

Mapping the Field of Carbon Emissions Disclosure: Expanding the Research Scope

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Received: April 2025 / Revised: June 2025 / Accepted: August 2025

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Abstract

Research aim: This study aims to present a taxonomy of the existing literature on carbon emissions disclosure within the context of the evolving climate regime. Specifically, this study systematically maps the research on carbon emissions disclosure from 1997 to 2024 through an integrated bibliometric network and content analysis.

Design/ Methodology/ Approach: This study analyses research trends in the field of carbon emissions disclosure from 2007 to February 2024 using a combination of systemic literature review, bibliometric network analysis, and content analysis. Using VOSviewer software, a bibliometric cluster analysis was performed after retrieving 466 relevant documents from the Web of Science (WoS) database. After a network analysis of direct citations, 74 high-impact papers were found to meet the inclusion criteria and were categorised into four clusters. Within the four clusters, a content analysis was conducted to identify the key themes and stages of development in carbon emissions disclosure studies.

Research finding: Firstly, the bibliometric analysis revealed four major research clusters. Based on the content analysis, the four research clusters were analysed and themes identified, namely dimensions of reporting, quality of disclosure–CDP questionnaire, implications for disclosure, and climate regime. The second part of the content analysis shows a timeline with three main phases: Period 1, from 1997 to the early 2000s (recognition); Period 2, from the early 2000s to the mid-2010s (understanding emerging markets); and Period 3, from the mid-2010s to the present (adaptability). This phased framework examines the academic growth of the field and highlights the transition from voluntary reporting to strategic adaptation, reflecting broader changes in climate policy and market behaviour.

Theoretical contribution/Originality: The findings can help scholars understand the current status of research and development trends.

Practitioner/Policy implication: This paper outlines the collection process of relevant evidence for carbon emissions disclosure and undertakes a comprehensive review of the existing literature to improve understanding of the current state of knowledge.

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Research limitation: The literature reviewed this study is limited to the WoS database and excludes conference publications, editorials, and book chapters. Future studies can expand the scope of the present study by accessing other databases.

Keywords: Carbon emissions, Disclosure, Systematic literature, Bibliometric network analysis

Type of article: Conceptual paper

JEL Classification: M40, M41

1. Introduction

Climate change is a global issue subjected to continuous debate among governments, organisations, and academics worldwide. Of particular concern is carbon dioxide emissions, among the primary drivers of climate change (IPCC, 2014, 2023). In this respect, it has been argued that businesses are the major contributors to emissions, and are driven towards profit maximisation at the expense of the public and those harmed by pollution (Dahlmann et al., 2019). Therefore, companies must recognise the potential impact of climate change on their business decisions while fulfilling their environmental obligations by considering the impact of their business activities. Specifically, there has been a call for companies to play a more active role in managing and disclosing relevant greenhouse gas (GHG) information (or carbon emissions disclosure) to various stakeholders, such as regulators, investors, and shareholders (Hossain & Farooque, 2019).

Research on carbon emissions disclosure has evolved from voluntary reporting to a strategic imperative reflecting the urgency of climate change and changing priorities. In light of this, mapping trends can facilitate the identification of gaps, emerging issues, and areas of diminishing focus in carbon disclosure. Carbon reporting is generally used as a medium to demonstrate corporate accountability to shareholders, potential investors, suppliers, and customers. Studies have been conducted on the information requirements for carbon reporting, specific reporting methods or standards, and whether reporting is voluntary or mandatory (Pattberg, 2017). Carbon disclosures can be seen as a commitment to accountability, especially when companies are manifestly trying to address the challenges and opportunities associated with climate change. Such steps are seen as criteria for assessing a company's credibility and legitimacy (Alsaifi, Elnahass & Salama, 2020b).

As mentioned earlier, the accounting and disclosure of carbon emissions has attracted widespread interest over the years, as reflected in the studies presented here. Consequently, we seek to contribute to the literature by extending and complementing the limited review studies on carbon emissions disclosure by reviewing a larger number of studies conducted in both developed and developing countries over an extended period of time. Specifically, we identified four studies that examine the literature on carbon emissions: Stechemesser and Guenther (2012); Hahn, Reimsbach and

Schiemann (2015); Velte, Stawinoga and Lueg (2020); and Borghei (2021).

Stechemesser and Guenther (2012) limit their study to the concept of carbon accounting as an integral part of environmental accounting, with the most recent article cited being from 2011. Hahn, Reimsbach and Schiemann (2015) provide a review of the general topics of disclosure requirements, management disclosure decisions, assurance, and market consequences based solely on a search of the EBSCO Business Source Premier database, and includes research up to early 2014. The review does not address the revolutionary developments following the Paris Agreement and appears to be less relevant for current researchers, as new regulations, such as the adoption of the Task Force on Climate-related Financial Disclosures (TCFD), have emerged since the 2000s. A considerable number of studies provide empirical research on the determinants of carbon disclosure. Velte, Stawinoga and Lueg (2020) systematically review 73 quantitative, peer-reviewed empirical studies on carbon disclosure and carbon performance. However, their review is limited to governance-related determinants and the financial consequences of carbon performance and disclosure, taking legitimacy theory into account. Similarly, Borghei (2021) conducts a literature review and maps the main research areas of the study on carbon disclosure through bibliographic mapping. This review offers clear insights into the literature on carbon disclosure and reporting through visualisation and content analysis of trends.

Although there is extensive research on carbon reporting, it is crucial that the literature is systematically reviewed to identify current gaps, rather than just showing the output of carbon disclosure research over time. At this point, it is important to analyse the literature to provide clear guidance on what has been discussed in the past. Hence, this study will highlight the least researched areas that deserve special attention and focus. Specifically, this review covers 74 studies on carbon emissions disclosure published in top-ranked journals. The review further classifies the sampled studies into four different clusters: the dimensions of reporting, the quality of disclosure–CDP questionnaire, implications of disclosure, and the climate regime. Based on these clusters, this review extends and complements the current state of knowledge by discussing the development of carbon disclosure studies using content analysis, and classifies the timelines into distinct phases: recognition (from 1997 to the early 2000s), understanding emerging markets (from the early 2000s to mid-2010s) and adaptability (from the mid-2010s to present).

