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Exploring Climate Change Adaptation, Mitigation and Marketing Connections

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Abstract: Adaptation and mitigation to the adverse impacts of rising weather and climate extremes require businesses to respond with adequate marketing strategies promoting sustained economic development. Unfortunately, the connections exploring such relationships have not been extensively investigated in the current body of literature. This study investigated the five marketing categories relating to sustainable practices (sustainable marketing, social marketing, green marketing, sustainable consumption and ecological marketing) within core research themes of climate change, global warming and sustainability from a bibliometric approach using the Scopus API. Additional topic modelling was conducted using the Latent Dirichlet Allocation (LDA) unsupervised approach on downloaded abstracts to distinguish ideas communicated in time through research and publications with co-occurrences of major Intergovernmental Panel on Climate Change (IPCC) Assessment Reports and Google search queries. The results confirmed marketing strategies aligned with the theme of sustainability with little work from small developing island nations. Additionally, findings demonstrated that research exploring business strategies through green marketing directed to green consumers with sustainable supply chain management had been dominantly increasing in the literature over recent years. Similarly, social marketing associated with green consumers was a common concern for the public and academics, rising over the years with strong influence from the published IPCC Assessment Reports. This study did not explore other published databases, including climate change-related meeting transcripts and published speeches from corporate and world leaders.

Keywords: climate change; adaptation; mitigation; marketing; sustainability

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1. Introduction

Climate change poses a significant threat to the world population due to the rising intensity, frequency and duration of weather extremes related to natural disasters [1]. Climate change-related hazards pose a serious risk to businesses irrespective of their size, whether small or big corporates [2]. Companies can incur losses related to stock and assets, supply chain disruptions, market share losses and increased costs of operations, including insurance, price volatility and product demand [3,4]. Business adaptation and mitigation of climate risks are critical in maintaining economic and environmental outcomes; thus, several business strategies put a strong emphasis on corporate social responsibilities promoting sustainable development [5], including mandatory disclosure of climate risks [6] and carbon footprints [7,8]. Businesses often relate to the concept of sustainability through marketing approaches creating value for products to stakeholders [9]. Often, sustainability optimises opportunities, threats and challenges associated with climate change, production and consumption, energy and resources, population demography and human behaviour. Minimising the risks from climate-related hazards while sustaining economic development lies heavily on businesses and their marketing strategies which can trigger behavioural responses of individuals, including government and state policies [10].

Current research connecting business adaptation and mitigation of climate change through the lenses of marketing strategies are limited. Diaz-Rainey et al. [11] showed that only 0.06% of finance and business journals discussed climate change topics from 20,735 publications. More recently, Hall [12] showed that <1% of papers in a more significant sample of marketing journals addressed issues related to climate change. Core research is often presented into themes of climate change, global warming and sustainability that entail a greater perspective on critical issues about sustainable development, adaptation and mitigation [13]. Subsequently, marketing strategies influencing business approaches in promoting climate change adaptation and mitigation through sustainable development are either misrepresented or limited within the core themes [12,14]. Therefore, this study explores climate change adaptation and mitigation connections through marketing strategies presented in the existing body of literature. The novelty of this paper stems from jointly investigating critical themes related to the adaptation and mitigation of climate change with relatable marketing perspectives [15], which has not been extensively assessed in the past [16,17] and is critical for combating the adverse impacts of the changing climate through sustainable development [9,15].

Therefore, this paper assesses the past literature related to critical themes and marketing principles in Section 2, followed by the materials and methodology used for analysis in Section 3. The results are reported in Section 4, followed by a detailed discussion in Section 5, with the conclusion presented at the end.

2. Literature Review

2.1. Marketing

Mainstream marketing focuses on offering goods and services that meet consumer needs and wants [18]. On the contrary, the marketing practices encourage increased consumption and economic development, leading to extensive environmental damage. The industrial revolution gave birth to the rise of modern marketing. The marketing concepts highlight that businesses should focus on meeting the needs and wants of the consumers. Therefore, the justification of marketing activities was dependent on meeting consumer satisfaction.

Social marketing provides an extension of the marketing concepts, ensuring that apart from meeting the needs and wants of the consumers, it is vital that firms are concerned about social responsibilities and are not doing any damage to society [19]. Social marketing is defined as applying commercial marketing concepts and techniques to promote behavioural changes [20]. By the 1980s, industries started considering the environmental issues but lacked true innovation. The industries are significant contributors of production by using natural resources. The by-product of production includes greenhouse gases, solid wastes, air, water and soil pollution that damage the ecosystem [10,19]. However, the traditional marketing paradigm did not consider the scarcity of natural resources and waste from production harmful to the natural system.

Over time, public interest in the environment grew, along with government-imposed legislation to protect the environment. The production of green products came into effect, ensuring that less damage was done to the environment and human health [19]. Marketing has gone through a paradigm shift towards environmental and social sustainability. Consumers embrace sustainable consumption, ensuring that they consume certain products and services that have less impacts on the environment, social equity and personal well-being [21]. Sustainable consumption implies that the use of natural resources is minimal, and the emission of waste and toxic materials from production does not threaten the needs of future generations.

Green marketing seeks to advertise products with environmental features and extends to product modifications, with changes brought to production processes and packaging [22]. The prominence of green marketing came into effect in the 1980s and early 1990s that focused on ecological marketing. Ecological marketing is defined as the positives and negatives of marketing activities that cause pollution, depletion of energy sources and

exhaustion of natural resources. Green marketing extends the definition of ecological marketing that focuses on meeting the needs and wants of humans, ensuring that minimal damage is done to the natural environment [22]. On the other hand, sustainable marketing is the latest trend that allows marketing principles to not conflict and organisations to gain a competitive advantage by meeting the needs of the target customers [19].

Sustainable marketing implies that the current consumption levels are unsustainable, and it is fundamental to change the consumer behaviour [15]. Sheth and Parvatiyar [23] revealed that a responsible production approach should drive the market for sustainable products and services and establish a sustainable society. The concept of sustainable development led to a sustainable marketing [24]. According to Belz and Peattie [25], sustainable marketing entails a long-term orientation of relationship-building made possible by identifying consumer needs to establish loyalty towards a sustainable vision. Kumar et al. [26] illustrated that a sustainable marketing strategy is derived from sustainable development and marketing. Sustainable marketing refers to a comprehensive development of marketing that includes environmental, green, and societal marketing [27]. Moreover, Calvo-Porral [15] illustrated that sustainable marketing integrates environmental, social and economic concerns into marketing activities and strategies.

The timeline of sustainable marketing began in 1953 when a study recognised Corporate Social Responsibility (CSR) as a set of strategies, policies and actions vital for any business to embrace responsibilities in the past, present and future [28]. After that, the Brutland Report defined sustainability as the development that caters to current generations' needs without forgoing the needs of future generations [29]. The academic interest in sustainability started in the 1990s, focusing mainly on micro and macroeconomics, environmental accounting, psychology, sociology and policy [27]. Sustainability was recognised as a business strategy in 2005 with the underlining principles of cautiously dealing with risks, appreciation and value for nature, and integration of the environmental, social and economic goals. Moreover, the principles included community participation in planning, commitment to best practices, continuous improvements and good governance [30].

Over the years, research and interest in sustainable marketing have become prominent. A survey study by Peterson et al. [31] investigated how consumers value and perceive sustainable marketing practices. The study confirmed that consumers' nature-based values positively influence consumers' support for sustainable marketing. Another study that surveyed manufacturing businesses in Thailand illustrated that technology adaptation orientation and environmental process development significantly affect the sustainable marketing success [32]. A qualitative study on Polish food industry enterprises confirmed that production companies should adopt principles of sustainable development to define themselves as a sustainable organisation [24].

An empirical investigation in Istanbul confirmed that consumers' attitudes and buying intentions are related to environmental consciousness, lifestyle and involvement factors [33]. A comprehensive study by Rudawska [34] investigated the implementation of sustainable marketing tools in Europe by SMEs that operated in the food and drink industry and confirmed that B2B uses the tools to a greater extent when compared to B2C. A cross-culture study researched the attitudes of Chinese and Korean students regarding their perspectives on whether sustainable marketing activities are practical in environmental, economic or social dimensions [35]. The findings confirmed that the environmental dimensions positively influenced WOM and brand attitudes for the Chinese sample and not for the Korean sample. The economic dimension was ineffective for both the Chinese and Korean respondents. In contrast, the social dimension was effective and favourable for the Korean sample but inadequate for the Chinese respondents.

A Korean study confirmed that consumers are aware of sustainability and environmental concerns being the key factors [36]. Another cross-culture study from the US, Germany and South Korea investigated how to encourage sustainable thoughts and behaviour effectively and confirmed that involvement motives lead to recycling behaviours and green transportation use; the US and Germany had involvement motives, while Koreans had

the highest level of social media involvement for sustainable behaviour [37]. It is evident that the number of empirical-based papers is scant on sustainable marketing, and very few industries have focused on implementing sustainable marketing tools. Moreover, consumer-based studies are also limited related to sustainable marketing.

