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Disclosure Dynamism: TCFD Aligned Climate Claims of UK Corporates

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ABSTRACT

This research examines how climate claims by companies from the United Kingdom have changed over the years, especially when they became certain about the mandate of the Taskforce on Climate-related Financial Disclosure (TCFD). We use text data from FTSE 100 companies for eight consecutive years, starting from 2016, and apply the robust ClimateBERT algorithm to analyse company statements related to climate claims, where they claim how they take care of climate in their business operations. Our findings show that the total number of corporate climate claims made has substantially increased since 2016, resulting in an overall improvement in corporate environmental claims till 2023. This coincides with the official announcement of the TCFD mandate.Our analyses also indicate that the proportion of claims in each report has increased over the years despite economic uncertainties. Additionally, the study findings reveal that even industries with minimal or negligible climate claims can still be associated with carbon-intensive activities. The complementary features of the legitimacy and stakeholder theories support our findings. By applying ClimateBERT, our research mitigates existing data challenges, yielding an efficient framework for analysing text through a robust natural language processing model. Our findings will assist policymakers in identifying necessary modifications to corporate climate disclosure and will help assess the impact of the Taskforce intervention on climate-related financial disclosure.

1 | Introduction

The United Kingdom (UK) is the first G20 nation to legally mandate comprehensive climate-related disclosures for its largest businesses and financial institutions, in alignment with climate-related financial disclosures. A press release[1] by the UK government on 29 October 2021 marks a pivotal moment in corporate climate accountability. From 6 April 2022, publicly quoted companies, large private companies, and Limited Liability Partnerships in the UK[2] are legally obliged to report climate impact based on the Taskforce on Climate-related Financial Disclosures (TCFD[3]) recommendation. TCFD's advice encourages companies to adopt an appropriate internal governance and risk management framework to deal with the non-diversifiable climate risk and to start generating socio-economic benefits alongside their financial gain. However, on 4th March 2022,[4] when the Industry and Regulatory Committee of the UK parliament warned that "UK will miss net zero targets without urgent action", several stakeholders[5] raised questions about the effectiveness of the TCFD. The corporate world realised the need for additional assistance in modifying its climate strategy and disclosures (Afrifa et al. 2020; Ngo et al. 2023). So, to assist in broadening the definition of 'disclosure' and provide necessary

climate-related information to stakeholders, COP 27[6] organised training on TCFD for companies.

Implementing TCFD recommendations enables investors to incorporate climate considerations into investment decisions, aligning with global efforts to limit temperature rise to 1.5°C, as agreed upon in the United Nations 2015 climate accord (Kim, Lee, and Vourvachis 2023; UN Climate Change 2015). However, a significant challenge is the credible assessment of greenhouse gas (GHG) emissions reported by companies. While ethical standards, as outlined in various codes of ethics, mandate accurate reporting of GHG emissions, there is a lack of consensus in current literature regarding appropriate methods for companies to report on their climate impact, raising questions about the adherence to these standards (Liesen et al. 2015).

Furthermore, although government interventions have effectively promoted corporate social responsibility (CSR) and environmentally responsible corporate behaviour (Giamporcaro, Gond, and O'Sullivan 2020; Kourula et al. 2019), the impact of the TCFD recommendations on the quality of climate disclosure remains unclear. This leads to a critical inquiry, especially in the context of the UK, where doubts persist about the feasibility of companies achieving net-zero emissions by 2050. Therefore, the validity of companies' climate claims is regarded as central to this debate. This study, consequently, seeks to fill this gap and examines climate claims at a granular level. In order to address the above-mentioned research gap, we ask the following research question: How *does the implementation of TCFD guiding principles impact the yearly occurrence of climate-related claims in companies' annual reports*[7]*?*

To answer the research question, we apply legitimacy and stakeholder theories to develop the theoretical framework of this study. Usually, higher demand from stakeholders about environmental and climate-related responsibility creates immense pressure on companies to maintain their legitimacy (Suchman 1995; Garrido-Merchán, González-Barthe, and Vaca 2023). However, the main challenge in calculating the impact of company activities on climate change is the lack of robust data or, in other words, the existence of a severe data gap (Busch et al. 2023; Gills and Morgan 2020). To bridge the data gap, Natural Language Processing (NLP) is used for text classification to assess a company's vulnerability to climate-related risks (Coen, Herman, and Pegram 2022). Access to big data related to possible factors affecting climate disclosure opens up the opportunity to apply Artificial Intelligence (AI) or Machine Learning (ML) algorithms for precise estimation of the quality of disclosure by companies (Ilhan, Sautner, and Vilkov 2021; Nguyen, Diaz-Rainey, and Kuruppuarachchi 2021). Advances in ML have introduced a new wave of automation to analyse a vast amount of unstructured text and speech data (Webersinke et al. 2021; Liu et al. 2023). Such advancements in data collection and processing have made it significantly more straightforward to do an adequate analysis than previous manual methods (Mora, Wu, and Panori 2020), and the company reporting results are much faster and more precise (Demaria and Rigot 2021).

By leveraging the power of AI and ML, companies can improve the accuracy and efficacy of their climate-related financial disclosures, which is highly valuable for their stakeholders(Zennaro et al. 2021) . However, following the news of the TCFD mandate from April 2022 for large UK companies, how these companies changed their approach to climate disclosure is yet to be estimated in detail. We, therefore, focus on the UK FTSE 100 companies over the period between 2016 and 2023 and apply the ClimateBERT algorithm (Varini et al. 2020), recognised as a superior state-of-the-art method appropriate for NLP (Devlin et al. 2018; Kölbel et al. 2020). Even though when companies employ 'cheap talk' and 'cherry-picking' techniques to give a false impression of their climate-related activities, ML and NLP techniques such as ClimateBERT can detect and quantify these strategies applied in corporate climate risk disclosures (Bingler et al. 2022). Similar to existing literature, we find that UK companies' overall climate-related claims and environmental initiatives have increased over the years (Orazalin, Ntim, and Malagila 2024). The same trend is observed even after the government declaration about the intention to make the TCFD mandatory starting in 2022. In addition, the COVID-19 crisis also raised questions about any possibility of a shift in the companies' attention from climate change (Mohommad and Pugacheva 2022). However, our analysis of company reports, which includes the peak period of the COVID-19 crisis, suggests that despite the crisis, companies continued to engage with climate strategies, as evidenced by the increase in climate-related claims during the pandemic period.

The findings of the study highlight the importance of examining the impact of TCFD related to the quality of climate-related disclosures by companies. Nevertheless, the literature indicates that reporting has improved due to the implementation of TCFD in the UK, although the quality of disclosures varies significantly among firms (Gebhardt et al. 2024). Thus, a detailed analysis is crucial, as it emphasises varying levels of adherence to these principles and their distinct impact on environmental reporting. Furthermore, the absence of detailed information hampers full comprehension of the nuances and effectiveness of the given disclosures. We, therefore, argue that more precise findings can guide companies in reporting complex issues on climate-related claims without jeopardising their reputation.

Our study contributes to the existing knowledge on climate-related claims by companies in three ways. Firstly, to our best knowledge, this is the first study on the use of NLP systems that facilitates the comparison of claims against actual measures, including using data from reputable Environmental, Social, and Governance (ESG) data vendors. So, this strategic approach reduces the risk of incomplete evaluations and protects against greenwashing practices. Secondly, it ensures the integrity of reporting on climate-related challenges, aligning seamlessly with the foundational principles of legitimacy and stakeholder theory. Furthermore, the disclosure of reliable figures on climate creates trust among company stakeholders, especially investors as indicated by existing literature (Benlemlih, Arif, and Nadeem 2023). Thirdly, the TCFD principle-based company's climate disclosure can encourage regulators and policymakers to assess the success of the policy intervention and the need for modification in the TCFD principles, which can help in achieving the target of below two degrees centigrade temperature by 2030.