This review aims to present a taxonomy of existing literature on carbon emissions disclosure within the framework of the developing climate regime. This will help outline a direction for future research in this area. In addition, this review combines techniques of bibliographic network analysis from systematic literature review (SLR) and content analysis in order to summarise the existing literature and assign it to evolutionary phases.

For this review, the journal articles were selected for analysis and

compilation through a structured literature search using appropriate keywords. The results of the bibliometric network analysis then provide additional insight into the current state of the field and point the way for future research. The results are presented in visual representations showing the research clusters generated by the software.

The rest of the article is organised as follows: Section 2 briefly explains the research methodology. Section 3 presents the cluster analysis mapping based on content analysis, followed by timeline mapping based on content analysis in Section 4. Section 5 concludes the paper with an outlook for future research.

2. Methodology

The initial phase involved conducting a SLR, followed by a bibliographic network analysis. A content analysis was conducted based on the network analysis data produced by VOSviewer to identify existing research gaps and establish future initiatives. Finally, content analysis was used to refine the themes and illustrate the developmental patterns of the study.

2.1 Systematic literature review method

This review used the Web of Science (WoS) search engine database maintained by Clarivate Analytics, which can be used directly in various bibliometric analysis tools. Most researchers use the WoS database to conduct bibliometric studies because of the quantity and quality of retrieved publications (Linnenluecke, Marrone, & Singh, 2020; Mustikarini & Adhariani, 2021). In addition, WoS is the leading database with bibliographic data and searches citations (including cited references) from different research areas by specific keywords, such as title, abstract, subject, author, or source title (Linnenluecke, Marrone, & Singh, 2020).

This study collected relevant research papers with a complete research structure from Social Sciences Citation Index (SSCI) databases in the WoS Core Collection. The searches focused on one main topic: carbon disclosure, also known as GHG disclosure. In order to identify all publications related to carbon disclosure, this paper included all synonymous terms used from prior reviews by Borghei (2021) and Hahn, Reimsbach and Schiemann (2015) to describe the same entity, by including the Boolean separator "OR". The following syntax was used in combinations of the keywords like "carbon" OR "co2" OR "GHG" OR "greenhouse" OR "climate change" OR "climate risk" OR "climate resilien*" OR "climate adapt*" OR "climate mitigat*" OR "global warming". In addition, the Boolean operator "AND" was used to capture "reporting" OR "disclo*". Here, the Boolean operators "AND" and "OR" were combined into one search string to query the titles from the WoS database.

Documents that contained a search keyword in the title, but are not related to business, management, or accounting were eliminated from the initial database. With regard to literature type, only journal articles were selected. Conference papers, book chapters, articles in press, and editorial review articles were all excluded. The review also focused on English articles to avoid translation difficulty. Lastly, with regards to timeline, no specific year was set to see the evolution of research.

The first publication on carbon emissions disclosure found in our database search dates back to 1977, indicating the beginning of academic interest in this area. Since then, the research output has increased significantly, indicating that the topic of carbon responsibility is gaining momentum around the globe. A systematic search revealed 466 relevant documents published between 1977 and February 2024. These were subjected to a rigorous screening process that met the defined inclusion and exclusion criteria (see Results below). All selected articles were included in the bibliometric network and cluster analysis to enable a thorough mapping of the intellectual structure of the field.

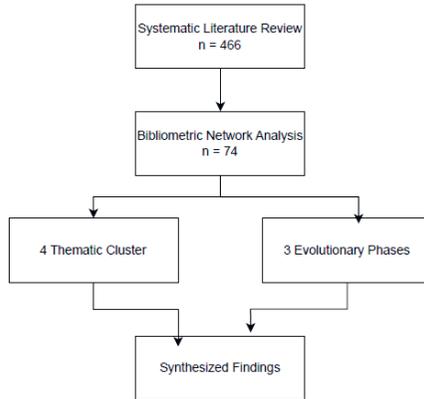
To visualise research trends and form clusters, we used VOSviewer to construct citation-based bibliometric networks. The software created a map of the citation network, with nodes representing individual publications, cluster colours categorising thematically related studies and links denoting citation relationships, highlighting influential works and knowledge streams. This method enabled the objective identification of significant research clusters and the assessment of their relative influence within the literature on carbon disclosure. Following the bibliometric analysis, we conducted a comprehensive content analysis of the articles within each cluster to highlight emerging themes and map the evolution of the field.

After conducting a citation-based bibliometric network analysis in VOSviewer, only 76 of the 466 publications met the threshold for inclusion in a cluster. These papers represent the core knowledge base of carbon disclosure research as they are frequently cited. In this analysis, five clusters were formed, labelled by the last name of the first author. The fifth cluster included only two publications, a number that is considered statistically insignificant for meaningful interpretation (van Eck & Waltman, 2017). In line with best practices, we excluded this outlier, resulting in four robust clusters for content analysis. A total of 390 publications did not have sufficient citation connectivity for cluster assignment; however, they were retained as a contextual reference.

Subsequently, a manual content analysis of all 74 clustered articles was conducted to improve the understanding of the research streams, focusing on theoretical foundations, methods, and emerging trends. This combined methodology of quantitative bibliometrics and qualitative content analysis enabled a thorough assessment of the development of the research field.

Figure 1 summarises the research process used in this study.