Nowadays, consumers have a growing interest in environmental preservation, ethics, sustainable manufacturing and the marketing of goods [16]. Hall [12] mentioned a substantial interest in marketing practices and climate change outside of marketing journals. It is alarming that less than 1% of journal articles in marketing are focused on or concerned about climate change. Marketing as a field may become stranded if issues of climate change impacts and consequences are not considered when deciding upon marketing practices, activities and strategies [12,38].

2.2. Climate Change

Over time, climate change has become one of the most debated topics because of the significant challenges humankind faces in the natural system [39]. The research on climate change and the vulnerability to natural hazards has significantly progressed over the last decade [40]. Climate change refers to the shift in global weather patterns caused by the emission of greenhouse gases from natural systems and through human activities [41]. At the same time, Titifanue et al. [42] stated that climate change refers to human-induced changes to the climate system caused by an increase in greenhouse gases. The natural systems include forest fires, earthquakes, oceans, wetlands, mud volcanoes and volcanoes, while human activities involve energy production, industrial activities, land use and land-use change [43].

Due to climate change and global warming, there is a dramatic rise in extreme weather events and natural disasters such as hurricanes, typhoons, floods, bush fires, drought and tornadoes [44]. Moreover, the rise in global temperature is causing the melting of polar ice, resulting in sea-level rise around the globe. It has been implied that global warming will rise to 1.5 °C between 2030 and 2052 if the current emission continues [41]. In addition, the thermal expansion of the oceans is caused by the increase in heat that causes water to expand. The natural disasters aggravated by climate change are becoming more frequent and expensive for developed and developing countries.

Climate change mitigation refers to reducing and avoiding emissions of heat-trapping greenhouse gases into the atmosphere and preventing further warming of the planet. According to Fawzy et al. [41], there are three main climate change mitigation approaches. The first type aims to reduce carbon-dioxide emissions that emphasise renewable energy, fuel switching, use of nuclear power, carbon capture storage and utilisation and efficiency gains. The second method involves carbon-dioxide removal methods, including bioenergy carbon capture and storage, biochar, enhanced weathering, carbon capture, afforestation and reforestation. Moreover, the third method involves altering the earth's radiation balance by managing the solar radiation [41].

Climate change adaptation refers to altering the behaviour and systems to adjust to the current and expected climate change effects. Adaptation in human systems aims to mitigate or avoid harm while also using good choices [45]. Human intervention in some natural systems may make it easier to react to expected climate and its impacts. Adaptation solutions can vary based on the community, business, region or country [46]; for example, cyclone early warning systems, drought-resistant crops, sustainable company operations and government regulations to construct more resilient societies and economies by managing risks cost-effectively in the future. Immense efforts to ensure sustainable adaptation to climate change require reductions in vulnerabilities associated with the socio-environmental dynamics through climate-resilient pathways [47].

Climate change and sustainable development need to be better coordinated to maximise the effectiveness of actions in both domains [48]. Furthermore, sustainable development pathways often combine adaptation and mitigation strategies. Sustainable development refers to the various forms of progress that meet the needs of the present gen-

eration without compromising the future generation needs [49]. Sustainable development is broad and requires integrating knowledge and skills from various disciplines. According to Nerini et al. [48], climate change and sustainable development should have an inherent interconnection to maximise achieving the goals.

Sustainable development has been enforced by the UN's 17 Sustainable Development Goals (SDGs) [50]. In 2015, 197 countries committed to combat climate change by endorsing the 2015 Paris Agreement on Climate Change. Moreover, the UN member countries have also adopted the 2030 Agenda for Sustainable Development. The 2030 Agenda for Sustainable Development is a comprehensive global action that includes 17 SDGs and 169 targets to be achieved by 2030 [48].

2.3. IPCC Reports

The Intergovernmental Panel on Climate Change (IPCC) is an organisation of governments that explores the warming of the climate system that is supported by the United Nations (UN) or the World Meteorological Organization (WMO). The IPCC was created for policymakers with regular and updated assessments on climate change, implications and potential risks, adaptation and mitigation options [51]. The IPCC reports are published every 5 to 7 years, contributing to climate science and knowledge articulated by prominent world scientists [52].

There are multiple stages of review essential for the IPCC process, ensuring that objective and transparent current scientific knowledge is reported. The expert reviewers and governments are invited to contribute at various stages to balance the draft report. The broad contribution from reviewers and governmental participation ensures that the scientific assessments maintain accuracy and completeness. The IPCC is divided into three Working Groups (Working Group I, II, III) and a Task Force. Working Group I deals with the physical sciences basis of climate change, Working Group II works on climate change impacts and Working Group III looks into climate change mitigation [53]. The Task Force's main objective is to report national greenhouse gas emissions and removals.

Since 1988, the IPCC has delivered six comprehensive scientific reports about climate change at the global level [51]. In 1990, the IPCC published its First Assessment Report that was based on IPCC scientific assessment (Working Group I), IPCC impacts assessment (Working Group II), and IPCC response strategies (Working Group III) [54]. The First Assessment Report served as the UN Framework Convention on Climate Change [55]. The Second Assessment Report was published in 1995 that focused on the science of climate change, scientific and technical analyses of impacts, adaptations and mitigations of climate, and economic and social dimensions of climate change [54]. The Second Assessment Report implied that 10 to 30% of greenhouse gas emissions in most countries could be reduced at negative or zero cost. Moreover, the literature indicated that climate change would cause aggregate net damage, and the combination of mitigation, adaptation and further research is viable for addressing climate change uncertainties [56].

In 2001, the IPCC published its Third Assessment Report (TAR), which included Working Group I, based on Scientific Basis. Working Group II comprised Impacts, Adaptation and Vulnerability, and Working Group III contained Climate Change 2001 on Mitigation [54]. The TAR demonstrated warming of the Earth's surface based on observed warming related to human activities. The TAR also projected increased global mean temperatures, rising sea levels and increased frequencies of heatwaves. The Fourth Assessment Report (AR4) was published in the year 2007 that included Working Group I (The Physical Science Basis), Working Group II (Climate Change 2007: Impacts, Adaptation and Vulnerability) and Working Group III (Climate Change 2007: Mitigation of Climate) [54]. AR4 indicated that human activities such as burning fossil fuels had caused global warming over the past 50 years [57].

The Fifth Assessment Report (AR5) was completed in 2014, including the synthesis report (IPCC, 2022c). IPCC approved publications on Impacts Adaptation and Vulnerability (Working Group II) and Mitigation of Climate Change for AR5 (Working Group III). AR5

revealed that it is 95% certain that humans are the leading cause of global warming. Moreover, the least developed nations and vulnerable communities will be severely affected by climate change's potential risks and impact [58]. Stabilising the temperature below 2 °C, relative to pre-industrial levels, will require businesses to depart from their normal activities and functions. In addition, the delays in taking appropriate actions to combat climate changes and global warming will be costly at technological, economic, social and institutional levels. In 2021, the Sixth Assessment Report (AR6) included the contribution of Working Group I (Climate Change 2021: The Physical Science Basis) (IPCC, 2022c). The remaining components of AR6 will be released in 2022. AR6 discussed the climate projections related to socioeconomic situations, the estimated consumption of fossil fuels in the future, land-usage changes, emphasis on industrial activities and greenhouse gas emissions [51].

3. Materials and Methods

The paper utilised three serial approaches to understanding key literature patterns associated with climate change adaptation, mitigation and marketing, as shown in Figure 1.