The rest of the paper is structured as follows. The following section provides information on relevant literature and theoretical

frameworks of corporate climate reporting. Section 2 provides specifics of the study models. Section 3 provides a brief description of the data. Section 4 discusses the study results. Finally, Section 5 concludes the paper with a brief discussion of the main findings and contributions.

2 | Literature Review

Due to mounting pressure on businesses to disclose their commitment towards climate, corporate sustainability reporting, in general, and climate disclosure in particular, has gained significant momentum in recent years (Benlemlih, Arif, and Nadeem 2023). Long et al. (2022) report that the most significant contributions to the field of climate disclosure have come more recently with the Paris Climate Agreement, which has been regarded as a significant motivator for research in this area. As a result, organisations are beginning to comprehend the importance of embracing awareness of climate risks in their operations.

Corporate sustainability and climate initiatives are also viewed positively by the market (Gaganis et al. 2021). For example, Brulle, Aronczyk, and Carmichael (2020) examine the relationship between corporate promotion and climate change, concentrating on the advertising expenditures of energy companies from 1986 to 2015. They find that major oil corporations increased their advertising spending during times of increased scrutiny and controversy related to climate change. In addition, Johnson and Greenwell (2022) note that some businesses may be able to use climate-related disclosures as a communication tool. By analysing longitudinal climate leadership, climate messaging, and stock price data for hundreds of UK companies, the authors determined that between 2010 and 2019, corporations, on average, increased their climate leadership and sustainability messaging. In addition, Orazalin, Ntim, and Malagila (2024) document that enterprises that emit more greenhouse gases tend to have lower market values, whereas businesses that implement process-based climate change initiatives tend to have higher market values. Additionally, there is evidence that suggests that voluntary carbon disclosure correlates positively with the financial performance of an organisation (Alsaifi, Elnahass, and Salama 2020a; Luo and Tang 2014). The multi-integration of socio-political theories is very popular in explaining corporate responsibilities (Mellahi et al. 2016). Similarly, voluntary carbon disclosure by companies is also explained by combining different theories (Hsueh 2019).

2.1 | Theoretical Framework

It is central to involve stakeholders to achieve sustainability goals (Rathobei, Ranängen, and Lindman 2024). The stakeholder theory can explain how companies capture the demands of their stakeholders related to the environment in their organisational strategies (Hendry 2005). Evidently, the resulting corporate climate change mitigation strategies are shaping the landscape of climate disclosure and action due to consistent stakeholders' pressure. Likewise, the key stakeholders, including banks, investors, customers, and regulatory bodies, increasingly demand transparency and commitment from corporations towards climate change mitigation. Socially responsible activities of a company are linked to positive customer perceptions about its professionalism, achievements, commitment to sustainable development, exemplary governance, and consideration for the interests of its stakeholders (Cadez, Czerny, and Letmathe 2019). Thus, we apply the stakeholder theory to show how companies translate their non-financial commitment towards climate into their financial benefits.

There is evidence in recent literature that regards companies' climate actions as primarily symbolic (Doda et al. 2016; Haque and Ntim 2020). The regulatory intervention on climate change is, however, regarded as promising (Coen, Herman, and Pegram 2022). Moreover, after the voluntary adoption of the TCFD in Australia, Wedari, Jubb, and Moradi-Motlagh (2021) find a significant indication of greenwashing with the increase of emissions by companies. In another contemporary study on New Zealand, Houqe and Khan (2023) observe a positive impact of carbon regulation and standardised reporting on the quality of carbon reporting. So, according to (Duff 2017), legitimacy theory complements the stakeholder theory in explaining corporate social responsibility and related aspects (responsibility towards climate, which is the main focus of this study). The extensive pressure from the company's stakeholders forces them to prove their care for the climate and interest in incorporating climate into the operational strategies (Ding, Liu, and Chang 2023). When there is no mandate to disclose the impact of company operations on climate, then the legitimacy theory can better explain the greenwashing initiatives by companies, if any (Burke, Hoitash, and Hoitash 2019). To the best of our knowledge, there is limited use of the two theories mentioned above in the context of the mandatory implementation of the TCFD. Usually, higher demand from stakeholders about environmental and climate-related responsibility creates immense pressure on companies to maintain their legitimacy (Suchman 1995; Garrido-Merchán, González-Barthe, and Vaca 2023). Moreover, the process to maintain legitimacy can improve existing environmental initiatives or introduce a new set of improved processes directed towards climate activities demanded by the stakeholders (Ashforth and Gibbs 1990; Orazalin, Ntim, and Malagila 2024).

2.2 | Greenwashing and Regulatory Framework

There are also concerns regarding the possibility of greenwashing, in which companies make deceptive or exaggerated climate claims to improve their image without reducing their operational impact on climate (Haque and Ntim 2020). According to the findings of a systematic review of the literature on greenwashing (de Freitas Netto et al. 2020), it is a complicated and multi-faceted phenomenon with various concepts and forms that can be categorised into four groups: information-related, image-related, process-related and product-related greenwashing, which are all concerning for policymakers. In summary, some companies attempt to improve their public image by providing information about climate-related initiatives that do not always correspond to reality. For example, Wedari, Jubb, and Moradi-Motlagh (2021) find potential greenwashing by many high-emitting

companies in Australia that submit voluntary climate-related disclosures. Even though these businesses typically provide a high level of disclosure quality, there is some evidence of possible greenwashing, as some companies make vague or unsubstantiated claims about the climate-related initiatives they are undertaking.

The existing literature makes it unclear whether UK companies follow the previous trends observed in other countries, especially after adopting TCFD. Studies show that while firms claim compliance with climate risk frameworks, actual implementation remains limited, particularly regarding quantitative and financialized information (Di Marco et al. 2023). The alignment of results from analyses on STOXX Europe 600 banks and top-listed firms in New Zealand highlights a wider trend in international climate reporting practices (Houqe and Khan 2023; Friedrich, Velte, and Wulf 2023). While there is a clear trajectory towards improved transparency and the adoption of standardized frameworks such as the TCFD recommendations, the persistent gaps in reporting, especially in forward-looking information and bank-specific metrics, reveal a systemic issue in the corporate world's approach to climate change mitigation.

The above-mentioned systemic issue suggests a need for enhanced regulatory frameworks and more rigorous enforcement mechanisms to ensure that corporate climate disclosures are both accurate and meaningful. Thus, researchers use NLP to extract climate-related textual data automatically. Usually, the NLP algorithms use a bag-of-words and ignore the context in the analysis. The collection of the individual words is always treated independently (Wallach 2006). However, the NLP algorithms are not sufficient to verify the climate claims by companies (Callaghan et al. 2021; Bingler et al. 2022). Dictionaries or extensions of the bag-of-words model are hard to use to detect the differences in climate risk created by companies and their climate claims (Kim and Kang 2018; Sautner et al. 2023). In climate claims investigations, we need to understand the semantic and syntactic relations among words to better analyse the context. The complex nature of climate claim-related data demands large language models (LLMs) that can outperform the NLP (Devlin et al. 2018). Deep Learning techniques can provide higher accuracy than traditional NLP (Luccioni, Baylor, and Duchene 2020; Varini et al. 2020; Callaghan et al. 2021). Bidirectional Encoder Representations from Transformers (BERT) is a successful model trained on large amounts of textual and unlabelled data extracted from various sources, including online resources (Devlin et al. 2018). Later, the BERT model is extended by RoBERTa (Liu 2019), Transformer-XL (Dai 2019), and ELECTRA (Clark et al. 2020) and tested in a different context, including climate claims by corporations. However, there is no evidence of the application of ClimateBERT related to climate claims by UK corporations when they are aware of the mandatory adoption of TCFD. Figure 1 delineates our investigative structure and primary research query, which we explore in more detail in the following sections.