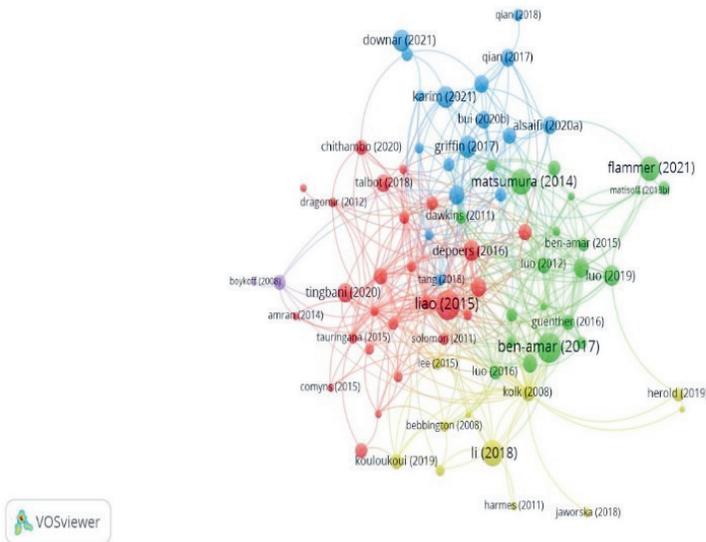
Figure 1: Research Process



3. Findings: Cluster Mapping

Figure 2 shows a VOSviewer visualisation of the 74 publications, displaying the relationship between the clusters in terms of citations. Each cluster has a colour (i.e., red for Cluster 1, green for Cluster 2, blue for Cluster 3, and yellow for Cluster 4) that indicates the group to which the cluster has been assigned. The research themes of these clusters, which were identified through the content analysis, are discussed below.

Figure 2: Citation Network Clusters on Carbon Emission Disclosure



3.1 Cluster 1: Dimensions of reporting

Cluster 1, the largest cluster in the analysis, encompasses 25 publications primarily focused on carbon disclosure studies (Table 1). The content analysis reveals two main discussions: the quality of carbon disclosure, assessed through various disclosure indices, and the determinants influencing such disclosures. The literature in this cluster spans from the early 2000s to the 2020s. In the early 2000s, the absence of specific disclosure frameworks for GHG emissions led researchers to rely on indicators from the Global Reporting Initiative (GRI) for climate change reporting. The GRI, in collaboration with the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI), established the GHG Protocol, which serves as a fundamental instrument for GHG accounting and reporting.

Table 1: Dimensions of Reporting

No.	Document (author, year)	Citations	Main focus	Key determinants/ issues	Measurement method
1	Liao, Luo & Tang (2015)	701	Disclosure quality	Corporate governance (CG)	CDP scores
2	Stanny & Ely (2008)	286	Disclosure determinants	Institutional investors; scrutiny level	CDP scores
3	Rankin, Windsor & Wahyuni (2011)	195	Disclosure practices	Internal systems; external guidance	Disclosure index
4	Peters & Romi (2014)	173	Disclosure determinants	Corporate governance (CG)	CDP scores
5	Prado-Lorenzo et al. (2009)	160	Disclosure determinants	Company attributes	Disclosure index
6	Talbot & Boiral (2018)	136	Disclosure quality	GRI guidelines	GRI framework
7	Liesen et al. (2015)	136	Disclosure determinants	External stakeholder pressure	GHG protocol, CDP, GRI
8	Depoers, Jeanjean & Jérôme (2016)	135	Disclosure quality	GHG information accuracy	CDP scores, annual reports

No.	Document (author, year)	Citations	Main focus	Key determinants/ issues	Measurement method
9	Solomon et al. (2011)	114	Disclosure quality	Interview- based assessment	Qualitative interviews
10	Tauringana & Chithambo (2015)	110	Disclosure determinants	DEFRA guidance; moderating role of CG	Disclosure index
11	Cotter & Najah (2012)	107	Disclosure determinants	Institutional investors (CDP influence)	Carbon disclosure leadership index (CDLI)
12	Hollindale et al. (2019)	98	Disclosure determinants	Corporate governance (CG)	Disclosure index
13	Haque & Deegan (2010)	95	Disclosure quality	Longitudinal trends	Disclosure index
14	Dragomir (2012)	84	Disclosure quality	GHG emissions reporting accuracy	GHG protocol vs. sustainability reports
15	Tingbani et al. (2020)	82	Disclosure determinants	Corporate governance (CG)	Disclosure index
16	Amran, Periasamy & Zulkafli (2011)	66	Disclosure determinants	Company attributes and CG	Disclosure index
17	Bui, Houqe & Zaman (2020)	64	Disclosure determinants	CG and carbon performance (emissions intensity)	CDP scores
18	Jaggi et al. (2018)	63	Disclosure determinants	CG, ownership structure	Disclosure index
19	Comyns & Figge (2015)	59	Disclosure quality	Longitudinal trends	Disclosure index
20	Giannarakis et al. (2017)	59	Disclosure determinants	Environmental performance	CDP scores
21	Giannarakis et al. (2018)	54	Disclosure determinants	Environmental performance, ownership, climate verification	CDP scores

No.	Document (author, year)	Citations	Main focus	Key determinants/ issues	Measurement method
22	Chithambo et al. (2020)	54	Disclosure determinants	Stakeholder pressure; CEO influence	Disclosure index
23	Eleftheriadis & Anagnostopoulou (2015)	53	Disclosure determinants	Company attributes	Disclosure index
24	Krishnamurti & Velayutham (2018)	45	Disclosure determinants	Corporate governance (CG)	CDP scores
25	Kalu, Buang & Aliagha (2016)	43	Disclosure determinants	Company attributes	Disclosure index

Prado-Lorenzo et al. (2009) were pioneers in the analysis of sustainability reports from large firms, utilising a disclosure index that included multiple climate-related variables. Employing various documents to create a comprehensive list of climate change disclosures, Haque and Deegan (2010) conducted an in-depth analysis of disclosures from prominent Australian energy corporations. Regarding commitment level to the Kyoto Protocol, Amran, Periasamy and Zulkafli (2011) employ content analysis to document disclosures by large public firms, similar to Freedman and Jaggi (2005). Their study is among the initial comparisons between developed and advanced rising economies in the Asia-Pacific area on adherence to Kyoto Protocol stipulations. Consistent with prior research, Jaggi et al. (2018) utilise the differentiated weights for individual components established by Freedman and Jaggi (2005) to obtain data pertaining to the Kyoto Protocol.