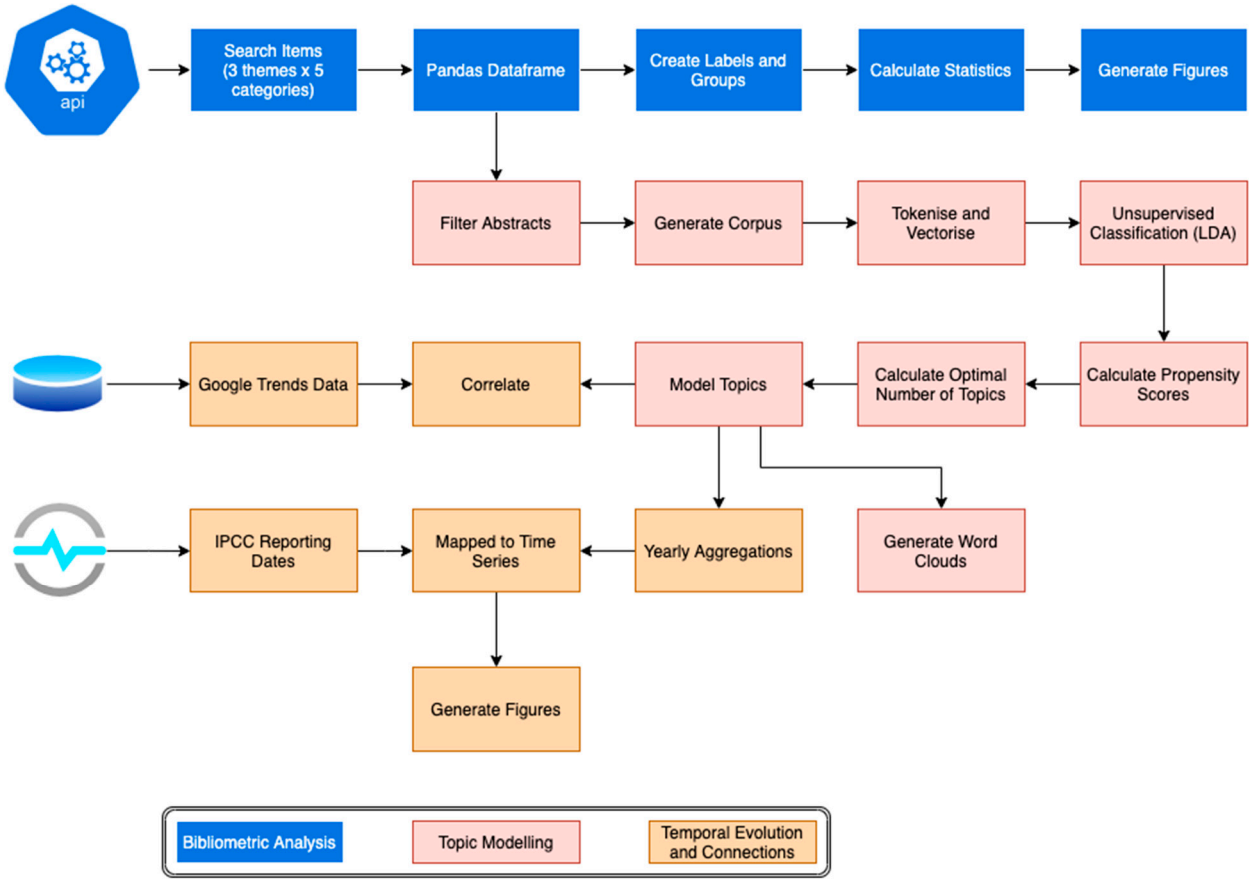

Figure 1. Analysis approach used in this study.

3.1. Bibliometric Analysis

A bibliometric analysis of key papers was conducted after downloading metadata from the Scopus API holding information regarding the authors, citations, abstracts, affiliations and other relevant publication details. Note that the API was limited to 20,000 queries only. The search items used to query the Scopus API included were divided into three themes, namely "climate change", "global warming" and "sustainability". These themes spanned the earth, environment, social, engineering and political sciences, which returned extensive search results (>300 K). Additional categories were chosen as filters during search queries to understand marketing connections and narrow down search results. The categories used

to search within the themes included terms including "sustainable marketing", "social marketing", "green marketing", "sustainable consumption" and "ecological marketing". A total of 15 search queries (3 themes × 5 categories) were made through the Scopus API, returning items that were merged into a *pandas* data object (known as dataframe) with labels of the respective theme and category. The merged dataframe was later used to compute the total number and types of documents, the time evolution of published items and citations, the top-ten leading authors and countries of affiliations and a global footprint of active contribution to research from all authors.

3.2. Topic Modelling

The Scopus API only searches for the title, abstracts and keywords, but the uneven distribution of documents under each theme and category introduces sampling bias. To identify leading topics of interest from the available abstracts, the bibliometric data were further analysed by topic modelling. Several topic modelling approaches have been used in the past to understand common topics of interest by mining the literature intelligently, but for this study, the most widely used Latent Dirichlet Allocation (LDA) unsupervised approach was conducted using the scikit-learn python package. All abstracts were post-processed into a corpus by removing commonly used stopwords using the spacy python package. The data were tokenised and counted with vectorisation for unsupervised classifications. To determine the optimal number of topics used for LDA analysis, the propensity scores were calculated for the number of topics ranging from 5 to 25. The number of topics corresponding to the minimal propensity score was chosen as the optimal topic for LDA analysis. All the topics identified were demonstrated with a word cloud.

3.3. Temporal Evolution and Connections

To understand the temporal fluctuation in the identified topics, the output from LDA was transformed into yearly aggregations of topical contributions. Similarly, Google trends data were downloaded for the selected themes and categories from worldwide Google searches. These datasets were correlated to understand the time delays in immediate and published peer-reviewed responses. Likewise, IPCC assessment report release years (shown in Table 1) were also compared with the temporal variations to understand the reaction from the public and the published authors.

Table 1. Timeline of crucial IPCC reports.

Report	Year Released
First Assessment Report (AR1)	1990
Second Assessment Report (AR2)	1995
Third Assessment Report (AR3)	2001
Fourth Assessment Report (AR4)	2007
Fifth Assessment Report (AR5)	2013
IPCC Special Report on Global Warming	2018
Sixth Assessment Report Approved (AR6)	2020

4. Results

4.1. Bibliometric Statistics

The total number of search queries returned by the Scopus API for the relevant terms is shown in Figure 2. As expected, the number of documents under the themes outperforms the categories, suggesting that research related to climate change, global warming, and sustainability covers a broad spectrum of topics compared to marketing activities promoting adaptation and mitigation policies for sustainable development. In the marketing categories, ecological marketing was the least known researched topic after sustainable marketing.

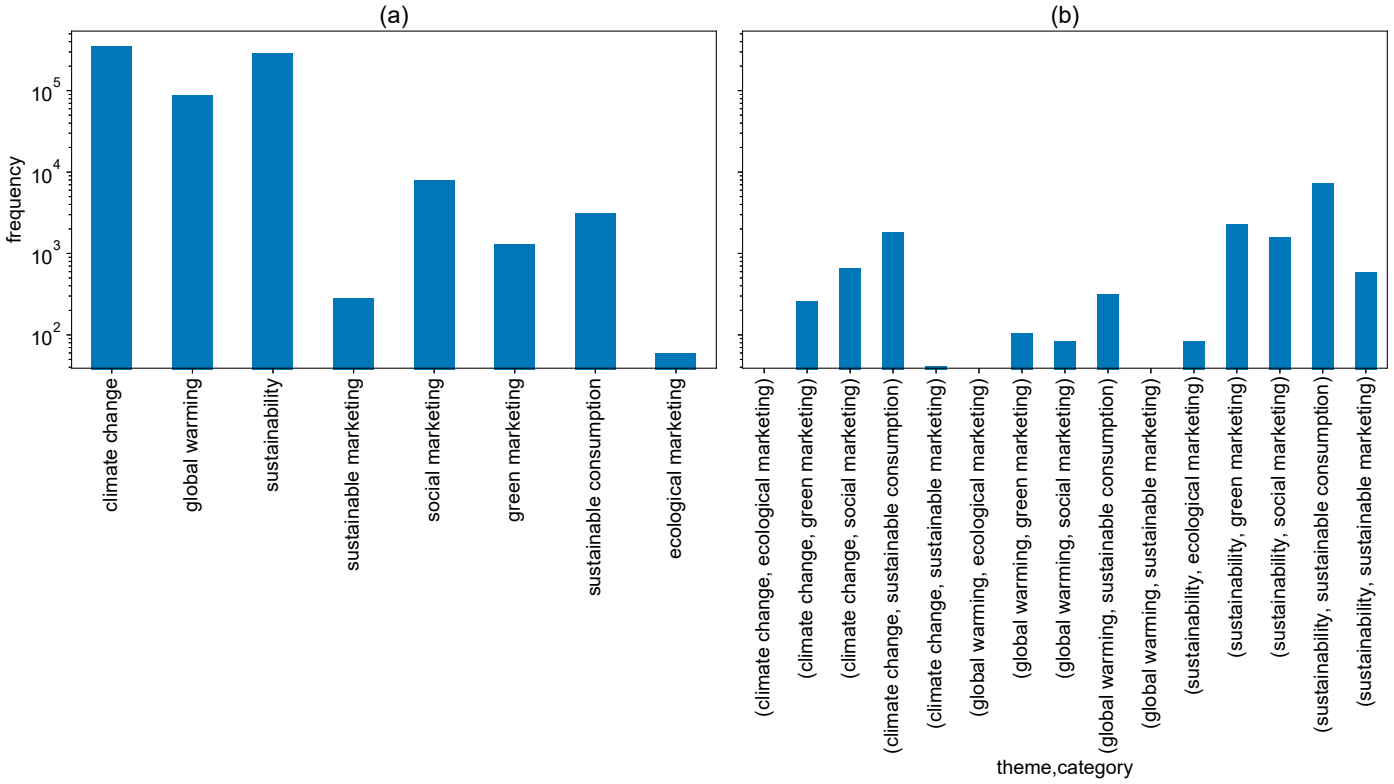

Figure 2. Total frequency of results from the search query of (**a**) themes and category and (**b**) category within themes from Scopus API. Note that the y-axis has a log scale.

