term "carbon credits" to encompass various types of financial instruments with comparable functionalities, including licenses, permits, and others, as defined in the research conducted by Lovell et al. (2010). We organize the paper as follows: the first section addresses the theoretical framework that also supports the empirical bases; in the second section, we present the methodology of the work; in the third section, the results of the study are presented and discussed; and in the final section, the conclusions, including implications of the research and perspectives for future research.

2. Theoretical Framework

2.1 Carbon Market

Scientific analyses compiled by the Intergovernmental Panel on Climate Change (IPCC) highlight a probability of over 95% that climate changes are attributable to the increase in anthropogenic GHGs, which already have significant impacts on the availability of natural resources, affecting access to water, food production, and health (Stern, 2006; Hoffman & Woody, 2008; Lu & Abeysekera, 2014; IPCC, 2018). Given this reality, the need for effective policies and concrete actions to mitigate the effects of climate change becomes increasingly urgent. To find solutions to the environmental problem of global warming, the Kyoto Protocol was outlined in 1997. This international treaty was enacted in 2005 and set mandatory reduction targets for the main GHGs, averaging 5.2% from 2008 to 2012 relative to 1990 levels. These targets were mandatory only for the most industrialized countries, designated as "Annex I countries". To achieve them, three flexibility mechanisms were developed: Emissions Trading (ET), Joint Implementation (JI), and the Clean Development Mechanism (CDM). Only the latter allowed the participation of developing countries.

The local government was given the function of issuing a certification document for GHG emission reductions (Certified Emission Reductions - CER). CER trading gave rise to the so-called carbon market, classified into two types: regulated and voluntary (Öker & Adıgüzel, 2017).

In the regulated carbon market, there is government interference (direct or indirect) to encourage/discourage actions by economic agents, known as the Emissions Trading System (ETS). GHG emission reductions are systematically sought in voluntary markets, including monitoring and auditing systems, but without government interference and certification. A baseline is established for project reductions. The credits generated are certified by specialized but non-governmental companies and offered as offsets for a voluntary emission reduction target (Wambsganss & Sanford, 1996; Bumpus & Liverman, 2008; Lovell et al., 2010).

The European ETS envisaged three initial phases with emission reduction targets: Phase I 2005-2007, Phase II 2008-2012, and Phase III 2013-2020. The first coincided with the Kyoto Protocol and assigned each country the establishment of emission limits within their territories in specific and intensive GHG emission sectors; the distribution of licenses by the government was free and already foresaw the purchase of credits from third parties in case of exceeding the limits (Öker & Adıgüzel, 2017). The second phase mainly addressed emission limit adjustments and inclusion of countries and sectors, and finally, the third phase included the figure of auctions to replace free distributions (Lovell et al., 2010).

Another relevant transnational policy was the Paris Agreement, celebrated by 195 countries at the Conference of

Parties (COP 21) in 2015. This Agreement proposed adjusting the commitment to emission reductions to limit global temperature increase between one and a half to two degrees Celsius (United Nations, 2015). Article 6.2 of COP 21 establishes that countries adopt cooperative measures and guides on transferring mitigation results between countries - the so-called Internationally Transferred Mitigation Outcomes (ITMOs). Records of these transfers must comprise each country's Nationally Determined Contribution (NDC) according to Article 6.4.

Subsequently, in 2021, the Glasgow Climate Pact was signed at COP-26, establishing carbon market regulations. At COP-27 in Sharm El Sheikh in 2022, the Loss and Damage Fund was created to help vulnerable countries recover from climate-related disasters; while at COP-28 in Dubai in 2023, an agreement was reached for a gradual reduction of fossil fuel dependency aiming at GHG emission reduction (United Nations, 2024).

2.2 Carbon Credit Accounting Policies

Carbon accounting has various definitions and dimensions; however, the most coherent conceptualization of the development of the accounting area was described by Tang (2017), who argued that carbon accounting is a system that uses a set of accounting methods to record and analyze information about climate change. Additionally, the author complements that the recording and reporting of assets, liabilities, revenues, and carbon-related expenses serve as a basis for decision-making (Tang, 2017, p. 10). The absence of an accounting standard implies adopting various recording methods, constituting a barrier to such operations' adequate comparability and verifiability (Lovell et al., 2013; PwC & IETA, 2021).