Rankin, Windsor and Wahyuni (2011) perform a thorough evaluation of Australian businesses' responses to climate change before the enforcement of mandatory reporting under the National Greenhouse and Energy Act 2007. The study establishes a robust methodology for quantifying and reporting GHG emissions by generating an index based on ISO 14064-1 requirements. Dragomir (2012) assesses GHG accounting methodologies utilised by prominent oil and gas corporations in the European Union, emphasising the congruence between environmental database metrics and emissions reporting in accordance with the GHG Protocol. The study stresses the need for standardised techniques in improving the precision and reliability of corporate GHG reporting. Comyns and Figge (2015) investigate the quality of GHG reporting across 45 oil and gas companies, employing various reporting standards, such as the GRI Guidelines, the GHG Protocol, and sector-specific frameworks.

Liesen et al. (2015) extend the field of study by categorising corporate GHG disclosures according to scope, type, and reporting boundaries, using

the guidelines of the GHG Protocol, the Carbon Disclosure Project (CDP), and the GRI. Nevertheless, Talbot and Boiral (2018) contend that GRI reports are superior to CDP questionnaires because of their consistency and appropriateness for longitudinal research. They highlighted the GRI's application-level system, which facilitates the identification of companies with the highest disclosure standards, thereby enhancing the reliability of sustainability reporting over time. Meanwhile, Depoers et al. (2016) introduce the concept of traceability as an essential quality attribute in emissions reporting. Their analysis underscores the significance of verified and transparent data, hence enhancing the discourse on improving the legitimacy and accountability of corporate GHG disclosures.

The literature indicates variability in the quantification of disclosures, with some studies employing a binary approach (disclosed vs. not disclosed), while others utilise weighted assessments based on compliance with reporting standards (i.e., Chithambo et al., 2020; Eleftheriadis & Anagnostopoulou, 2015; Hollindale et al., 2019; Prado-Lorenzo et al., 2009; Tauringana & Chithambo, 2015; Tingbani et al., 2020). More refined techniques facilitate more complex evaluation of the quality and scope of carbon disclosures in various circumstances. Collectively, these studies underscore the significance of standardised frameworks and methodologies in advancing the quality and reliability of carbon reporting.

3.2 Cluster 2: Quality of Disclosure–CDP Questionnaire

Cluster 2 consists of 21 publications on the quality of disclosure using the CDP questionnaire, a global initiative that promotes carbon disclosure through institutional investor influence (Table 2). Both Clusters 1 and 2 examine the quality of disclosure, but their methodological approaches are rooted in fundamentally different research paradigms. Most studies in Cluster 1 take a macro-analytical approach and use composite indices to assess the completeness of disclosure in different sectors and regions. Cluster 2, on the other hand, uses a micro-standardised approach using CDP questionnaires, which allows for direct comparability, but may exclude material issues for emerging economies.

Since 2003, the CDP has collected annual carbon emissions data from companies worldwide to standardise corporate climate change responses. In 2007, CDP broadened its focus to cover S&P 500 corporations, after initially focusing on Financial Times 500 companies. When compared to alternative sources like annual reports or sustainability reports, the CDP's structured questionnaire reduces self-selection bias and guarantees consistent and trustworthy data (Luo & Tang, 2016). Participation in the CDP is voluntary, with firms categorised based on their level of disclosure: non-participants, partial disclosure, private disclosure to investors, and public disclosure

(Dawkins & Fraas, 2011; Matsumura, Prakash & Vera-Muñoz, 2014).

The CDP questionnaire is frequently regarded as a binary variable in research on carbon disclosure, in which firms either respond or do not (Ben-Amar, Chang & McIlkenny 2017; Grauel & Gotthardt, 2016). Nevertheless, certain studies employ more sophisticated methodologies. For example, Dawkins and Fraas (2011) divide disclosure into three ordinal categories: no disclosure, partial disclosure, and full disclosure. Ben-Amar and McIlkenny (2015) expand upon this analysis by evaluating disclosure transparency and quality using CDP scores, thereby offering a more detailed comprehension of corporate disclosure practices. Meanwhile, Ott, Schiemann and Günther (2017) clearly differentiate between response decision (i.e., whether a firm responds) and publication decision information (i.e., which response is made public).

The CDP highlights the importance of reporting Scope 1, 2, and 3 emissions, with Scope 2 and 3 gaining increasing attention due to their indirect environmental impacts (Matisoff, Noonan & O'Brien, 2013). Palea and Drogo (2020) concentrate on carbon intensity, excluding Scope 3 due to measurement challenges, while Blanco, Caro and Corbett (2016) assess the comprehensiveness of Scope 3 emissions reporting. The CDP disclosure score encompasses governance, risk management, accounting, and emissions reduction activities, and it assesses the comprehensiveness of carbon disclosure on a scale of 0 to 100 (Guenther et al., 2016; Luo, 2019). It provides a comprehensive metric for evaluating corporate carbon performance and ensuring that disclosure practices are in accordance with global standards.