On the contrary, filtering each marketing category within the themes demonstrates the discrepancies in research ideologies connecting issues related to climate and marketing approaches for resilience. Marketing connections under climate change and global warming were limited to green marketing, social marketing and sustainable consumption, whereas all marketing categories were dominant under sustainability. Arguably, marketing approaches are well researched, with sustainability as the key theme, as indicated from the types of documents published in Figure 3.

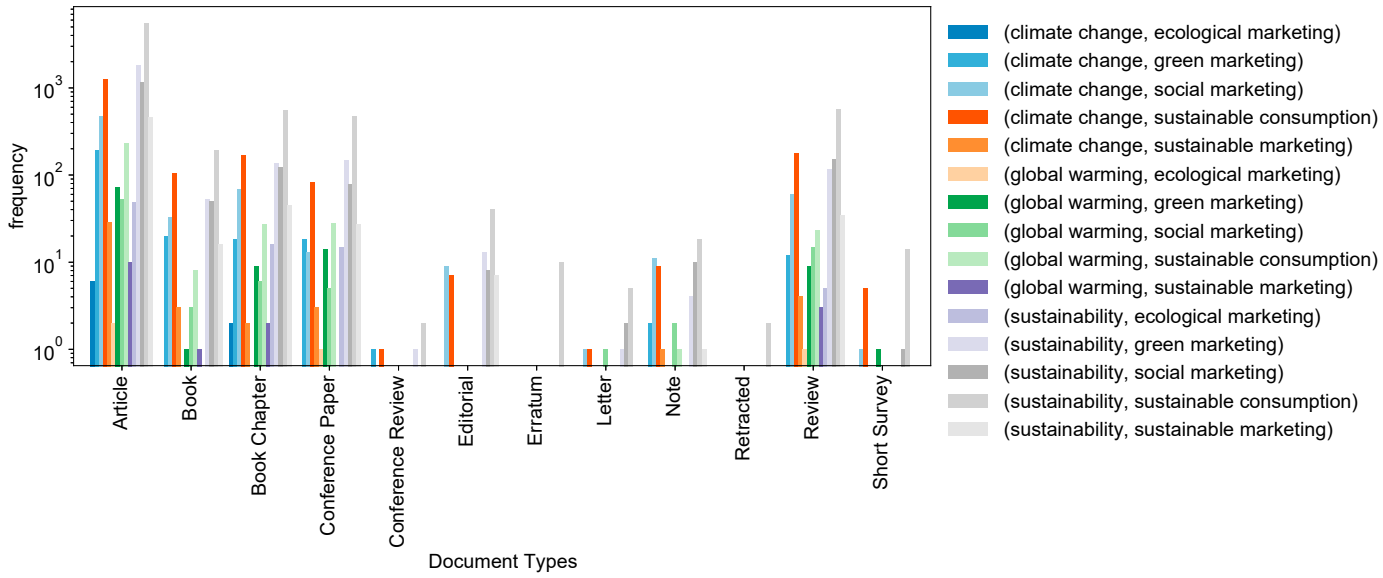

Figure 3. Frequency of the types of published documents related to the major themes (climate change, global warming and sustainability) and filtered marketing categories.

All marketing categories associated with sustainability are prevalent across the different published documents. Most documents published were peer-reviewed articles dominated by the theme of sustainability. The yearly fluctuation in research with significant themes and categories can also demonstrate marketing connections to climate change awareness. Figure 4 highlights the annual fluctuations in the total number of documents published and the total citations gained by the respective marketing categories within each theme.

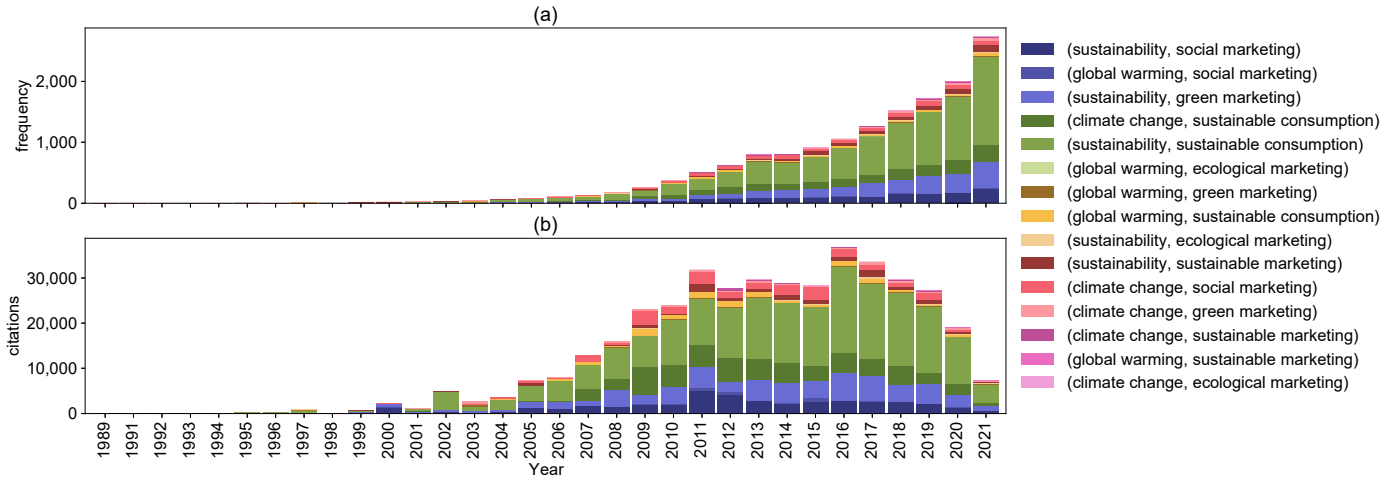

Figure 4. Yearly fluctuation in (**a**) total number of documents published and (**b**) total citations for the respective marketing categories within themes (climate change, global warming and sustainability).

The total number of published documents and citations gained momentum post-2000. The most documented and heated discussion topics were sustainability and sustainable consumption, sustainability and green marketing, and climate change and sustainable consumption. Over the years, the total number of documents published increased drastically; however, the total number of citations has declined since 2016.

Alternatively, separately grouping the data by the themes and marketing categories also yields interesting insights, as demonstrated in Figures 5 and 6, respectively.

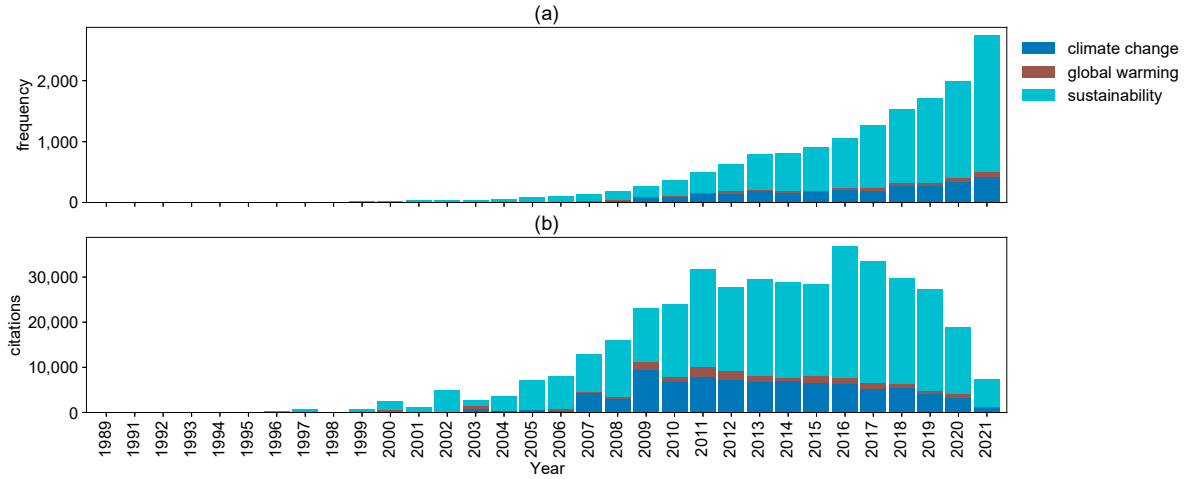

Figure 5. Yearly fluctuation in (**a**) total number of documents published and (**b**) total citations within the major themes (climate change, global warming and sustainability).