In addition, we follow the approach used in systematic literature review papers (Mustafa et al. 2022) and conduct a detailed search in the Scopus database with the following two

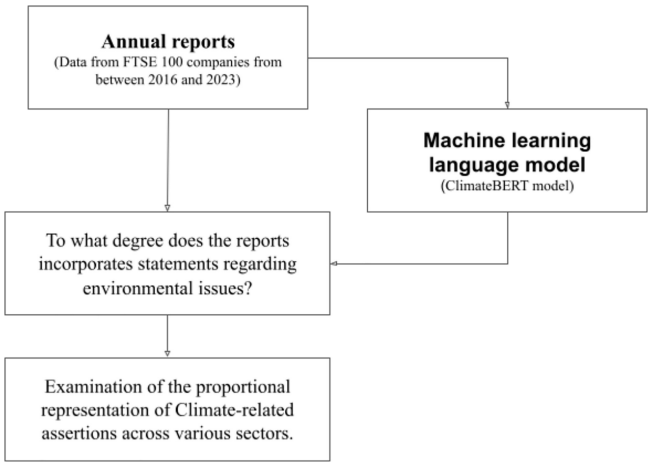

FIGURE 1 | Schematic representation of the research framework.

keywords 'Climate Reporting*' and 'ClimateBert*'. We restrict the search of the articles to the subject areas of 'social science', 'business, management, and accounting, 'economics, econometrics, and finance', and papers written in English (Pizzi, Rosati, and Venturelli 2021). We look for the appearance of the keywords in the 'abstract, title and keywords' from 2007 until the end of 2022. We find 54 papers as shown in Appendix A. The findings show a significant increase in climate reporting in 2020 compared to previous years. We argue that in 2017, the reporting framework by TCFD is one of the significant drivers alongside the existing initiative related to company climate initiatives. This is consistent with the TCFD 2023 status report, which reveals that the TCFD's evolving guidelines have significantly influenced corporate climate disclosure. According to the report in the fiscal year 2022, 58% of companies have achieved compliance with at least five of the 11 recommended disclosures, showcasing a substantial increase from 18% in 2020. Furthermore, from 2020 to 2022, there has been an increasing number of companies disclosing climate-related risks, implementing board oversight, and setting climate-related targets. The report also indicates that more than 80% of the largest asset managers and 50% of the largest asset owners meet at least one of the 11 recommended disclosures. In addition, nearly 70% of the top 50 asset managers and 36% of the top 50 asset owners comply with at least five recommendations.

However, the growing application of ClimateBERT in the last few years is mainly to overcome the limitations of the traditional NLP models. Thus, applying ClimateBERT in assessing the climate-related claims of the UK companies in the context of TCFD is a timely study and is of immense academic and practical implication, discussed in this paper's final section.

2.3 | NLP Models Related to Environmental Issues

The NLP models are helpful a tools when working with big data, and with the help of AI models, it is now possible to conduct in-depth and rapid analyses. These advanced models are instrumental because climate disclosures and other environmental issues must be monitored and analysed in detail as they involve vast amounts of data. Furthermore, the NLP models

enable access to invaluable insights with higher accuracy that would not be accessible otherwise. Therefore, the NLP models are necessary to understand companies' current challenges and achievements in the context of environmental impact and climate change.

Recently, the NLP algorithms are experiencing significant transformation due to advancements in the state-of-the-art and cutting-edge technologies like AI and ML. In particular, systems built on AI can execute previously unachievable tasks, such as automatically interpreting and generating human language, since the models can learn from large datasets and make accurate predictions and classifications. One of the first NLP models based on AI is Word2Vec, developed in 2013 by Tomas Mikolov at Google (Mikolov et al. 2013), where the authors proposed an Artificial Neural Network (ANN) to model a vector representation of words. The authors demonstrate that the model can capture the meaning of specific phrases, propose additional words for a partial sentence, and suggest synonyms. Later on, the power of the NLP models soared with the development of a specialised ANN named Transformers (Vaswani et al. 2017), utilised to develop the BERT model. This model acquires knowledge of extended temporal relationships within the dataset. It can evaluate the relative importance of different elements within the input data in the decision-making process and identify the extent of interconnectedness among distinct portions of the input text. Moreover, by incorporating complex ANN mechanisms, the BERT model facilitates the flexibility to manage input sequences of varied lengths and detail complexities.

The RoBERTa model is an improved version of the original BERT model developed by Meta AI (Liu 2019). The RoBERTa model is trained on a larger dataset than its predecessor, improving its performance across various tasks. The enhancement materialises by training the algorithm on an expanded dataset of lengthier sequences, enabling the algorithm to gain a wide-ranging understanding of the input by effectively capturing and incorporating long-term dependencies. The model also improved by learning to predict parts of the text hidden on purpose and improving the optimiser in its ANN architecture, which helps it learn faster than ever before.

The emergence of sizeable generative language models such as GPT-2 and GPT-3 (Brown et al. 2020) has created an unprecedented opportunity to create human-like language, opening up new avenues for researchers and users to explore. Alongside high potentiality for these models, their implementation has different ethical implications. However, there are concerns about privacy invasions, biases against certain groups and topics, opportunities for manipulation, and the potential for misuse. Furthermore, modern NLP models, when they are tested, lack a clear system to explain how they arrive at determining certain outputs. The opacity of many advanced AI-enhanced NLP models raises trust concerns among stakeholders, leading to a growing demand for more transparent AI models (Arrieta et al. 2020). In addition to these ethical concerns, another issue with large language models comes partly from the computational mechanisms used to train them, such as their lack of robustness, high computational complexity, and energy costs (Bender et al. 2021). One approach to addressing these issues is to develop smaller models, such as DistilRoBERTa[8] (Sanh et al. 2019). This simplified version of the RoBERTa model offers better reliability and reduced computational complexity. Despite its smaller size and fewer parameters, it performs comparably to larger models. After training the NLP models on a large dataset, they can be refined for specific domain analysis through a process known as fine-tuning. These additional steps involve further training on a specific dataset to tailor the model's general language understanding to a particular domain. Fine-tuning adjusts the model's parameters, enabling it to handle texts with specific meanings, structures, or terminologies that a general model might otherwise miss or fail to recognise.