Since any standard setter on carbon credits issues no accounting standard, it is difficult for accounting professionals and companies to choose the accounting practice for recognizing, measuring, and disclosing transactions related to a low-carbon economy. In 2004, the International Financial Reporting Interpretations Committee (IFRIC) published IFRIC-3, which was related to the report of carbon licenses according to existing International Accounting Standards (IAS). However, it caused controversy and was withdrawn after six months. One of the contested points by the industry was the mixed presentation model of carbon accounting, with some losses and gains presented in equity and the income statement, considered an ambiguous position (Lovell et al., 2011). In December 2012, the IASB formally reactivated it as a standalone research project by the IASB and joint work with the FASB. 2015, it was renamed from emissions trading schemes to pollutant pricing mechanisms (Cheung, 2023; IFRS, 2015).

2.3 Carbon Accounting in Research

The accounting for emissions allowances in an ETS program has been the subject of discussions and research. In this sense, the result of the survey conducted by PricewaterhouseCoopers (PwC) in partnership with the IETA in 2007 with organizations participating in the EU ETS identified six approaches regarding the EU ETS. However, the prevailing approach was to recognize the allowances granted by the government at zero value, with the obligation recognized at the book value of the allowances already granted/acquired, with the excess at the prevailing market price. Regarding Certified Emissions Reductions (CERs), respondents initially recognized the CERs acquired at cost, but in terms of subsequent treatment, only 38% revalued the CERs after initial recognition. It identified a wide variation in balance sheet classification for EU ETS with fifteen different approaches and for CERs with eleven distinct approaches (PwC & IETA, 2007). The survey was updated in 2021, and the results remain consistent with the 2007 findings, indicating slow progress in establishing standardized accounting practices for carbon emissions despite changes in the carbon market (PwC & IETA, 2021).

Similarly, Lovell et al. (2010) investigated how the largest emitters of the European Union Emissions Trading System (EU ETS) accounted for emission allowances. In addition to analyzing the FSs (26 companies), they interviewed five accountants from these companies, concluding that there needed to be more diversity in accounting practices and a need for records. Similar results were found by Warwick & Ng (2012) when investigating accounting practices through content analysis of 250 companies in 2007. The authors found that only 47 energy sector companies had carbon accounting records, making comparing performance difficult (Warwick & Ng, 2012).

In the investigation by Lovell et al. (2013), the authors explored the underlying reasons for carbon disclosure practices and non-disclosure among political actors in companies linked to the EU ETS through inquiry. High levels of non-disclosure of carbon accounting information were found, affecting transparency, comparability, increasing uncertainty, and risk about company information impacting emissions trading (Lovell et al., 2013). Lovell et al. (2013) argue that there is a paradox in concealing accounting practices and their financial effects in contrast to European Union regulations demanding greater scrutiny by company boards regarding emissions costs (Lovell et al., 2013).

The study by Black (2013) emphasized the identification of accounting practices regarding emission allowances and liabilities in Phase II of the EU ETS, analyzing the financial statements of 62 companies for the 2011 fiscal year of companies based in Spain, Germany, and the UK. The main conclusion of this study, consistent with other studies to date, is that there continues to be a diversity of approaches to accounting practices regarding carbon permissions.

Garcia-Torea et al. (2022) studied the accounting treatment of emission allowances by participants in the EU ETS to identify whether the auction allocation system implemented in 2013 generated changes in accounting practices, finding no changes. Carbon accounting being a contested area, there is a need for greater engagement by the accounting profession and other political climate-related bodies to enhance and develop climate governance and monitoring, improvement, and learning systems regarding the carbon market and its accounting practices (Lovell et al., 2011).

3. Method

We explain how the study was conducted, covering its development's conceptual and operational definitions. We detail the steps of defining the sample, comparing it with the previous study and performing the analysis to ensure methodological transparency.