Table 2: Quality of disclosure–CDP questionnaire

No.	Document (author, year)	Citations	Focus area	Key findings/ relationships	Measurement approach	Significant contribution
1	Matsumura, Prakash & Vera-Muñoz (2014)	579	Economic Impact	Firm value effects of carbon disclosure	CDP scores	First to quantify market value impact
2	Reid & Toffel (2009)	538	Regulatory	Shareholder actions drive disclosure	CDP scores	Established investor influence model
3	Ben-Amar, Chang & McIlkenny (2017)	452	Governance	Board independence improves disclosure	CDP scores	Cross-country governance analysis
4	Luo, Lan & Tang (2012)	244	Multi-factor	Social, financial, and institutional drivers	CDP scores	Comprehensive driver framework

No.	Document (author, year)	Citations	Focus area	Key findings/ relationships	Measurement approach	Significant contribution
5	Dawkins & Fraas (2011)	160	Visibility	Environmental performance linkage	CDP scores	Early visibility-disclosure link
6	Ben-Amar & McIlkenny (2015)	147	Governance	Board gender diversity effects	CDP scores	Gender diversity focus
7	Kim & Lyon (2011)	145	Regulatory	Mandatory reporting effectiveness	CO2 emissions calculations	Regulatory impact evidence
8	Luo (2019)	105	Performance	Carbon intensity as key determinant	CDP scores	Institutional moderation effect
9	Matisoff, Noonan & O'Brien (2013)	98	Quality	Scope 2/3 reporting trends	CDP scores	Scope 3 reporting pioneer
10	Flammer, Toffel & Viswanathan (2021)	84	Activism	Shareholder activism impact	CDP scores	Recent activism evidence
11	Guenther et al. (2016)	82	Stakeholder	Carbon performance linkage	CDP scores	Stakeholder theory application
12	Kılıç & Kuzey (2019)	74	Governance	Emerging market governance effects	Disclosure index	Emerging market focus
13	Freedman & Jaggi (2005)	61	Comparative	Cross-national disclosure patterns	Content analysis	Early comparative study
14	Luo & Tang (2016)	60	Cultural	National culture influence	CDP scores	Cultural dimension addition
15	Blanco, Caro & Corbett (2016)	54	Quality	Scope 3 completeness issues	CDP scores	Scope 3 methodology
16	Palea & Drogo (2020)	54	Economic impact	Debt financing cost effects	CDP + ASSET4	Financial cost analysis
17	Ott, Schiemann, & Günther (2017)	54	Multi-factor	Economic-environmental performance	CDP scores	Performance linkage

No.	Document (author, year)	Citations	Focus area	Key findings/ relationships	Measurement approach	Significant contribution
18	Matisoff (2013)	51	Quality	Mandatory vs. voluntary comparison	Plant/firm/regulatory data	Policy effectiveness
19	Schiemann & Sakhel (2019)	51	Economic impact	Information asymmetry reduction	CDP physical risk scores	Information economics
20	Grauel & Gotthardt (2016)	49	Regulatory	Legal system differences	CDP scores	Legal system comparison
21	Li et al. (2017)	47	Media and finance	Media coverage and equity costs	Financial/non-financial data	Media impact analysis

Flammer, Toffel, and Viswanathan (2021) explore the reporting of climate risk within the CDP, with an emphasis on physical, regulatory, and other risks. The significance of comprehensive risk disclosures in improving corporate accountability is further demonstrated by their research. Schiemann and Sakhel (2019) highlight the significance of robust methodologies in physical risk reporting, as they address concerns regarding the accuracy of reported emissions. Furthermore, several studies have identified the factors that influence carbon disclosure, such as corporate governance attributes (e.g., Hollindale et al., 2019; Jaggi et al., 2018), external stakeholder pressure (e.g., Chithambo et al., 2020; Liesen et al., 2015), and company characteristics (e.g., Amran, Periasamy & Zulkafli, 2011; Eleftheriadis & Anagnostopoulou, 2015; Kalu, Buang & Aliagha, 2016; Prado-Lorenzo et al., 2009). The character and extent of corporate carbon disclosures are collectively influenced by these factors. In essence, the CDP has emerged as an essential platform for standardising and improving corporate carbon disclosure. Its methodology, including the disclosure score and focus on Scope 2 and 3 emissions, provide important insights into corporate climate strategies. Nonetheless, challenges remain in ensuring the precision and comprehensiveness of reported data.

3.3 Cluster 3: Implications on disclosure

Studies in Cluster 3 focus on the contemporary debate on the impact of carbon disclosure, particularly its implications for investors and firm valuation (Table 3). It integrates accounting research within the capital markets environment, highlighting the value relevance of carbon emission levels and the consequences of carbon emissions disclosure.

The literature highlights a growing recognition of the impact of climate

change on investors. Early studies, such as Sullivan and Gouldson (2012), initiated discussions on whether corporate climate change reporting meets investor needs. Subsequent studies, including Griffin, Lont and Sun (2017) and Alsaifi, Elnahass and Salama (2020a), demonstrate that GHG emissions disclosure negatively affects share prices and investor reactions. However, Liesen et al. (2017) find limited evidence of financial markets valuing absolute GHG emissions levels. From regulatory insight, Baboukardos (2017) examines the impact of the UK’s 2013 regulations, which mandate GHG emissions reporting, on the link between market value and emissions. Downar et al. (2021) further show that regulated companies reduced emissions by approximately 8% compared to a control group. In addition, Gerged, Matthew and Elheddad (2021) identify an inflection point in the relationship between GHG emissions disclosure and the cost of equity, suggesting that higher emissions increase the cost of capital for environmentally sensitive sectors. Notably, Lemma et al. (2019) highlight that voluntary CO₂ emissions disclosure is negatively associated with a firm’s cost of capital, with higher carbon risk firms exhibiting better disclosure quality. Bui, Moses and Houqe (2020) extend this analysis by examining multi-country differences in how GHG emissions affect the cost of equity capital.