2.4 | ClimateBERT Model

Webersinke et al. (2021) develop a ClimateBERT language model by fine-tuning a DistilRoBERTa model, further training it on a dataset of texts addressing climate change. This enables the model to recognise specific representations related to the issue. The training process is intensive, relying on labelled datasets and a large corpus of approximately two million paragraphs on climate-related topics, sourced from research articles, news, and climate reports. Through this process, the model learns how to recognise and interpret critical concepts, entities, and relationships in the context of climate change. After the training, the ClimateBERT model performs a wide range of NLP tasks linked to climate change, providing a powerful tool for extracting meaning from vast datasets. Additionally, this model enables businesses to make more informed decisions and addresses climate change more effectively by identifying and quantifying the extent to which corporate climate risk disclosures involve 'cheap talk' and 'cherry-picking' statements (Bingler et al. 2022). Recently, Stammbach et al. (2023) perform further fine-tuning on the ClimateBERT model, enhancing its ability to detect environmental or climate-related claims due to its enhanced specificity for climate-related tasks. According to the authors of the model, given the large dataset and computational constraints, re-training a large RoBERTa model is less feasible. Consequently, a fine-tuned version of ClimateBERT is a more optimal choice than RoBERTa for creating a model that classifies climate-related claims. To create the environmental claims model, the data samples are collected from five distinct textual sources provided by companies. The first is TCFD reports, to then continue with annual reports from the United States Securities and Exchange Commission, corporate earnings calls, earnings conference call transcripts, and data from the Carbon Disclosure Project questionnaire responses from 2021. Then, this data sample is annotated by 16 domain experts in sustainable investments, following the annotation guidelines drafted through an iterative process, which included examples of clear and borderline environmental claims (Stammbach et al. 2023).

By following the guidance on unfair commercial practices from the European Union (European Commission 2009), Stammbach et al. (2023) define the environmental claim as:

> "The practice of suggesting or otherwise creating the impression (in the context of a commercial communication, marketing or advertising) that a product or a service is environmentally friendly (i.e.

> it has a positive impact on the environment) or is less damaging to the environment than competing goods or services."[9]

Therefore, the fine-tuned ClimateBERT model for environmental claims is an NLP model that performs classification tasks, aiming to predict whether a sentence contains environmental claims. Both the model[10] and the dataset[11] are open source, providing accessible resources for further research and development.

3 | Methodology and Data

In this study, we use text data from the annual reports of FTSE 100 companies over eight years, from 2016 to 2023. The selection of this timeframe is deliberate, aimed at capturing the anticipatory actions and early adjustments made by companies in response to the evolving climate concerns. Following the 2015 Paris Agreement, the initial phase of industrial strategies by governments worldwide promoted investment in clean growth by companies. Several companies have made significant commitments to reduce their carbon footprints by investing in renewable energy and adopting sustainable operations.[12] Moreover, one-third of the UK's FTSE 100 companies have made notable strides in committing to the United Nations' Race to Zero campaign, which targets achieving net zero carbon emissions by 2050. Therefore, we begin by examining the changes from 2016 to 2020. The rationale for starting in 2016 is that, following the 2015 Paris Agreement, businesses began to view the climate as a key stakeholder.

The first press release related to TCFD took place in October 2021. It is quite common for companies to be aware of new mandates before their official announcement. Therefore, it is likely that they began adjusting their financial statements for the period ending in 2019–2020. This timeframe represents a crucial *pre-implementation* phase where companies started aligning their strategies and disclosures with the upcoming TCFD guidelines (Zhang 2024). Following the press release in 2021, TCFD became mandatory in April 2022, so it is probable that companies began demonstrating their commitment, particularly ahead of their peers. We illustrate this with a diagram covering the years 2021–2023 (Figure 3).

To analyse these early efforts, we use 780 reports (after excluding a few reports which are not useful for extracting text data) covering eight years and processed them using a Python script with a multiprocessing algorithm that extracts text from the digital files of the annual reports. The script iterates through directories, opens each file, and converts the extracted text into a structured format, which is then tokenised and lemmatised. The tokenizer breaks down the text, dividing it wherever it detects sentence boundaries, while lemmatisation reduces words to their base forms. Additionally, we remove digits and performed space removal and lower casing of the texts. Sentences with fewer than five words are removed to focus on significant content. This procedure gives us 3.9 million useful sentences for analysis. Each processed sentence is tagged with metadata, including the company name and year and a structured set of sentences relevant to the company's activities for the given year. After preprocessing the data, we analyse the sentences and metadata using the ClimateBERT fine-tuned model for climate-related claims. This model categorises the text, assigning a label to indicate if it contains a climate-related claim. Figure 2 details the methodology used for data analysis of our study. Finally, once the labelling of the sentences for each company is completed, we

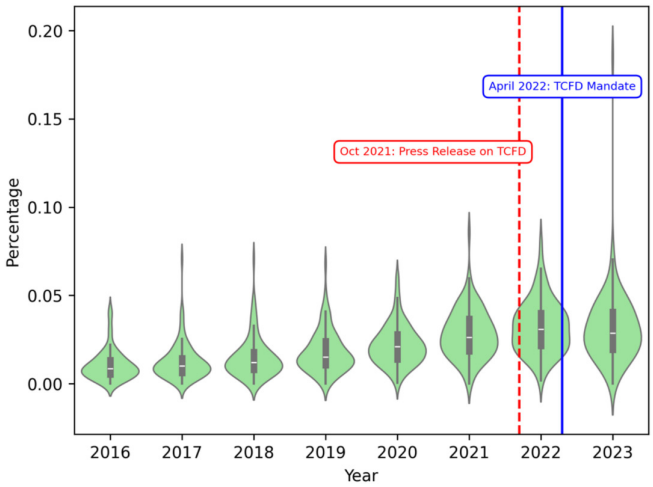

FIGURE 3 | Evolution of climate-related claims by FTSE100 companies. *Note:* A press release on TCFD by the UK government on 29 October 2021. From 6 April 2022, all publicly quoted companies, large private companies, and Limited Liability Partnerships in the UK are required to report climate impact based on the TCFD recommendation.

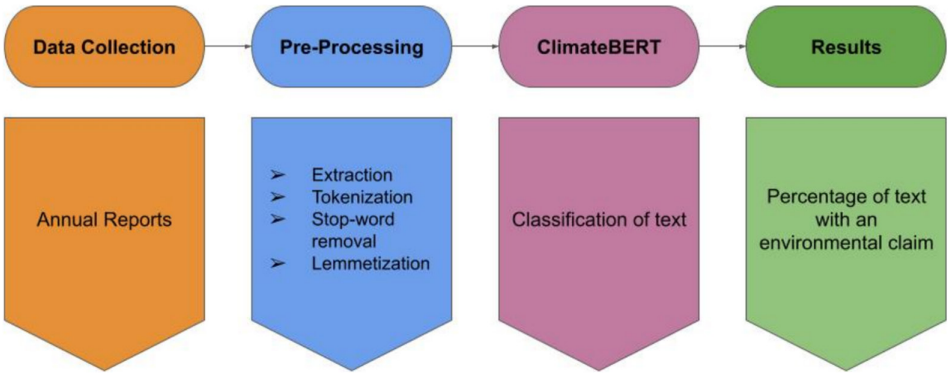

FIGURE 2 | Steps in data analysis.

calculate the proportion of sentences that contain climate-related claims for each company and year. This proportion is determined using the formula:

$$P(C_{i,y}) = \frac{S_{i,y}(climate\ claim)}{n_{i,y}} \quad (1)$$

Where $P(C_{i,y})$ represents the proportion of climate claims for company i in year y, $S_{i,y}(climate\ claim)$ is the number of sentences with a climate claim, $n_{i,y}$ is the total number of sentences for that company and year. By using this method, it is possible to systematically quantify the percentage of climate claims respect to all the sentences. Figure 2 explains the methodology used for the paper's data analysis.

4 | Results

As mentioned above, we examine the research question by extracting the linguistic information, processing it, and passing it through the fine-tuned ClimateBERT algorithm to measure the percentage of climate claims[13] in the annual reports (from 2016 to 2023) each year. We calculate the relative percentage that represents the number of climate claims contained within the text denoted as $P(C_{i,y})$.