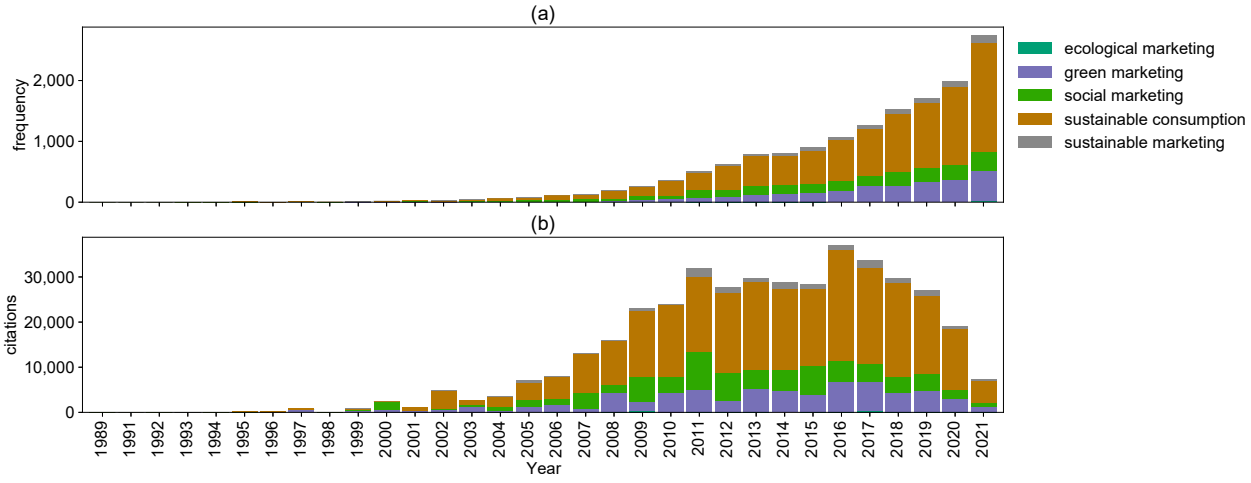

Figure 6. Yearly fluctuation in (**a**) total number of documents published and (**b**) total citations within the marketing categories.

Interestingly, marketing categories are prevalent concepts within sustainability compared to climate change and global warming, with reduced citations post-2009. On the contrary, sustainable consumption is the most widely known marketing application aligned with all the themes. Likewise, marketing categories associated with ecological and sustainable marketing are rare concepts in the themes identified in this study.

The temporal fluctuations highlight the trends of marketing principles and strategies related to climate change and global warming that are either miscommunicated or not articulated adequately in such studies. On the contrary, marketing strategies are better communicated using the concept of sustainability and sustainable consumption.

Moreover, the demographics of the research activity highlight active regions and communities exploring relationships within the themes and marketing categories identified in this study. The top-ten leading researchers and the affiliated countries assessing the themes and marketing categories are presented in Figure 7.

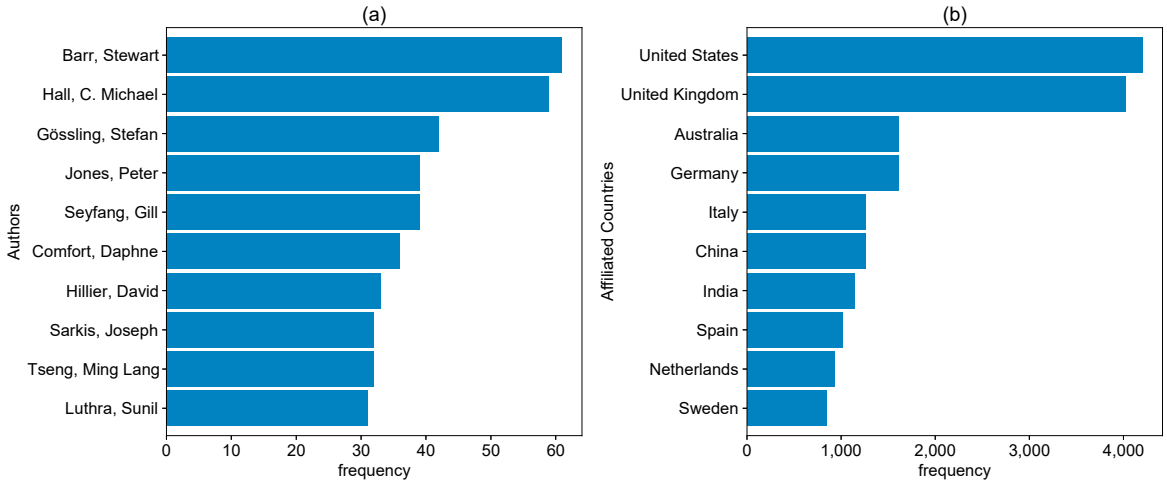

Figure 7. Top-ten researchers (**a**) and affiliated countries (**b**) assessing connections within the themes (climate change, global warming and sustainability) and the marketing categories.

All leading researchers have made more than 30 contributions in documenting the connections of marketing categories with the themes. Most of the contributions were made from developed countries, including the US and UK, with more than 4K contributions. Nonetheless, contributions from all around the globe narrowed down to cities are also demonstrated in Figure 8.

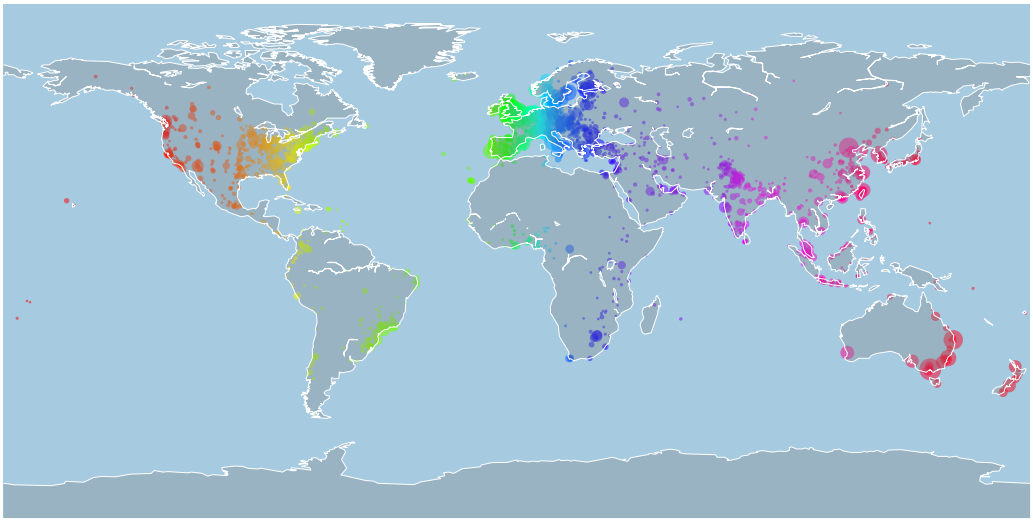

Figure 8. Global distribution of affiliated cities of author contributions investigating marketing categories connections with the key themes (climate change, global warming and sustainability).

Researchers and collaborators are widespread across metropolitan cities around the globe, especially in Europe, China, India, the East Coast of the US and Australia, including regions in New Zealand, Africa, Asia and South America. Notably, there is minimal representation from small developing countries and island nations.

4.2. Modelled Topics

Extending beyond bibliometric analysis, topic modelling of abstracts may reveal additional insights other than the thematic approach utilised through literature reviews. A common approach to initiating topic modelling using unsupervised learning is selecting the number of topics. The optimal number of topics represented through modelling was chosen from the minimal derived perplexity scores, as shown in Figure 9.

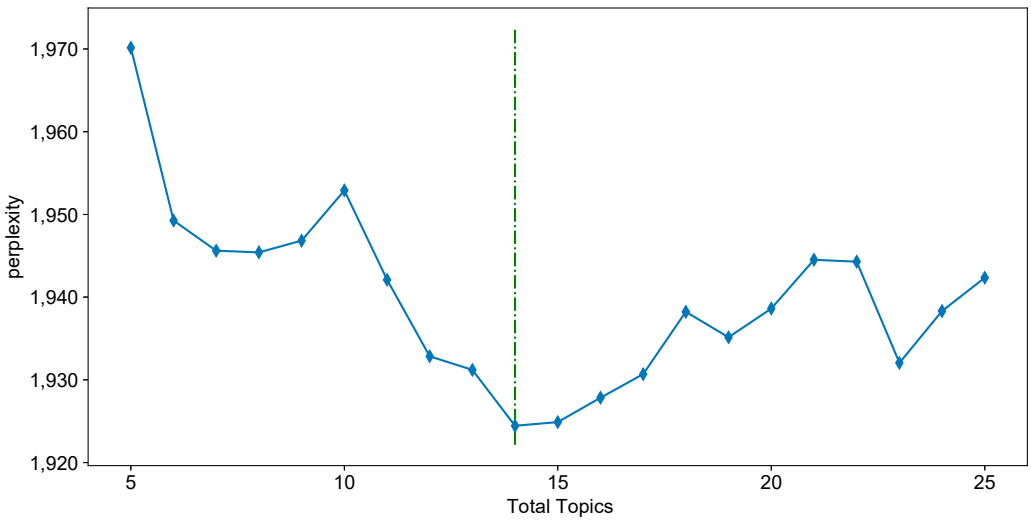

Figure 9. Perplexity scores derived using the different topics used for LDA.

The perplexity scores show a steady decline for a few topics, but local minima occur with the total number of topics of 14. Note that initial bibliometric analysis was conducted with 15 groups (themes and categories); thus, the optimal number of topics based on perplexity scores seems reasonable.