3.1 Identify Subsections

We used the same sample as Kouloukoui, Marinho, Gomes, Kiperstok and Torres (2019). We extracted data from the world's largest polluting companies listed in the 2017 Carbon Disclosure Project (CDP). The study period runs from 2015 to 2021. We selected 2021 due to full data availability during data collection in July 2023.

Out of the top 100 most polluting companies globally, only 36 responded and authorized disclosure of their responses to the CDP questionnaire regarding GHG emissions. Consequently, the study incorporates 252 data points (36 companies × seven years). This sample represents a diverse array of sectors, including oil and gas (26 companies), mining (four), coal (four), transportation and marine logistics (one), and chemicals (one). Furthermore, it encompasses companies from various regions worldwide, including Russia, the United States, Mexico, the United Kingdom, France, Australia, Italy, Norway, China, Canada, South Africa, Austria, and Switzerland. The United States and Canada have the most significant representation of companies, 13 and 5, respectively, with the remaining companies distributed across 13 other countries.

The selection of the CDP database as the primary data source is warranted due to its focus on disseminating information concerning climate change and associated risks. Moreover, the CDP report is widely acknowledged as one of the most valuable frameworks for disclosing climate-related information, particularly compared to other frameworks (Hahn et al., 2015; Luo & Tang, 2016).

We accessed the financial statements (FS) from 2015 to 2021, obtained through the websites of the sample companies. However, Westmoreland Coal Company still needs to make its FS for 2016, 2018, 2019, 2020 and 2021 available. Consequently, the total FS analyzed amounted to 247, including explanatory notes corresponding to each period. Thus, the final sample comprised 36 oil and gas, mining, coal, chemical, and marine freight companies.

3.2 Participant (Subject) Characteristics

We used the model Lovell et al. (2010) proposed to analyze the accounting treatment of carbon credits in FS. We organize the analysis model into seven key questions: i) Where are grants initially recognized in the balance sheet?; ii) Where are purchased allowances recorded in the balance sheet?; iii) How are purchased Certified Emission Reductions (CERs) initially recognized in the balance sheet?; iv) At what value are initially granted subsidies recognized in the balance sheet?; v) Are granted/acquired allowances subsequently amortized/depreciated?; vi) Are granted/acquired permissions reevaluated after initial receipt/purchase?; vii) How is the emissions obligation valued?

They analyzed the explanatory notes of companies' financial statements in the sample and aimed to address these questions. Content analysis served as the method to comprehend the sample's accounting choices regarding treating carbon credits. The NVivo software version 11 facilitated the analysis and management of qualitative data (Lumivero, 2023; Freire, Gomes, Santos, & Silva, 2023). Data about the accounting treatment of carbon credits were located and categorized within the software according to the model outlined by Lovell et al. (2010). Furthermore, statistical analyses were carried out in Excel and Stata version 14.

In summary, out of the top 100 largest polluters globally (Kouloukoui et al., 2019), 36 had available information in the CDP regarding their GHG emissions from 2015 to 2021. Among these, nine provided information regarding

carbon credits and their impacts on assets, liabilities, and results in their FS.

4. Results

This section presents the results of characterizing the total population, comprising 100 companies, and the sample of 36 companies. Subsequently, it delineates the profiles of companies that provided information regarding the accounting of carbon credits. This approach offers a comprehensive understanding of the current scenario regarding accounting policies applicable to carbon credits.

4.1 Sample characterization

The study conducted identified the origins of countries' emissions, revenues, and assets (Figure 1). The US, Russia, the UK, and the Netherlands significantly contributed to fifteen countries. China and Switzerland have high revenues and assets but have lower emissions. The rise of American corporations is due to the US being a major player in the global market and having high energy consumption with high emissions (IPCC, 2022). A strong link is found in data analysis between greenhouse gas emissions, company assets, and revenue (Table 1).