We find that most companies in our sample are making more climate-related claims over time. This is consistent with the results of Johnson and Greenwell (2022), who noted that climate messaging in CDP survey responses and Twitter data from 2010 to 2019 by companies has increased substantially during their study period. However, our study focuses on a different time frame from 2016 to 2023, when the companies became aware of the TCFD mandate, and we use advanced machine learning methods.

Nevertheless, the findings of our analysis provide strong evidence of a substantial increase in climate claims by companies in the UK after the Paris Agreement (2015) and *in anticipation* of the implementation of TCFD, as shown by a violin plot in Figure 3. It shows density curves, meaning each curve represents the approximate frequency of the climate-related claims in each year as well as an overlaid box plot. The median values are indicated as a white horizontal line within each violin plot, and it shows the increase of the percentage of climate-related claims over the years. This is more noticeable after October 2021 press release announcement by the UK government.

Consequently, the implementation of TCFD principles has heightened companies' awareness of the importance of environmental protection and respect, essential for maintaining their competitiveness in their industries. Furthermore, we also examine the climate-related claims by companies in different industries. Following the Fama–French industry classification, we group industry-level information and analyse this information to capture any trend or variations in climate claims in a particular industry. The results are presented in Table 1. The construction, consumer non-durables, materials, and manufacturing industries are showing substantial increase in climate-related claims, while energy and transport industries have comparable claims to those previously mentioned. This is surprising as energy and transport industries are considered very highly carbon-intensive industries, and so their claims should be higher than

TABLE 1 | Percentage of environmental claims by industries from 2016 to 2023.

Fama–French industry	2016	2017	2018	2019	2020	2021	2022	2023	Change
Business equipment	0.67	0.92	0.61	0.86	1.54	2.24	3.01	2.15	2.1979
Business services	0.79	1.4	1.35	1.42	2.05	2.75	2.85	2.67	2.3565
Construction	1.01	1.3	1.94	2.79	2.73	3.76	4.23	4.35	3.3241
Consumer durables	1.61	1.47	2.27	3.32	3.77	5.10	5.07	3.10	0.9216
Consumer non-durables	1.57	1.93	2.51	2.73	2.45	3.14	3.76	4.01	1.5478
Consumer services	0.70	0.82	1.06	1.36	1.62	1.97	2.08	2.09	2.0087
Energy	0.99	1.16	1.71	1.91	2.87	3.61	3.76	3.86	2.8904
Finance	0.62	0.54	0.64	0.88	1.47	1.78	2.08	1.86	2.0215
Healthcare	0.76	0.83	0.94	0.96	1.41	1.73	2.00	1.87	1.4640
Manufacturing	0.93	1.18	1.42	1.95	2.09	3.03	3.97	5.17	4.5817
Materials	1.64	2.12	2.57	2.8	3.51	4.44	4.88	4.67	1.8532
Real Estate	1.11	1.81	2.00	2.26	3.19	3.33	3.77	3.53	2.1806
Telecommunications	1.14	0.87	0.79	1.29	1.60	2.27	2.46	2.75	1.4184
Transportation	0.96	1.45	1.93	2.78	2.22	2.68	2.97	3.38	2.5212
Utilities	2.55	2.11	2.28	3.21	3.4	4.04	4.52	4.44	0.7369
Wholesale & retail	1.12	1.33	1.32	1.57	1.74	2.41	2.79	3.08	1.7418

Note: FTSE 100 companies from 2016 to 2023. Authors' calculation of percent environmental claims in different industries (Year-wise). Change refers to the change from 2016 to 2023. All figures are in percentage.

the other industries. Overall, the industries represented by the FTSE 100 experienced a rapid increase in the average percentage of claims between 2016 and 2023.

Figure 4 shows a wide variety of climate claims across the industries, and that also varies with the years. A common pattern is visible for manufacturing, energy, consumer non-durable (e.g., food, tobacco, textiles), and material companies with their consistent higher climate claims in their annual reports. The data clearly indicates a rising trend in environmental claims in nearly all sectors. In particular, the manufacturing and construction sectors show significant increase of 4.58% and 3.32%, respectively, in their climate claims. In contrast, other sectors, such as consumer durables and utilities, experience smaller increases in claims, with 0.92% and 0.73%, respectively. Additionally, sectors like energy and transportation show moderate increases of 2.89% and 2.52%. In Appendix B, we show the above findings in a heatmap. In summary, our data highlights that some sectors have experienced significant shifts in claims, while others maintain steadier profiles.

It is always important to examine the data granularity to assess the implications of policy intervention. Thus, we create a classification based on the number of climate claims in a given sector. We find that specific sectors have more climate claims than others. Therefore, once we have each company's percentage value of claims, we label each value according to its quintile for the specific year, using Equation 1. We calculate the proportion of climate claims for each company i in year y and then we assign a rank according to the following equation:

$$R_{i,y} = Rank\big(P(C_i, y)\big) \tag{2}$$

where the rank is determined by dividing the data into five quantiles, these ranks correspond to the categories: *Very Low, Low, Medium, High, and Very High*. The mean value of each quartile for 2016 to 2023 is presented in Table 2.

Classifying the mean values for each quintile in the five groups assists us in determining if the company in question has a high or low percentage of climate claims compared to its peers in the same industry and is included in the index. Additionally, we explore the impact of pre-processing steps on ClimateBERT's performance. Our experiments include running the model with and without processes such as stopwords removal and lemmatization. These tests reveal no significant changes in the outcomes.

The diagrams in Figure 5a,b present Sankey charts that illustrate the relationship between FTSE100 companies' average climate claims across two periods: 2016 to 2020 (pre-TCFD period) and 2021 to 2023 (post-TCFD period following the press