The frequency distribution of contributing words for each topic is shown as a word-frequency diagram in Figure 10.

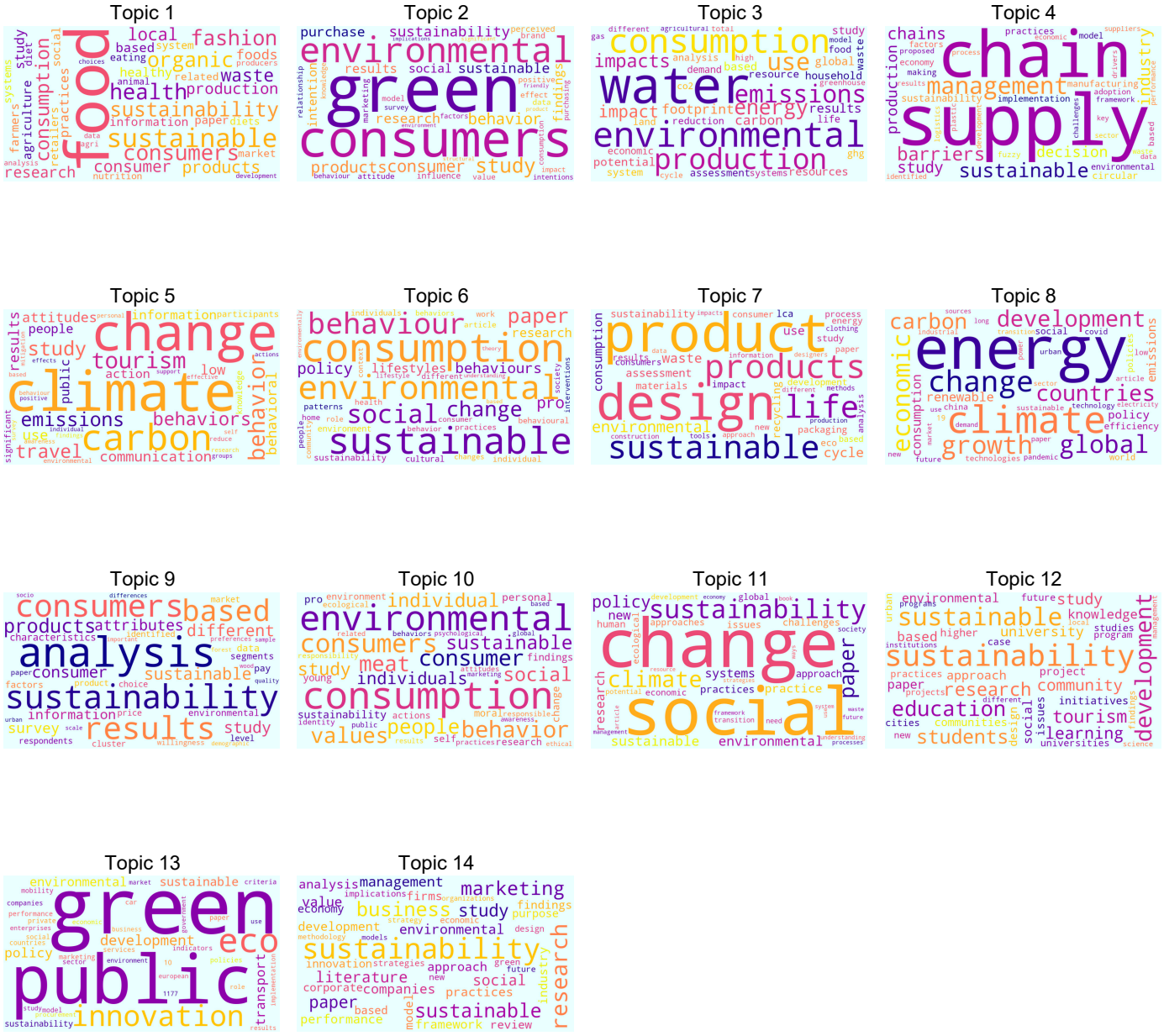

Figure 10. Key topics modelled using LDA from all the abstracts of search queries relating to respective marketing categories within themes (climate change, global warming and sustainability).

Topic 1 can be interpreted as research-driven for sustainable consumer-focused products, including food, health and fashion relating to waste production. Topic 2 includes environmental research targeted at green consumers' behaviours in accessing sustainable products. Similarly, Topic 3 entails research on water consumption with connections to carbon emissions from energy and impacts on the environment. Topic 4 relates to supply chain management for a sustainable industry with effective decisions spanning production to distributions. Topic 5 refers to studies on carbon emissions connections to climate change with impacts on travel and tourism. Likewise, Topic 6 focuses on sustainable consumption-related environmental behaviour promoting social change. Topic 7 focuses on product design of sustainable products related to the life cycle, including use and consumption. Topic 8 relates to renewable energy and climate change, emphasising economic growth and development.

Moreover, Topic 9 can be interpreted as studies on consumer products promoting sustainability. Topic 10 focuses on consumer behaviour and values related to sustainable

consumption. Similarly, Topic 11 relates to social change based on climate policy promoting sustainability. Topic 12 focuses on studies on sustainable development, which are community-based such as student education and learning. On the other hand, Topic 13 relates to green, eco-friendly public transport through policies and innovation for a sustainable environment. Lastly, Topic 14 relates to business research with sustainable marketing promoting sustainability.

4.3. Temporal Connections

The temporal fluctuations in the topics generated from LDA demonstrate the variations in the topics over time. Figure 11 shows the temporal changes of the topics modelled and their co-occurrence with major IPCC reports.

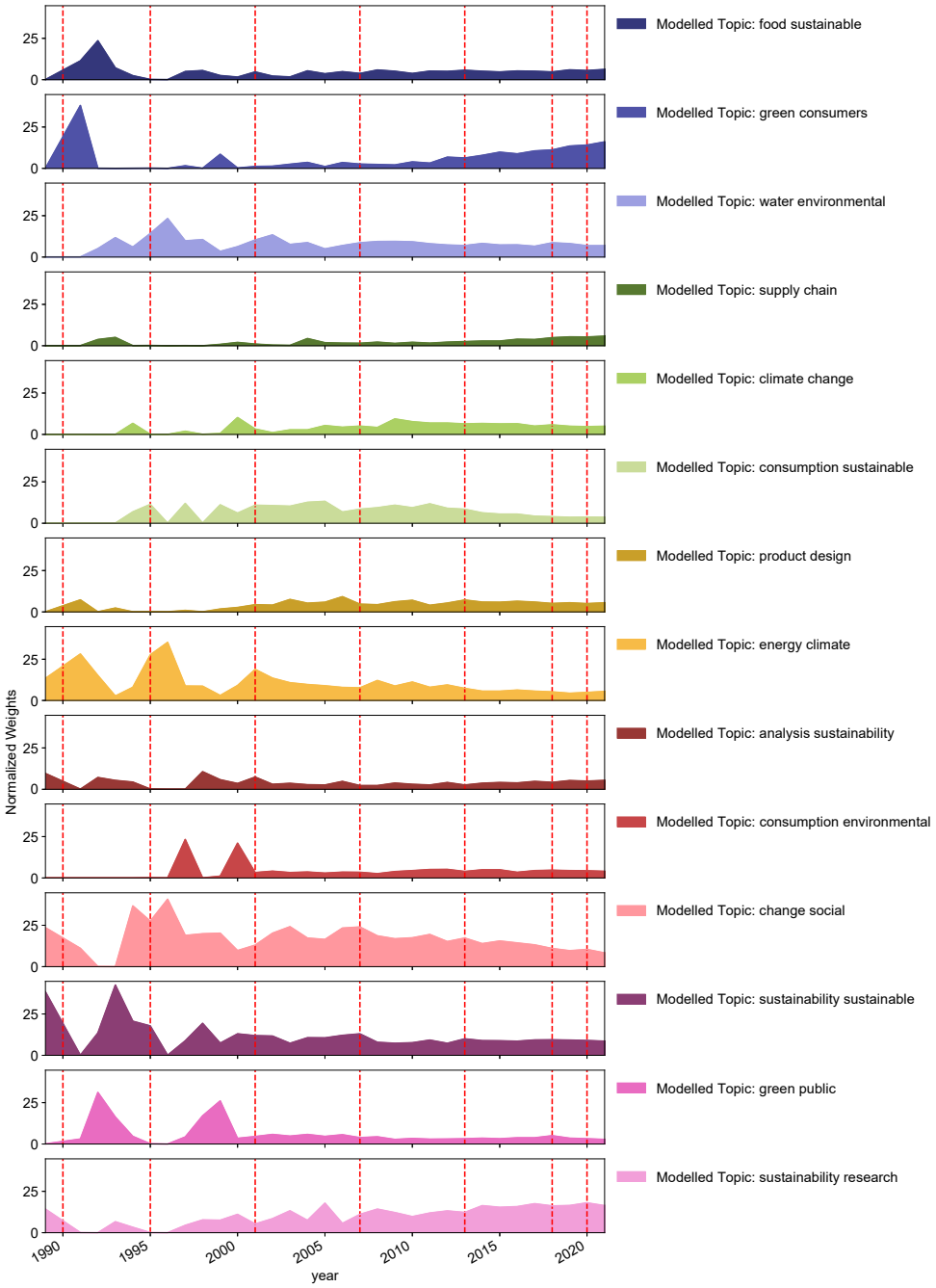

Figure 11. Temporal variation in the modelled topics using LDA and its co-occurrence with IPCC Reports.