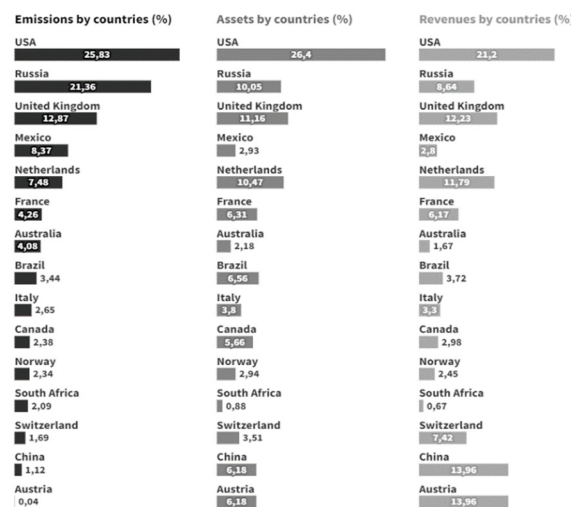


Figure 1. Sample distribution by countries.

Table 1. Pearson correlation between emissions, total assets, and total revenues

	Emissions Amount	Total Assets	Total Revenues
Emissions Amount	1.0000		
Total Assets	0.7290*	1.0000	
Total Revenues	0.4890*	0.8763*	1.0000

Note. Source: Results from information available on the CDP and LSEG Data & Analytics.

The sectoral analysis (Table 2) shows the dominance of the oil, gas, mining, and coal industries. Most oil and gas activities are in the US, Russia, Mexico, Netherlands, France, Brazil, Italy, Norway, China, and Austria, accounting for a large portion of total assets and revenue. The study by Lovell et al. (2010) highlights the importance of specific sectors in the global economy, with most emissions originating from the combustion sector and a smaller amount from the refinement sector, consistent with the current research findings.

Table 2. Classification of GHG emissions, Assets, and Revenues by sector

Sector	GHG emissions	Total Assets	Total Revenues
Oil and gas	83.4%	86.8%	85.9%
Mining	10.1%	6.8%	4.6%
Coal	4.5%	3.9%	7.6%
Chemical	1.6%	0.8%	0.6%
Sea Freight and Logistics	0.4%	1.7%	1.3%

Source. Information available on CDP and LSEG Data & Analytics.

This research collated information on total assets, total revenues, and GHG emissions by companies of sample from the CDP and LSEG Data & Analytics databases for the analyzed period (Table 3).

Table 3. Characteristics of companies with information on carbon credits

Company	Country	Sector	GHG emissions	Total Assets USD	Total Revenues USD
Royal Dutch Shell	Netherlands	oil and gas	15,017.0	386,176.3	267,910.
BP	UK	oil and gas	13,791.0	267,221.0	219,056.7
Total	France	oil and gas	8,541.0	232,697.7	140,148.3
Eni SpA	Italy	oil and gas	5,319.0	139,998.3	74,909.
Statoil ASA	Norway	oil and gas	4,695.0	108,457.3	55,567.3
Sasol Limited	South Africa	Chemical	3,195.0	27,899.3	13,586.7
OMV AG	Austria	oil and gas	81.0	35,723.3	23,002.7
Suncor Energy	Canada	oil and gas	1,804.0	85,241.	29,881.
Canadian Natural Resources Limited	Canada	oil and gas	1,173.0	48,393.0	9,999.3
Total			53,616.0	1,331,807.3	834,061.0

Note. Source: Information available on CDP and LSEG Data & Analytics.

The study shows that significant emitters have a solid financial capacity based on assets and revenues. Most companies disclosing carbon credit operations are European, with few exceptions. The absence of US companies in the disclosure framework is notable. The oil and gas industry is prominent, in line with previous research advocating for more scrutiny of climate actions (Weikmans & Gupta, 2021).

Countries like France, Italy, Norway, and Austria disclose information on carbon credit accounting. These companies represent a significant portion of the total values in the sample. European companies play a crucial role in accounting for carbon credits, which is consistent with previous research findings (Lovell et al., 2010).

An analysis in Figure 2 shows how companies disclosed information on carbon credits from 2015 to 2021, demonstrating the evolution of disclosure practices during these seven years.