Table 3: Implications on Disclosure

No.	Study (Year)	Citations	Research Focus	Key Findings	Measurement Approach
1	Griffin, Lont & Sun (2017)	235	Investor response	Significant market reaction to disclosure events	GHG metrics + CDP Scores
2	Qian & Schaltegger (2017)	148	Performance link	Strong correlation between disclosure and carbon performance	Emission intensity + CDP
3	Sullivan & Gouldson (2012)	101	Case study	UK supermarkets show varied disclosure practices	Published reports analysis
4	Broadstock et al. (2018)	82	Financial performance	Money-metric performance impacts disclosure quality	Bloomberg emissions data
5	Hassan & Romilly (2018)	80	Economic impact	Bidirectional ESG disclosure-performance relationship	GHG metrics (Bloomberg)

No.	Study (Year)	Citations	Research Focus	Key Findings	Measurement Approach
6	Alsaifi, Elnahass & Salama (2020a)	77	Financial impact	Positive disclosure-FP correlation in emerging markets	CDP Scores
7	Tang & Demeritt (2018)	72	Disclosure drivers	Regulatory pressure dominates reputational factors	Mixed methods
8	Lemma et al. (2019)	72	Cost of capital	Carbon risk affects financing costs	CDP + Scope 1 emissions
9	Bui, Moses & Houqe (2020)	68	Equity costs	Disclosure reduces cost of equity capital	CDP + intensity metrics
10	Baboukardos (2017)	66	Market value	Carbon disclosure enhances firm valuation	CO2e (ASSET4)
11	Liesen et al. (2017)	66	Asset pricing	Complete disclosure reduces cost of capital	Binary + GHG metrics
12	Karim, Albitar & Elmarzouky (2021)	63	Governance	Capital expenditure drives disclosure quality	Disclosure index
13	Qian, Hörisch & Schaltegger (2018)	62	EMA adoption	CDP participation stimulates EMA implementation	CDP banding
14	Downar et al. (2021)	61	Regulatory effect	Mandatory reporting improves FP in EU ETS	EU ETS registry data
15	Siddique et al. (2021)	53	Financial impact	Disclosure quality affects FP in Asia	CDP scores
16	Alsaifi, Elnahass & Salama (2020b)	47	Market reaction	CDP announcements affect stock returns	Event study method
17	Gerged, Matthews & Elheddad (2021)	44	Equity costs	GHG disclosure reduces financing costs	Bloomberg emissions

Hassan and Romilly (2018), Qian and Schaltegger (2017), and Siddique et al. (2021) argue that companies with improved environmental performance are more likely to enhance their carbon performance and disclose more carbon-related information. This suggests a bidirectional relationship where better environmental performance motivates increased disclosure, rather than disclosure directly driving performance improvements. The link between carbon emissions and financial performance has been widely studied across disciplines. Alsaifi, Elnahass and Salama (2020a) employ a financial index to quantify the association between carbon disclosure and firm financial performance, highlighting a measurable relationship. Prior to that, Tang and Demeritt (2018) explored how carbon reporting influences internal business processes and contributes to emission reductions. Collectively, these studies provide evidence that carbon disclosure is positively associated with firm performance during the examined period.

The positive association between carbon disclosure and firm performance suggests that disclosure practices may have broader financial and operational benefits. Environmental performance appears to motivate greater disclosure, however, the extent to which disclosure drives performance improvements remains less clear.

3.4 Cluster 4: Climate Regime

Cluster 4 comprises 11 publications that focus on the strategies employed by companies in carbon disclosure, as summarised in Table 4. This cluster addresses critical issues surrounding carbon disclosure practices and their implications for corporate environmental accountability. Kolk et al. (2008) provide foundational insights into the evolution of carbon trading, emphasising the contentious nature of emissions data disclosure, as evidenced by the inaugural CDP inventory published in 2003. Bebbington and Larrinaga-González (2008) further contextualise this discourse by elucidating the greenhouse effect, identifying anthropogenic influences on GHG concentrations, and outlining the scientific underpinnings of global climate change. Notably, Harmes (2011) identifies two pivotal assumptions regarding investor environmental awareness: the influence of institutional investors and the “business case” for climate change mitigation.

In a different scope of study, Gibassier and Schaltegger (2015) conduct a qualitative analysis to explore the integration of carbon management accounting with external reporting of carbon emissions, thereby establishing a connection between internal performance management and external performance reporting. Herold and Lee (2019) expand on this theme by categorising internal and external carbon management practices within the global logistics industry, utilising data from Bloomberg ESG and the CDP.

The cluster also examines the dynamics of carbon communication among companies. Kouloukoui et al. (2019) employ codified keywords to analyse sustainability reports and disclosed information on climate risks, revealing a correlation between climate change risk disclosures and specific characteristics of companies in emerging economies, such as Brazil. In a comparative analysis of developing and advanced developing countries, Lee, Park, and Klassen (2015) utilise content analysis to assess the frequency of carbon communication, drawing on data from newspapers. Supporting this premise, Li et al. (2018) demonstrate that companies in China, similar to many emerging economies, are more inclined to disclose carbon-related information when faced with external demands for informal environmental legitimacy, particularly given their historically low levels of environmental sustainability.