Topic 1 on sustainable foods was more dominant in research before 1995 and peaked after the IPCC's First Assessment Report release. Post-1995, this topic had moderate mentions in research, and it remained stable over the years despite several releases of IPCC Assessment Reports. On the other hand, research related to Topic 2 on green consumers peaked after the First IPCC Report and remained minimal until the Fifth Assessment Report. Likewise, Topic 3 on water consumption in the environment peaked after the Second Assessment Report in 1995.

In contrast, Topic 4 on supply chain management only gained momentum in research after the Fourth Assessment Report in 2007. Interestingly, Topic 5 on climate change-related research was primarily active after individual Assessment Reports but declined after the release of the Fifth Assessment Report in 2013. Similarly, Topic 6 on sustainable consumption aligned well with the Second Assessment Report in 1995, whereas Topic 7 on product design only increased in research after the Third Assessment Report in 2001.

Moreover, researchers actively communicated Topic 8 on energy and climate after the release of all the Assessment Reports; however, the intensity has slowly declined over the years. On the other hand, Topic 9 on sustainability analytics has been active in the research community over all years, while Topic 10 on environmental consumption has been active after the Second Assessment Report in 1995. The most active research topic has been Topic 11 on social change with fluctuations after each release of IPCC Assessment Reports, followed by Topic 12 on substantiality related to development. On the contrary, Topic 13 on green public transport peaked after the First and Second Assessment Reports and remained steady in research activity after 2001. Furthermore, Topic 14 related to sustainability based on business research has gained increasing attention in research publications over the years.

Additionally, the correlations of modelled topics in published research and Google searches from the public also show exciting patterns in Figure 12.

The highest correlations for each dataset were >0.5. The Google trends search related to social marketing correlated highly (~0.92) with the modelled topic of green consumers. Similarly, the Google trends search related to green marketing was associated positively (~0.83) with the modelled topic of energy and climate. Notably, Google trends searches related to climate change were primarily uncorrelated with nearly all modelled topics.

For the common period in the modelled topics and Google searches, the co-occurrences of IPCC's major report publications also demonstrate the response of the public and the academic community, as shown in Figure 13.

Most of the terms used in Google searches for this study (especially climate change and global warming) show higher responses at or immediately after the release of the IPCC reports. Note that the term global warming was mainly searched on Google immediately after the release of the Fourth Assessment Report but steadily declined over the years. In contrast, climate change was heavily searched on Google after the Special Report on Global Warming in 2018. On the other hand, Google searches for the terms social marketing and ecological marketing showed a steady increase over the years, while terms such as sustainability and sustainable marketing remained steady. Alternatively, Google searches for terms such as green marketing and sustainable consumption have significantly reduced over the years.

Moreover, after the advent of the World Wide Web, several modelled topics (such as climate change, water consumption and energy climate) do not peak precisely at the release of the IPCC reports, arguably due to the time taken from research to publication, including the peer-review process. Furthermore, the modelled topics related to green consumers, supply chain, sustainability analysis and sustainable business research have significantly increased over the years. In contrast, modelled topics related to sustainable consumption, energy climate and social change have declined dramatically.

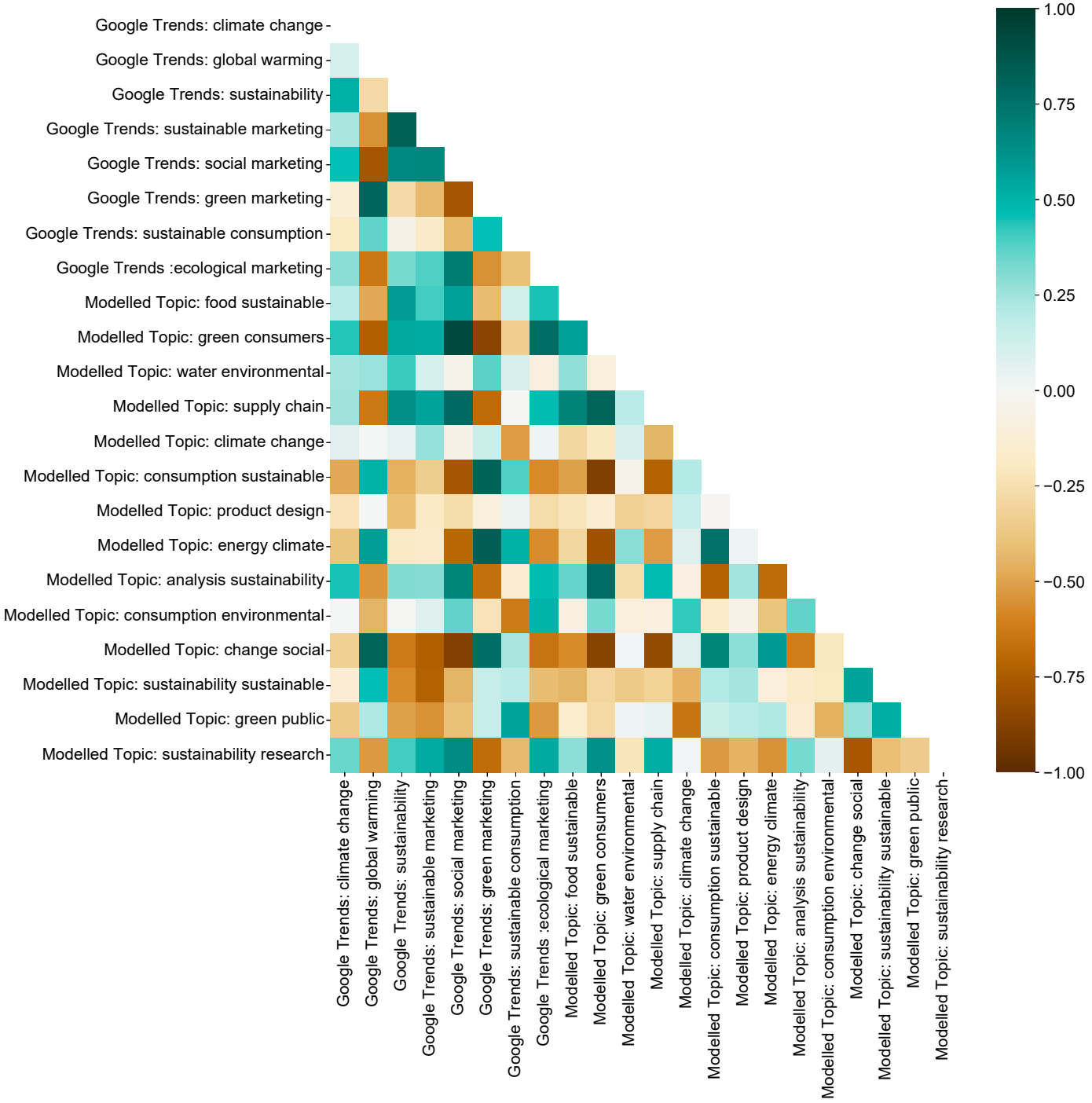

Figure 12. Correlations of public (Google trends) and researchers' activity (modelled topics) related to the major themes (climate change, global warming and sustainability) and filtered marketing categories.