Year	Eni SpA - Italy	OMV AG - Austria	Total - France	Sasol - South Africa	Royal Dutch Shell - Netherlands	BP - United Kingdom	Statoil - Norway	Suncor - Canada	Canadian - Canada
2015	X	X		X				X	
2016	X	X		X				X	
2017	X	X	X					X	
2018	X	X	X					X	
2019	X	X	X					X	
2020	X	X	X		X	X		X	
2021	X	X	X		X	X	X	X	X

Figure 2. Periods covered by information on carbon credits

The geographical distribution indicates a focused implementation of these reporting methodologies in Europe, explicitly emphasizing 2020 as the period in which carbon disclosure efforts intensified.

4.2 Accounting Practices Results

Table 4 provides a detailed analysis of the accounting strategies adopted concerning granted subsidies, purchased allowances, acquired CERs, and obligations related to carbon emissions. The findings illuminate the complexity and diversity among the companies in the sample concerning their accounting practices related to carbon emissions.

Table 4. Summary of accounting practices

Where are the grants initially recognized on the balance sheet?		Where are purchased licenses recorded on the balance sheet?		How are purchased CERs initially recognized on the balance sheet?		At what value are the subsidies initially granted recognized in the balance sheet?	
Inventory	11 (41%)	Intangible Assets	7 (30%)	Inventory/Intangible Assets	1 (7%)	Cost	18 (100%)
Intangible Assets	4 (15%)	Inventory/Intangible Assets	3 (13%)	Inventory	5 (36%)		
Other Receivables	1 (3%)	Inventory	5 (22%)	Reduction of liabilities (Other provisions)	7 (50%)		
Other Assets	11 (41%)	Other Receivables	1 (5%)	Intangible Assets	1 (7%)		
		Other Assets	7 (30%)				
Are granted/vested permissions re-evaluated		How is the emission obligation valued? after initial receipt/purchase?					
Yes, with revaluation posted in the result	7 (100%)	a)	The carrying value of the licenses already granted/acquired, with the balance valued at the prevailing market price				25 (74%)
		b)	No obligation is recognized unless there is a deficit, with the balance valued at the prevailing market price				2 (6%)
		c)	Emission obligations are measured by the weighted average cost per unit of emissions expected to be incurred in the compliance period. Emissions are treated as a cost of production and, as such, are recognized in the operating, commercial, and general expenses of the period in which the emissions occurred.				7 (20%)

The results indicate that of the observations concerning the initial classification of granted subsidies in the balance sheet, 41% were classified under inventories, 15% under intangible assets, 3% under other receivables, and 41% under other assets. Regarding the initial classification of purchased allowances, out of the 23 observations, 30% were categorized as intangible assets, 13% as a combination of inventories and intangibles, 22% as inventories, 5% as other receivables, and 30% as other assets. Regarding the initial classification of purchased CERs, out of the 14 observations, 7% were classified as a combination of inventories and intangibles, 36% as inventories, 50% as other provisions, and 7% as intangible assets.

In terms of measuring subsidies, all 18 observations indicated acquisition cost. All seven observations were positive concerning reevaluating received and acquired allowances in subsequent periods. Regarding the measurement of obligations, out of the 34 observations, 74% used cost for obligations corresponding to the corresponding assets and market value for obligations exceeding existing assets, while 6% of the observations showed accounting of obligations only based on the value of assets and market value; finally, 20% were based on the weighted average cost of expected emissions.

4.2.1 Distribution of Granted Subsidies

Table 5 delineates the distribution of granted subsidies described in the balance sheet by country and sector. Royal Dutch Shell, Total, Eni SpA, Statoil ASA, Sasol Limited, OMV AG, Suncor Energy Inc., and Canadian Natural Resources Limited provided information on their balance sheets. Subsidies were recognized as intangible assets among these companies, with two observations. Additionally, in three observations, subsidies were recognized as inventory; in two observations, they were classified as other assets; in one observation, it was classified as other receivables. Notably, the UK and Norwegian companies had yet to report subsidies on their balance sheets, while companies in other countries, such as the Netherlands, France, Italy, South Africa, and Canada, did so. These data offer a detailed view of how grants are initially recognized on the balance sheet of the companies analyzed in this study.