Table 4: The Climate Regime

No.	Study (year)	Citations	Research focus	Key contribution	Measurement approach
1	Kolk, Levy & Pinkse (2008)	406	Reporting quality	Early analysis of GHG verification practices	CDP questionnaire responses
2	Li et al. (2018)	305	Disclosure drivers	Media attention and green innovation link	CDP scores
3	Bebbington & Larrinaga-González (2008)	183	Theoretical foundation	Seminal review linking accounting to climate science	Literature synthesis
4	Lee, Park & Klassen (2015)	126	Market impact	First evidence of Korean market reactions to disclosures	Media content analysis
5	Pellegrino & Lodhia (2012)	114	Comparative analysis	Cross-national disclosure practice comparison	Corporate report analysis
6	Apergis, Eleftheriou & Payne (2013)	65	Regulatory impact	IFRS adoption effects on environmental reporting	Bloomberg emissions data
7	Kouloukoui et al. (2019)	63	Risk disclosure	Climate risk keyword analysis framework	Term frequency analysis
8	Harmes (2011)	53	Science review	Climate science foundation for disclosure studies	Literature synthesis

No.	Study (year)	Citations	Research focus	Key contribution	Measurement approach
9	Herold & Lee (2019)	45	Management practices	Taxonomy of carbon disclosure strategies	ESG + CDP scores
10	Jaworska (2018)	42	Discourse analysis	Linguistic patterns in climate reporting	Mixed-methods analysis
11	Gibassier & Schaltegger (2015)	41	Case Study	Deep dive into corporate disclosure processes	Qualitative case study

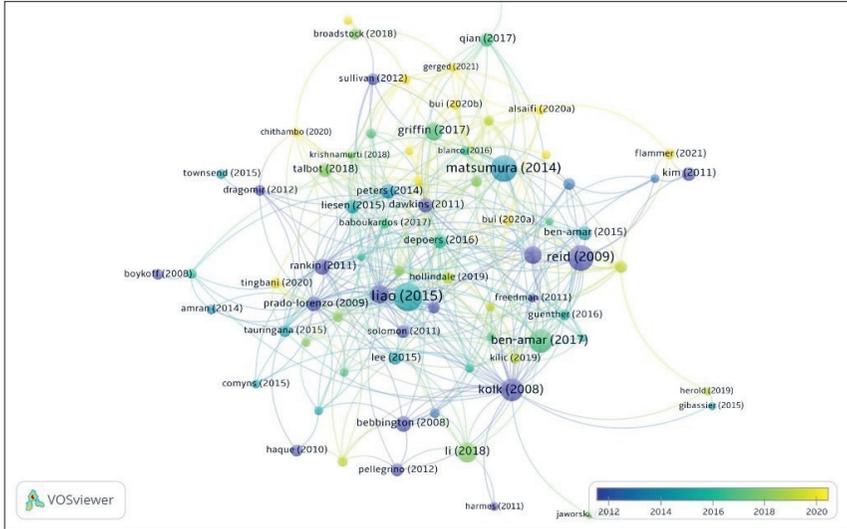
Previously, Pellegrino and Lodhia (2012) used a cross-case research design to demonstrate the high level of media attention to these climate change issues using publications from the Australian mining industry. Meanwhile, Apergis, Eleftheriou and Payne (2013) examine the impact of accounting information related to R&D expenditure on carbon emissions and particularly before and after the adoption of the IFRS in three EU countries, i.e., UK, France, and Germany. The emissions data was taken from various sources such as the European Commission and the Bloomberg database.

In summary, Cluster 4 highlights the complexities of carbon disclosure strategies and communication practices among companies. The literature points out the importance of linking internal carbon management with external reporting and the varying levels of carbon communication influenced by external pressures, particularly in emerging economies.

4. Findings: Timeline Mapping

The evolving climate change paradigm contributed to the development of carbon disclosure studies. Research on carbon disclosure will remain a crucial component of the global initiative to address climate change, providing insight and guidance to stakeholders, corporations, and governing bodies. In VOSviewer, the overlay visualisation makes it easier to display the chronological development of research topics, with nodes colour-coded to show their connection to older or newer publications (Figure 3). According to the analysis of each cluster based on 74 publications, the study period was categorised into three phases timeline: Period 1 from 1997 to the early 2000s (recognition), Period 2 from the early 2000s to the mid-2010s (understanding emerging markets), and Period 3 from the mid-2010s to the present (adaptability). These phases are not linear, and the research may evolve concurrently or interact. The following factors determined the analysis timeframes.

Figure 3: Overlay Visualisation by Year



4.1 From 1997 to early 2000s (recognition)

During this period, standards and criteria were developed to standardise sustainability and emissions reporting in corporations to enhance credibility, consistency, and reliability. The Kyoto Protocol, signed in 1997, was a turning point in climate policy and carbon emissions reporting since it is established legally binding carbon reduction targets for industrialised countries. The current literature acknowledges that the early 2000s were pivotal, as standardised frameworks and criteria were developed to enhance corporate reporting on sustainability and GHG emissions. Initiatives like the GRI, the GHG Protocol, and sector-specific criteria signify a crucial advancement in the uniformity of corporate disclosure and communication on sustainability impacts and carbon footprints.

A further element in the recent research on carbon disclosure is the emergence of efforts aimed at leveraging the influence of institutional investors to generate demand for carbon disclosure. The most recognised carbon disclosure programme is the CDP, a global consortium of institutional investors aimed at assessing corporate responses to climate change and soliciting annual carbon emissions data from firms globally (Kolk, Levy & Pinkse, 2008). Carbon disclosure thereafter advanced swiftly, exemplified by programmes such as the GRI, which offers standardised frameworks for voluntary corporate reporting. The inaugural CDP report, published in 2003, only encompassed the Financial Times 500, whereas S&P 500 businesses

were incorporated in the 2007 CDP report, which had data from 2006. These reports include data on a diverse array of climate-related activities. The disclosure trends at CDP and the accessibility of carbon data from the CDP report present a chance to analyse corporate responses to climate change more comprehensively. Fagotto et al. (2007) were among the first that highlighted the important of comprehensive transparency to address climate change. Consequently, the emergence of voluntary carbon emission disclosure legislation towards mandatory initiatives has been a significant topic in early literature aiming for transparency and emissions management.

4.2 Early 2000s to mid-2010s (understanding emerging markets)

In this phase, researchers shifted their focus on carbon disclosure from simply deciding whether to disclose or withhold information, or to engage in more in-depth discussion. This evolution occurred due to the shift of carbon reporting from a voluntary best practice to a legal obligation. In this context, the analysis indicates a significant focus on the S&P 500, Fortune 500, and FTSE, as the prior studies concentrated on developed nations. In 2011, American corporations were mandated to report their GHG emissions (Stanny, 2013). In 2012, GHG reporting was mandated for all companies listed on the London Stock Exchange in their annual financial reports for reporting years concluding on or after September 30, 2013.