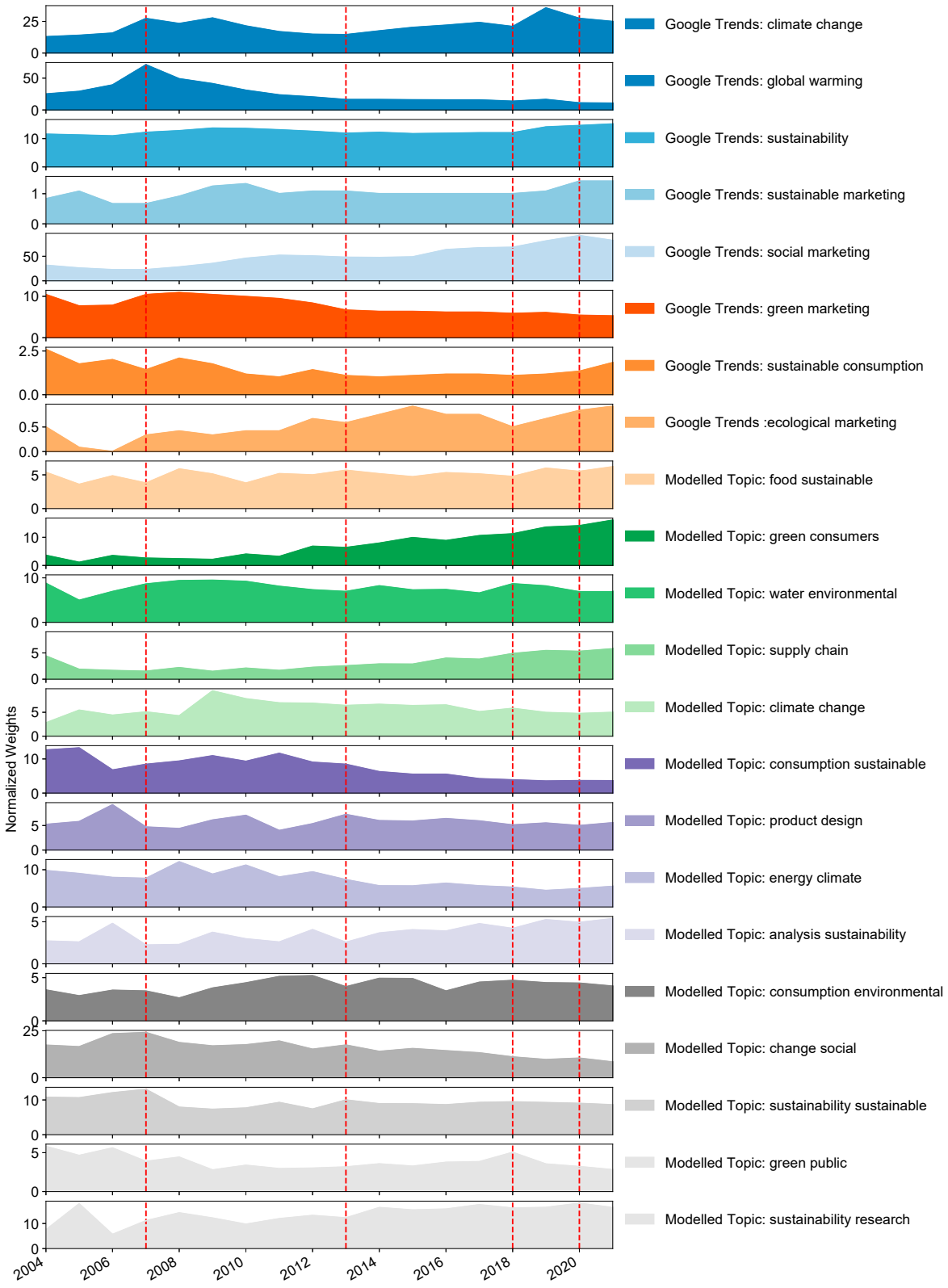

Figure 13. Temporal variation in the Google search trends from the public and the modelled topics from the academic community using LDA with the co-occurrence of IPCC reports.

5. Discussion

A climate-resilient future relies on adaptation and mitigation strategies promoting reductions in carbon-dioxide emissions with increased uptake of renewable energy and

sustainable technologies. An essential outcome of this study is a disconnection of broader themes related to climate change, global warming and sustainability and marketing strategies developed to support climate adaptation and mitigation through research. The bibliometric analysis showed that a greater emphasis on marketing strategies promoting climate change and global warming was limited compared to sustainability. Recently, Saleem et al. [16] also found that green marketing research had a greater emphasis on sustainability; however, the study did not explore themes of climate change and global warming and was only restricted to the bibliometric analysis of 1025 scholarly documents. Similarly, Bhardwaj et al. [17] identified one of the major themes as sustainability by building network diagrams while conducting a bibliometric analysis on green products with 1619 publications but had no mentions of climate change and global warming. This study explores a much greater number of articles extending beyond a bibliometric analysis and includes topic modelling by incorporating additional themes of climate change and global warming with sustainability to provide new insights.

Nonetheless, the results indicate that it is highly plausible that strategies such as sustainable marketing, social marketing, green marketing, sustainable consumption and ecological marketing are easily communicated in sustainability. Additionally, climate change and global warming themes are sceptical [59,60] or political in nature [61]. A vital issue in communicating climate change is framing the messages [62]. It has been shown that communicating climate change through adaptation and mitigation has been more effective [63]. Arguably, an individual's or business's concern for a sustainable environment may be much greater than the awareness brought through the science of climate change and global warming [64]. The emergence of sustainability science connecting nature and society promoting development through technological advancements appeals more to the public [65]. Several businesses associate more towards meeting sustainable development goals rather than directly committing to reductions in carbon footprints with improved efforts in reducing significant impacts to value chains, enhanced resource management and supporting global community efforts of climate adaptation [66].

Several debates in the literature have emerged related to the efficacy of carbon footprint disclosures issued by corporate organisations. Businesses usually commit to their corporate social responsibilities, such as meeting sustainable development goals, rather than fully disclosing carbon footprints, which can often be misreported or selectively reported [7]. Recently, Mahapatra et al. [8] found limited evidence of carbon footprint reduction with business performance, especially when commitments in sustainability reports of businesses are not met fully with positive economic and environmental outcomes. Nonetheless, several companies are actively working to improve their climate change adaptation measures to drive business innovation through competition, legitimation, and ecological responsibility [67]. This is also evident from the increasing trends in the modelled topic 14 associated with sustainability-based business research, which was scarce in the last decade [68].

This study also demonstrates the role of climate change awareness through reporting agencies such as the IPCC in driving research related to marketing practices of businesses favouring climate change adaptation and mitigation. As expected, the disconnect between the public and published authors in expressing these sentiments may exist mainly due to the time taken in publications. Nonetheless, it has been shown that the major IPCC reports have driven individual queries on the web and significantly motivated research related to climate change and marketing. Similar results have been reported in Hulme et al. [69], highlighting IPCC reports-driven editorials in *Nature* and *Science* journals. Note that the role of other climate awareness meetings, conferences, protests and natural disasters may have affected the Google searches from individuals and research from the academics [39,70].

6. Conclusions

This study used bibliometric analysis and topic modelling of downloaded abstracts to identify key connections between the marketing categories (sustainable marketing, social marketing, green marketing, sustainable consumption and ecological marketing) within

key themes (climate change, global warming and sustainability). Our results demonstrate that marketing principles and strategies about climate change and global warming are either miscommunicated or not adequately articulated in the published literature but better communicated using the concept of sustainability and sustainable consumption. Generally, businesses' adaptation and mitigation strategies align with their social corporate responsibilities and pledges of carbon footprint reduction in sustainability reports related to sustainable development. Likewise, marketing strategies employed for a greener economy relate to adaptation and mitigation measures that bring reputation and confidence amongst consumers, suppliers and investors. Furthermore, adaptation and mitigation strategies greatly reduce the risks associated with global warming and climate change. Still, the scepticism and political influence related to these themes likely exacerbate miscommunication and misinformation and are thus likely underrepresented in the literature investigated. In addition, research is limited in smaller island countries that are at the frontline of the adverse impacts of the changing climate. The bibliometric analysis also revealed a rapid rise in the number of publications associated with the marketing categories and the themes, especially sustainable consumption and sustainability, green marketing and sustainability, and sustainable consumption and climate change; however, the number of citations peaked in 2016 and, since then, has declined most likely due to the lack of funding or interest to readers.

On the other hand, topic modelling of downloaded abstracts demonstrated the connections of marketing categories under the key themes of climate change, global warming and sustainability. Key topics identified in connection with marketing principles related to food and waste production, green consumers, water consumption, sustainable supply chain management, climate change and carbon emissions, sustainable consumption behaviours, product design of sustainable products, renewable energy and climate change, sustainable consumer products, consumer behaviour and consumption, policy-driven social change, sustainable development through learning, green public transport and business research in sustainable marketing. The topics highly communicated to readers included renewable energy and climate change, policy-driven social change, sustainable development through learning and business research in sustainable marketing. Still, only a few topics (green consumers, supply chain management and business research in sustainable marketing) generated curiosity and increased interest among researchers and readers. It suffices to say that current research in business strategies through green marketing directed to green consumers while reducing emissions through sustainable supply chain management is rampant in the literature.

Similarly, nearly all modelled topics show a strong influence from the IPCC reports on climate change with temporal offsets compared to searched queries on the Google platform from users that align well with the peaks of the normalised number of searches. Moreover, a high correlation of Google trends related to the search query of social marketing with the modelled topic of green consumers in the published literature suggests that social marketing associated with green consumers has been a common concern for both the public and academics over the years.

Although the analysis included 15 search queries (3 themes $\times$ 5 categories) using the Scopus API, it may have excluded published materials from other publishers. Nonetheless, a large sample of data were still downloaded from the Scopus API, including publications from several notable journals. It is highly unlikely that results may diverge after the inclusion of additional papers. This study was only limited to published materials and data from Google trends, but analysis of social media datasets, climate change-related meeting transcripts and published speeches from the world and corporate leaders may also provide additional insights.

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