Table 5. Distribution of granted subsidies in the balance sheet by country and sector

Company	Country	Sector	Inventory	Intangible Assets	Other Assets	Other Receivables	Total
Royal Dutch Shell	Netherlands	oil and gas		1			1
BP	United Kingdom	oil and gas					0
Total	France	oil and gas	1				1
Eni SpA	Italy	oil and gas	1				1
Statoil ASA	Norway	oil and gas				1	1
Sasol Limited	South Africa	chemical		1			1
OMV AG	Austria	oil and gas			1		1
Suncor Energy Inc.	Canada	oil and gas			1		1
Canadian Natural Resources Limited	Canada	oil and gas	1				1
Total			3	2	2	1	8

4.2.2 Distribution of Allowances and CERs Acquired

Table 6 describes the allowances acquired from third parties disclosed in the FS of the companies participating in the sample from 2015 to 2021.

Table 6. Allowances acquired from third parties

Company	Country	Sector	Intangible Assets	Inventory/Intangibles	Inventory	Other Receivables	Other Assets	Total
Royal Dutch Shell	Netherlands	oil and gas						0
BP	UK	oil and gas		1				1
Total	France	oil and gas			1			1
Eni SpA	Italy	oil and gas	1					1
Statoil ASA	Norway	oil and gas				1		1
Sasol Limited	South Africa	chemical	1					1
OMV AG	Austria	oil and gas						0
Suncor Energy	Canada	oil and gas					1	1
Canadian Natural Resources Limited	Canada	oil and gas						0
Total			2	1	1	1	1	6

Companies that acquired allowances from third parties recorded them in inventories, intangibles, other receivables, and other assets. All companies were European, except for Suncor (Canada) and Sasol (South Africa).

Regarding the accounting practices for CERs, Royal Dutch Shell and Eni classified them as inventories and intangibles, while OMV AG classified it under other provisions, declared as a liability reduction account.

4.2.3 Recognition

Table 7 shows the response to the question: At what value are granted subsidies initially recognized in the balance sheet?

Table 7. At what value are granted subsidies initially recognized in the balance sheet?

Company	Country	Sector	Cost
Royal Dutch Shell	Netherlands	oil and gas	1
BP	United Kingdom	oil and gas	1
Total	France	oil and gas	1
Eni SpA	Italy	oil and gas	
Statoil ASA	Norway	oil and gas	1
Sasol Limited	South Africa	chemical	
OMV AG	Austria	oil and gas	
Suncor Energy Inc.	Canada	oil and gas	1
Canadian Natural Resources Limited	Canada	oil and gas	1
Total			6

Out of the eight companies that mentioned having subsidies, six stated that they are measured by cost. Concerning the question about granted/acquired permissions reevaluated after initial receipt/purchase, according to the model of Lovell et al. (2010), only two companies declared in their FS that they reevaluated them, namely Total in Europe and Sasol in South Africa.

Table 8 presents the results of the question: How is the emission obligation valued based on the model of Lovell et al. (2010)?

Except for Canadian Natural Resources, all others declared how liabilities are treated. Six are treated as acquisition costs, and the excess as the corresponding assets at the current market value. BP, from the United Kingdom, only accounts for surplus, that is, the value of the obligation not reserved by acquired securities and using the market value. And, Suncor (Canada) accounts for the weighted average cost it expects to incur.

Table 8. How is emission obligation valued?

Company	Country	Sector	Cost Market	+ Market deficit	Weighted average cost
Royal Dutch Shell	Netherlands	oil and gas	1		
BP	United Kingdom	oil and gas		1	
Total	France	oil and gas	1		
Eni SpA	Italy	oil and gas	1		
Statoil ASA	Norway	oil and gas	1		
Sasol Limited	South Africa	Chemical	1		
OMV AG	Austria	oil and gas	1		
Suncor Energy Inc.	Canada	oil and gas			1
Canadian Natural Resources Limited	Canada	oil and gas			
Total			6	1	1

4.2.4 Comparison of Findings with Data from Lovell's Research

To analyze significant changes in accounting practices of carbon credit operations (Table 9), a comparative table between the findings of Lovell et al. (2010) and the findings of this research is provided.