The developmental periods before and after 2015 provide background for the growth of the research stream in prominent journals, suggesting an increase in carbon disclosure studies. This significant trend in 2015 may be attributed to the several significant agreements, including the 2030 Agenda for Sustainable Development Goals (SDGs) in September and the Paris Agreement on climate change in December. The United Nations General Assembly ratified the conclusion document titled *Transforming Our World: The 2030 Agenda for Sustainable Development*, referred to as the 2030 Agenda. It encompasses 17 SDGs, including SDG 13, which aims to address climate change and its effects. The Paris Agreement is a legally binding international climate accord established under the United Nations Framework Convention on Climate Change, commonly referred to as COP21. The agreement establishes a comprehensive action plan to ensure the world remains on course to prevent hazardous climate change by restricting global warming to below 2°C above pre-industrial levels.

Recent focus has transitioned to emerging economies, evidenced by notable economic growth and urbanisation resulting in a considerable rise in their carbon emissions. Initially, emerging economies were free from legally mandated emission reduction objectives; however, as their emissions escalated, so did the pressure for them to undertake more substantial commitments. With rising apprehensions over climate change and carbon

emissions in emerging economies, there is an increasing focus on evaluating the quality and comprehensiveness of current reporting standards.

Disclosure indices and availability databases such as the CDP offer significant insights into business carbon disclosure practices. Nevertheless, this review indicates that research within developing countries is relying more on carbon disclosure indices for assessing corporate carbon disclosure, meanwhile research in developed countries frequently employs databases such as the CDP. In the past, companies in developing countries shown lower participation rates in initiative voluntary disclosure platforms such as the CDP compared to those in developed countries. As a result, accessing the quality level on carbon emissions and climate-related disclosures can be challenging in some developing countries. Because of this, the assessment of corporate carbon using disclosure indices provide a systematic framework through publicly available sources, including annual reports, sustainability reports, and corporate websites. Moreover, in the absence of standardised regulatory guidelines, academics frequently employ these indices to evaluate the scope and quality of corporate carbon emission disclosures. As a result, disclosure indices have emerged as a prominent benchmark for evaluating company disclosure practices, especially within voluntary frameworks.

4.3 Mid-2010s to present (adaptability)

During this time, carbon disclosure data was more readily available, and academics expanded their scope of study to the causes and impacts of disclosure practices. This encompasses examining the determinants factors such corporate characteristics, types of industry, corporate governance, regulatory environment, and climate change regulations on the decision to disclose information. Together with the diverse effects of climate change reporting and disclosure, it addressed both financial and non-financial aspects, including environmental or sustainability performance to fulfil the needs of market participants. A review reveals that the correlation between company performance and disclosure procedures was examined during this period, evaluating their potential impact on risk assessments, capital costs, and stock prices. The volume of articles significantly increased at this time, reflecting a growing concern among researchers regarding carbon emissions.

As the significance of emissions data for carbon disclosure became increasingly evident, research initiatives commenced to enhance data collecting and verification methodologies. Researchers are increasingly focused on expanding the investigation into the application of emissions data to improve the precision and detail of metrics such as total CO₂-equivalent emissions and carbon intensity. This data offers enhanced insight into emissions developments within organisations and is more meaningful for interpretation over time. The current discussion on the implications of carbon

disclosure reveal a significant gap that necessitates further investigation into the disclosure practices of companies, particularly in emerging economies. Prior literature shows lack empirical evidence related to the relationship between environmental commitment and carbon performance in terms of emissions reduction. In addition, the current empirical literature indicated that the effect of carbon disclosure on accounting performance is still scarce. The inadequate and inconsistent evidence about the recognition, assessment, and monitoring of the impacts of these emissions cannot be overlooked, given the growing public knowledge of carbon emissions data. Future research should identify and analyse the combined moderator and mediator factors to evaluate the impact of carbon disclosure. Together, the integration of artificial intelligence, machine learning, and other emerging technologies to improve carbon footprint research and monitoring facilitates further investigation.

5. Conclusion

In the course of this study, a bibliometric network analysis was conducted alongside the content analysis to explain the origins of the knowledge base and improve the understanding of carbon emissions disclosure studies. The results of our analysis revealed significant gaps in carbon disclosure research in terms of the scope and depth of information disclosed by companies on various dimensions related to the evolving climate regime and associated policies and regulations. Based on the content analysis, four research clusters were analysed and themes identified, namely dimensions of reporting, quality of disclosure: CDP questionnaire, implications for disclosure, and climate regime. The second part of the content analysis shows a timeline with three main phases: Period 1, from 1997 to the early 2000s (recognition); Period 2, from the early 2000s to the mid-2010s (understanding emerging markets); and Period 3, from the mid-2010s to the present (adaptability).

Most importantly, this review provides important insights that will help academics and researchers to position their research in this area and find new avenues of study. The results of this review would therefore make it easier to discover new research perspectives for the future. The adaptation phase provides a roadmap for the disclosure of technology integration with the TCFD recommendations and the inclusion of industry-related disclosure requirements.

While this review was conducted rigorously, there were nevertheless limitations may represent avenues for future reviews. The literature in this study is limited to the WoS database and excludes conference publications, editorials, and book chapters. Future researchers could expand the scope of the present study by accessing several different databases such as Scopus or Google Scholar, database to overcome the limitations of the present

study. Another limitation is that only VOSviewer was used as a bibliometric tool to perform different analysis types; future research could extend the scope of this study by using other bibliometric tools such as CiteSpace, and CRExplorer for better visualisation and more comprehensive review.

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