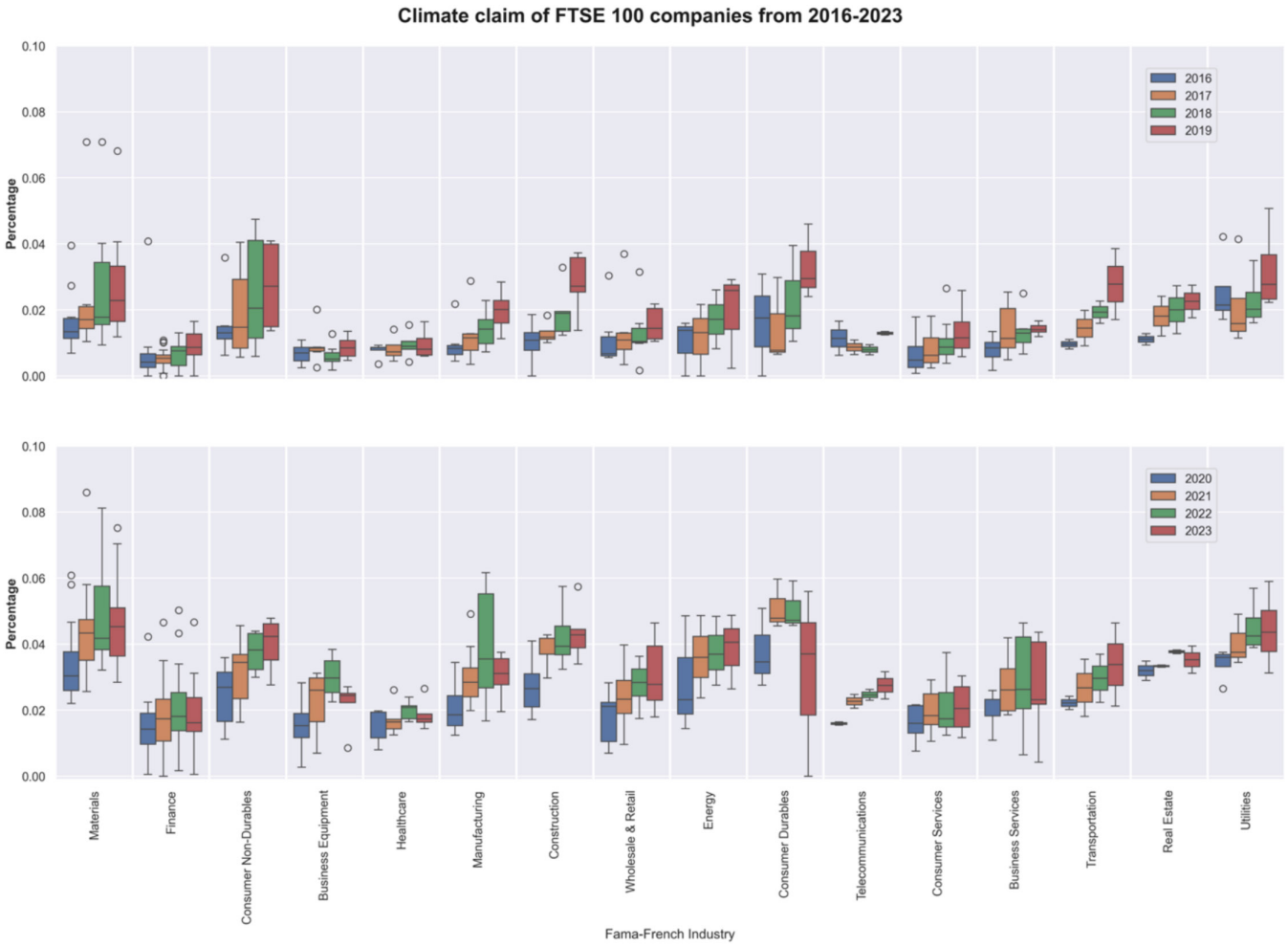

FIGURE 4 | Percentage of climate claims presented by sectors through the testing period.

release in October 2021). Additionally, we also categorised industries based on their extent of CO2 emissions (intensive and non-intensive) and their geographical distribution across the UK regions. Figure 5a covers years 2016–2020 and shows an apparent disparity between climate claims and CO2 emissions, revealing the regional variability in environmental impact and climate action within the UK. This underscores that even industries with low or very low climate claims can still be linked to carbon-intensive activities. However, this trend reverses during the period from 2021 to 2023, as shown in Figure 5b, where carbon-intensive industries no longer display low levels of claims. Evidently, it is unexpected that the carbon-intensive industries exhibit a medium percentage of claims given the increasing regulatory and stakeholder pressures for sustainability efforts. Both figures provide a comprehensive view of corporate climate claims across two different time frames. However, changes in the distribution of climate claims associated with carbon-intensive activities across industries and regions highlight the complexity of transitioning to sustainable practices.

TABLE 2 | Mean values for each quartile across 2016 and 2023.

Year	Very low	Low	Medium	High	Very high
2016	0.21	0.57	0.85	1.23	2.41
2017	0.33	0.68	1.00	1.38	2.78
2018	0.38	0.85	1.17	1.66	3.26
2019	0.54	1.12	1.50	2.17	3.63
2020	0.84	1.51	2.05	2.61	3.96
2021	1.11	2.01	2.68	3.45	4.84
2022	1.36	2.28	3.11	3.89	5.38
2023	1.17	2.17	2.86	3.84	5.87

Note: This reports the mean value climate claim score of each year in each quartile.

In summary, these findings show a positive signal to company stakeholders and policymakers about climate claims by the UK companies, and this is consistent with other studies (Coen, Herman, and Pegram 2023; Trouwloon et al. 2023). Our theoretical framework supports the findings, which is based on legitimacy and stakeholder theories, and is consistent with existing literature (Ding, Liu, and Chang 2023; Duff 2017). A substantial increase in climate claims explains the need to maintain the legitimacy of UK companies. Moreover, year-wise and

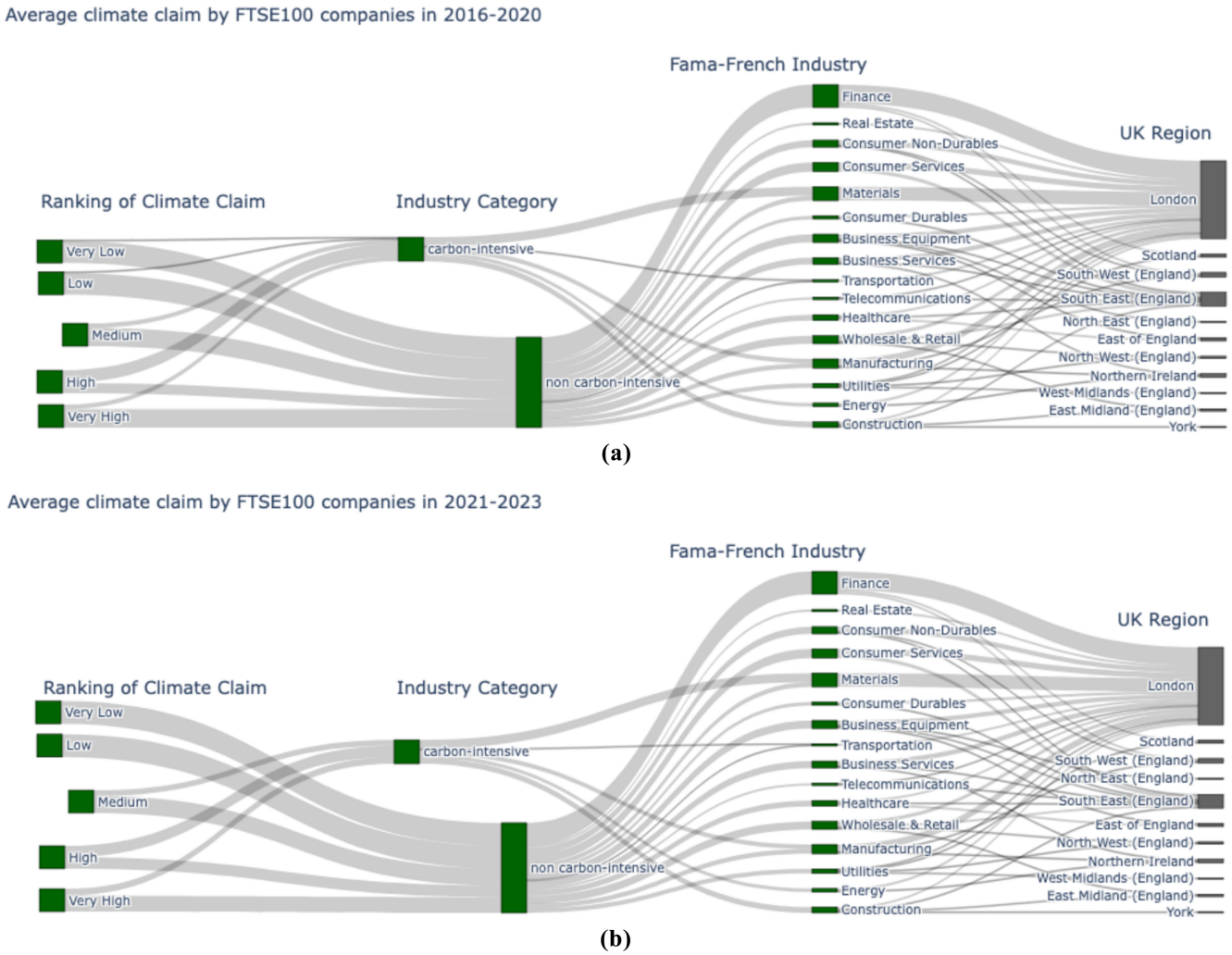

FIGURE 5 | (a) & (b). Sankey Diagram: Classification of climate claims across different industries.

industry-level claims by most companies in almost all industries are evidence of increased climate demand from their financial stakeholders.