Table 9. Comparison of data from this research with the model of Lovell et al. (2010)

Accounting for emission allowances	Disclosure Summary	Lovell et al. (2010).	This research	
			36 companies	9 companies
Subsidies granted - initial recognition	Intangible Asset	42.0%	5.6%	22.2%
	Inventory		8.3%	33.3%
	Other Assets		5.6%	22.2%
	Other receivables		2.8%	11.1%
	No disclosure	27.0%	77.8%	11.1%
Allowance acquired - initial recognition	Intangible Asset	42.0%	5.6%	22.2%
	Inventory/Intangibles		2.8%	11.1%
	Inventory		2.8%	11.1%
	Other receivables		2.8%	11.1%
	Other Assets		2.8%	11.1%
CERs - initial recognition	No disclosure	27.0%	83.3%	33.3%
	No disclosure	77.0%	91.6%	66.7%
	Other provisions		2.8%	11.1%
	Intangible		2.8%	11.1%
	Inventory		2.8%	11.1%
Subsidies granted - measuring at initial recognition	Null value	31.0%		
	No disclosure	23.0%	83.3%	33.3%
	Fair value	15.0%		
Amortization/depreciation of emission allowances	Cost		16.7%	66.7%
	No disclosure	69.0%	100%	100%
Re-evaluation of emission allowances	Disclosed			
	No disclosure	50.0%	94.4%	77.8%
Measurement of liabilities	Yes		5.6%	22.2%
	Cost with balance at market value	58.0%	16.7%	66.7%
	No disclosure	23.0%	77.8%	11.1%
	Market deficit		2.8%	11.1%
	Average cost		2.8%	11.1%

Note. Adapted from Lovell et al. (2010), Table 4.7 Summary of survey of EU ETS top issuers' financial reports.

4.2.5 Discussion on Comparative Analysis

The results of Lovell et al. (2010) are comparable with those of this research considering the total sample, that is, all 36 companies, as it compares the responses obtained with the general total and not with the subsample (Lovell et al., 2010, p. 6).

Over the 14-year interval between this research and that of Lovell et al. (2010), the diversity in the accounting subsidies treatment of carbon bonds remained, focusing on intangible assets (5.6%). Now, it also focuses on inventories (8.3%). According to Lovell et al. (2010, p. 23), securities are classified according to intended use. Thus, securities received free of charge from the government are kept as intangible assets, those acquired from third parties are accounted for as inventories, and those set aside for negotiation are classified as financial assets.

According to the study, at the time, 31% of securities obtained free of charge were apparent in the information sets. We did not find explicit evidence of the existence of such a concession in the investigation. However, Lovell et al. (2010) mentioned that from the 3rd phase of the EU TE program (2013-2020), there was no longer free distribution and distribution through auctions came into effect, a possible justification for emphasizing accounting as inventories, and not as intangible assets. Fifteen per cent of the sample of Lovell et al. (2010) assessed market value; in this research, all were treated at cost. It is worth noting that, as distribution was free in the initial periods, maintaining at cost means treating at null value. On the other hand, concerning measuring liabilities, 58% of the sample of Lovell et al. (2010) measured at cost corresponding to the assets and the surplus at market value; in the current research, this percentage was 16%.

As for information on depreciation and amortization, the absence was significant in the reference authors' sample (69%); in this sample, it was completely absent. Regarding revaluations, Lovell et al. (2010) identified a 50% lack of disclosure; this percentage was 94.4% in this research. A similar situation also occurred with the lack of disclosure of information about the accounting treatment for CERs; previously, it was 77%, and the percentage was 91.6%. Therefore, this research shows that the scenario until 2021 remained quite nebulous, with few companies disclosing information restrictedly. The treatment as inventories, in addition to intangible assets, appears again more prominently. Although this research chose Lovell et al. (2010) as a model for capturing data, the results of classification and measurement also coincide with those found by PwC (2007), Warwick and Ng (2012), Black (2013), and Garcia-Torea et al. (2022).

We identified a considerable increase in the recording of carbon accounting practices in the sample in 2020. The growth in records is likely linked to the movement of intensification of alerts from the global political and economic community, such as WEF (2019), the International Organization of Securities Commissions (IOSCO), and, ultimately, accounting standard setters. Although scientific data on the advances of the climate emergency date back decades, the debate about the climate agenda in the global market intensified only after the mobilization of economic agents (Sardeiro & Bilhim, 2021).

Corporate emissions have significant adverse effects on nations, particularly the most vulnerable (Folke *et al.*, 2021). Examining whether accounting practices serve the social purpose of public reporting is crucial (Zhang-Debreceeny, 2010). The growing interest in carbon accounting and finance is evident, Tang (2017); however, accounting practices have yet to progress accordingly.

5. Conclusions, Policy Implications, and Study Limitations

5.1 Conclusions

This study examined the accounting policies reported on carbon credits of the largest polluters globally based on the model developed by Lovell et al. (2010). The findings indicate that the situation remains like the scenario observed 14 years ago. Few companies disclose their accounting treatment, even among the most polluting entities. There continues to be significant diversity in the disclosed information, which compromises comparability, verifiability, and the understanding of accounting information, potentially hindering stakeholders' decision-making processes.

Overall, accounting classifications predominantly focus on inventory and intangible assets. According to Lovell et al. (2010), this choice is influenced by the method of obtaining information, the intended use, and local regulations. Carbon credits obtained at no cost tend to be treated as inventories, while those acquired through auctions are typically classified as intangibles. The classification as intangibles is justified when the purpose is to fulfil obligations to deliver to proper agencies at reporting times. In contrast, classification as inventories or other financial assets is appropriate when the intention is to sell. In certain countries and sectors, regulatory bodies determine the classification; for instance, in the European energy sector, carbon credits are classified as inventories.

Considering the design of this study, the selected sample, and the defined period, the results reveal that although

the majority of the population and sample are composed of companies from the United States, which are the main GHG emitters and have the most significant assets and revenues, the majority of information is provided by European companies. The political, economic and legal motivations underlying the accounting of carbon credits are evident, as the regulation of emissions trading in Europe signals a greater volume of accounting records and disclosures. Such findings suggest the need to review the strategic positioning of companies and countries (Weikmans & Gupta, 2021), as 98% of nations have signed the Paris Agreement (European Parliament, 2023). The oil and gas sector predominates, which aligns with its representation in the sample. The classification debate between intangibles and inventories arises from the perspective that intangibles are vital for developing operational activities, while inventories reflect assets held for sale.

This scenario suggests remodeling strategies to adapt organizations to a low-carbon economy. Therefore, the implementation of accounting regulations can not only improve the quality of information but also encourage organizational behaviors aimed at reducing the impacts of climate change. Concerning the formulation of regulations, they must be carefully prepared to avoid standardizations that result in misuse of purpose.

5.2 Policy Implications

The study's implications suggest that there are institutional gaps in action, in addition to the social, political, economic and cultural reasons that shape companies' choice of accounting practices. We suggest that some dimensions stand out in this regard: there is a need to create accounting standards and regulations robustly supported by social and ecological foundations to comply with the public interest.; the need for continuing (educational) training for professionals working in the market; the position of academia, institutions funding research grants and journals in targeting this relevant agenda; better targeting of the role of states in monitoring companies according to the fulfilment of each country's targets (Nationally Determined Contribution, NDC); and, finally, the need for the role of civil society in monitoring information related to the emissions of these companies. A combination of market mechanism development and state intervention is necessary for enhancing companies' planning and results in the short, medium, and long term.

5.3 Study Limitations

A limitation of this research is using a restricted set of the 100 most polluting companies worldwide over seven years. Future studies could expand the sample to analyze company behavior regardless of pollution levels. Furthermore, investigating companies' responses to new regulations that aim to integrate financial and sustainability information could provide valuable insights.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal and publisher adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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