5 | Discussion and Conclusion

Using the four main categories of the TCFD, we apply the ClimateBERT algorithm to examine the extent to which the UK FTSE 100 companies make their environmental claims. We find a steady and increased percentage of climate claims in the corporate reports of the FTSE 100 companies across all sectors. The climate claims remained very low in 2016, but corporate stakeholders should not conclude the non-possibility of net zero by 2050 based on the initial findings. This low level of climate claims can be attributed to a lower demand from stakeholders for detailed environmental disclosures, suggesting that companies respond more to external pressures than to an active interest in disclosures (Hoogerbrugge, van de Kaa, and Chappin 2023). However, as environmental reporting has become mandatory, the need for systematic and comprehensive climate-related claims has gained significant importance. Our findings are consistent with the research of Johnson and Greenwell (2022), which reports that there is an increase in sustainability messages each year. We, therefore, extend the Johnson and Greenwell (2022) findings by applying the ClimateBERT algorithm to the UK FTSE 100 companies' annual reports when companies became aware of the mandatory adoption of TCFD. In summary, the findings of this research give a positive signal of intervention by the TCFD and, as a result, a higher importance of climate risk in companies' business operations.

The findings have relevant academic implications as they contribute to the growing literature on climate change and corporate reporting (Mora, Wu, and Panori 2020; Demaria and Rigot 2021). Specifically, our findings indicate that companies in the UK are becoming more aware of the value of divulging information about climate change in their annual reports, as evidenced by increased climate-related claims. Additionally, by extending our timeline from 2016 to 2023, we provide a broader and more comprehensive dataset with a long-term perspective on climate reporting practices, expanding beyond previous studies that only covered shorter periods (Braasch and Velte 2023). Theoretically, we extend the existing literature on corporate disclosure (Ding, Liu, and Chang 2023). From the stakeholder theory perspective, this study underscores the role of stakeholder demands in corporate environmental accountability. It shows how stakeholder demands for more detailed environmental disclosures can be a driver in enhancing climate-related reporting practices among UK companies (Alsaifi, Elnahass, and Salama 2020b). Regarding legitimacy theory, the findings suggest that companies increasingly acknowledge the necessity of addressing environmental issues within their corporate reports (Chithambo et al. 2020). This effort aims to sustain their legitimacy in the eyes of stakeholders and address the ongoing challenge of credibility, as stakeholders continue to assess companies' climate-related reports (Busch, Johnson, and Pioch 2022).

Applying legitimacy theory as a complementary theory to stakeholder theory in the context of mandatory TCFD can enrich the CSR literature and open new avenues in related future research, highlighting the dynamic interplay between regulatory compliance and voluntary corporate behaviour in the realm of environmental reporting. This approach underscores the evolving nature of corporate responsibility, where adherence to frameworks like the TCFD is not merely a response to regulatory demands but also a strategic initiative to engage with stakeholders to satisfy their interests in environmental issues (Hristov and Appolloni 2022; Riso et al. 2024). The results help to visualise the application of legitimacy theory in practice. By incorporating climate change information into their reporting, companies not only adhere to the new regulatory requirements but also signal to their stakeholders that companies are committed to addressing the challenges of climate change (Gerged, Matthews, and Elheddad 2021; Gebhardt et al. 2024). This strategic disclosure aligns with the principles of legitimacy theory, as it helps companies maintain or enhance their legitimacy in the eyes of their stakeholders.

The practical implications of the findings are significant for both policymakers and companies. The framework's success in promoting more transparent and thorough climate-related reporting is evident. Companies can integrate climate information into their corporate reporting strategies, which have significant implications for comprehending the effects of environmental issues on business operations and financial performance (Caputo et al. 2021). For policymakers, the results of this study underscore the effectiveness of regulatory frameworks such as the TCFD in incentivizing corporate behaviour towards enhanced transparency and accountability regarding environmental issues. This evidence advocates for the ongoing development and stringent enforcement of policies aimed at improving climate-related disclosures. Additionally, this research further emphasises the potential of employing AI and ML techniques to analyse large volumes of corporate disclosure data to offer valuable insights into how companies respond to climate change issues (Muccione et al. 2024). The findings provide an essential signal for investors about assessing a company's climate claims and conducting a check with industry-level details. Peer assessment will allow investors to diversify their sustainable portfolio efficiently (Yue et al. 2020). The paper's findings give a positive indication to policymakers that there is a gradual increase in disclosure in the non-material categories by top companies. The financial achievements of these companies by following TCFD can motivate regulators to invite FTSE 350 companies to the net zero carbon mission.

The difficulty of determining whether climate claims by companies are genuine or solely a form of greenwashing is a limitation of the study. This research used advanced ML techniques to analyse the annual reports. However, this method cannot offer a conclusive evaluation of the veracity or effectiveness of the environmental or climate claims stated by the companies. Thus, there is a need for further investigation to comprehend the drivers and effects of companies' environmental/climate reporting. Another limitation of this paper is that the AI method applied does not incorporate Explainable AI, making it difficult to interpret how the model arrives at its conclusions regarding climate claims. The findings of this paper can be extended in the future to provide indications about possible modifications in climate reporting, which will promote accuracy and reduce the prevalence of potential greenwashing in corporate reporting.

Future research may investigate alternative methods to evaluate the veracity of environmental assertions made by organisations. Furthermore, studies could also concentrate on acquiring a greater understanding of the impact of corporate environmental reporting on financial and operational performance under a dynamic theoretical framework (Ameer and Khan 2023; Appannan et al. 2023). Specifically, integrating advanced NLP systems could improve how companies' environmental claims are verified by cross-referencing their reports with extensive datasets from reputable ESG data vendors. This approach would not only enhance the precision of climate disclosures but also establish a more robust framework for assessing the authenticity and impact of these reports, ultimately leading to a higher standard of environmental accountability in the corporate world. Also, future efforts should focus on integrating explainability into the AI models to enhance the interpretability of the model as suggested by Lai and Chen (2024). Additionally, future research can help develop guidelines for authorities to assist with the monitoring and accuracy check of climate claims by companies. Likewise, honest, accurate and trustworthy climate claims will encourage higher investment in companies' environmental initiatives, which will also mitigate the further deterioration of the most critical stakeholders of the corporate world's climate.

Endnotes

[1] https://www.gov.uk/government/news/uk-to-enshrine-mandatory-climate-disclosures-for-largest-companies-in-law

[2] https://www.gov.uk/government/publications/climate-related-financial-disclosures-for-companies-and-limited-liability-partnerships-llps

[3] As of October 17, 2024, 4900 companies from 103 jurisdictions endorse TCFD framework (Retrieved from http://www.fsb-tcfd.org)

[4] https://committees.parliament.uk/committee/517/industry-and-regulators-committee/news/161468/uk-will-miss-net-zero-target-without-urgent-action-warns-lords-committee/#:~:text=The%20report%20concludes%20that%20the,investment%20by%20consumers%20and%20businesses.

[5] The stakeholders in this paper are mainly customers, suppliers, investors, shareholders, debt financing institutes of companies.

[6] https://sseinitiative.org/all-news/cop27-three-lessons-from-200-hours-of-tcfd-training-for-15000-global-participants/

[7] In this paper we use climate claim and environmental claim interchangeably.

[8] For more details: https://huggingface.co/distilroberta-base and https://arxiv.org/abs/1910.01108

[9] This definition is found in Section 2.5 of the working document.

[10] The model can be found in the following link: https://huggingface.co/climatebert

[11] A Dataset for Detecting Real-World Environmental Claims: https://arxiv.org/abs/2209.00507

[12] UK's largest companies pledge hundreds of millions of pounds to tackle climate change: https://www.gov.uk/government/news/uks-largest-companies-pledge-hundreds-of-millions-of-pounds-to-tackle-climate-change

[13] An example of this type of claim is displayed in Appendix C.

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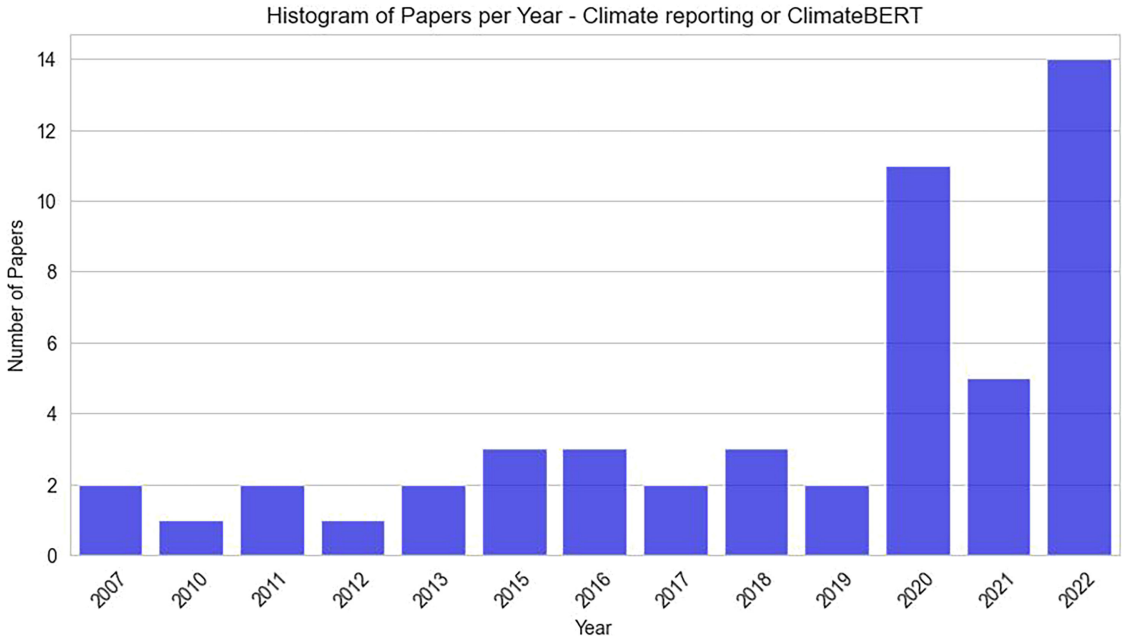
Appendix A

Scopus Search on Climate Reporting and ClimateBert

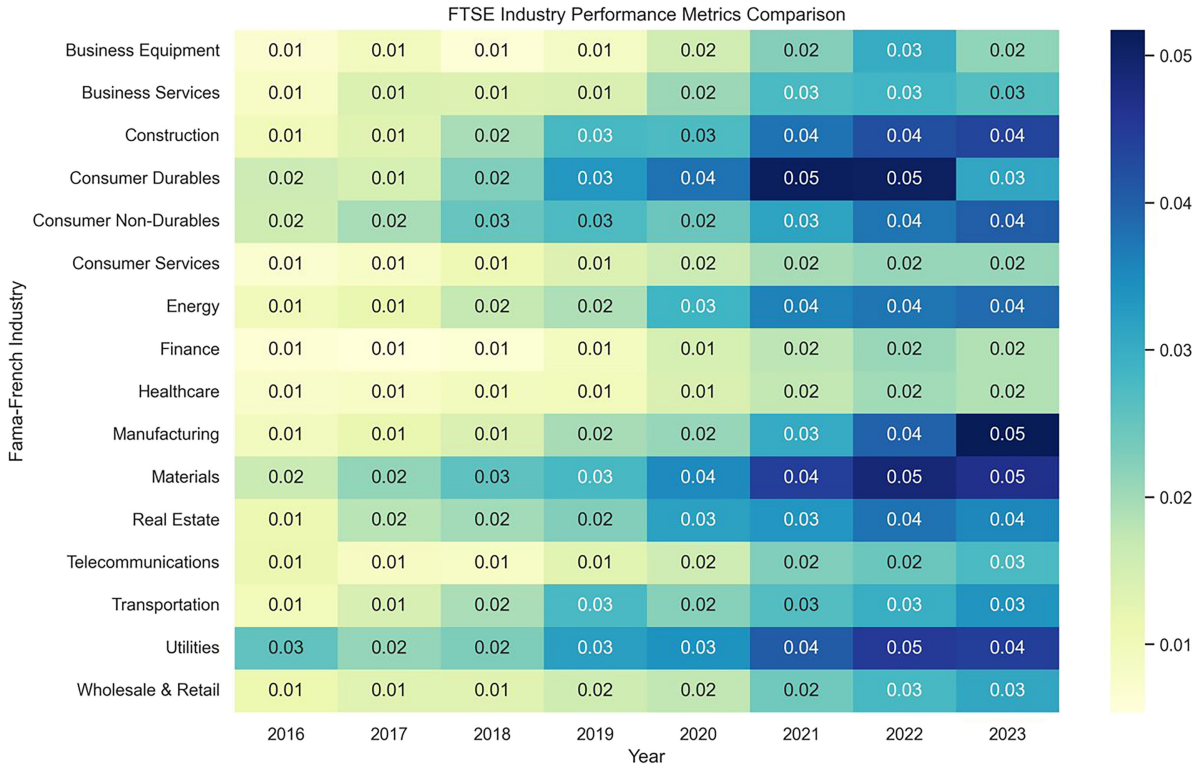
Figure A.1: Bar graph of papers published per year on 'climate reporting' or 'ClimateBERT' from 2007 to 2022.



Appendix B

Evolution of Industry Classification over the Sample Years

Figure B.1: A heatmap comparison of key performance metrics across industries.



Appendix C

As previously mentioned in Section 3, an environmental claim is defined by (Leippold et al. 2023), by following the working paper "Guidance on the implementation/application of Directive 2005/29/EC on unfair commercial practices" from the European Union and its definition in Section 2.5 of the working document. In the paper explaining the model, Leippold et al. (2023) provide examples of what they consider environmental claims, such as the following:

> "*A total population of 6148 is getting the benefit of safe potable drinking water due to this initiative.*"

> "Hydro has also started working on several initiatives to reduce direct CO2 emission in primary aluminium production."

In addition, we present an example of a climate claim in Figure C.1. However, the AI model (ClimateBERT) used is not inherently explainable (as other AI models), making it challenging to determine the exact reasoning behind why certain texts are classified as climate claims.

FIGURE C.1 | This figure illustrates an example of a climate-related claim, as extracted from Coca-Cola's 2021 Annual Report.