


Review

A Bibliometric Analysis of Carbon Labeling Schemes in the Period 2007–2019

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Abstract: Carbon labeling schemes enable consumers to be aware of carbon emissions regarding products or services, to help change their purchasing behaviors. This study provides a bibliometric analysis to review the research progress of carbon labeling schemes during the period 2007–2019, in order to provide insight into its future development. Number of publications, countries of publications, authors, institutions, and highly cited papers are included for statistical analysis. The CiteSpace software package is used to visualize the national collaboration, keywords co-appearance, and aggregation. The results are given as follows: (1) there are 175 articles published in the pre-defined period, which shows a gradual increase, with a peak occurred in 2016; (2) carbon labeling schemes are mainly applied to grocery products, and gradually emerged in construction and tourism. (3) Existing studies mainly focus on examination of utility of carbon labeling schemes, by conducting surveys to investigate individual perception, preference, and willingness to pay. (4) Future research will include the optimization of life cycle assessment for labeling accreditation, improvement of labeling visualization for better expression, and normalization of various environmental labels to promote sustainable consumption.

Keywords: carbon label; bibliometric analysis; CiteSpace; carbon labeling scheme; purchase intention; willingness to pay

1. Introduction

Greenhouse gas (GHG) emissions have given rise to global warming, which has aroused world concerns to adopt mitigation strategies to promote sustainable development [1]. Since the Paris Climate Summit in 2015, more than 160 countries have formulated policies regarding sustainable consumption and production to achieve emission reduction targets [2]. Among them, carbon labeling scheme is an insightful policy tool, by revealing lifecycle-based carbon emissions of a product or service, to encourage transition of low carbon consumption and production [3]. The first carbon labeling scheme was designed in 2006 by UK Carbon Trust [1]. One of its essential measures is to alleviate the impact of carbon emissions on the UK's sectors of production and services [4]. More than 2000 products with over 90 international brands have been issued by Carbon Trust to implement the scheme [5]. Since then, a number of developed countries (such as the U.S., France, Switzerland, Japan, and Canada) adopted such a policy to reveal information of environmental impact regarding a product or service [6]. Such scheme is intended to help consumers be conscious of climate change, to change their purchasing behaviors [7]. Consumer pro-environmental purchasing behavior is an important factor to promote decarbonization [8]. Over 80% of online surveyed consumers from eight countries admitted that they support carbon labeling policy as a useful tool to mitigate climate change [9]. Recent surveys further identified that consumers prefer purchasing carbon labeled products, and they are willing to

pay a premium of up to 20% of the original price [10]. However, purchasing behavior is a complex decision-making process, which may differ significantly from gender, age, education, and income level, to result in unintended consequences on market demand of carbon labeled products [7,11,12]. Whether the carbon labeling scheme triggers consumers to take pro-environmental purchasing actions lays room for future studies.

In addition, carbon labeling is a voluntary behavior for enterprises or organizations [13]. One of the main motivations about carbon labeling regards marketing strategies, but carbon labeling may enhance consumption behavior towards environmental sustainability. Although such a scheme provides an opportunity to take a holistic carbon accounting on product supply chain and improve its green performance, there is a lack of sufficient incentives to drive its implementation [14]. Since most of the enterprises are driven by profitable motivation, they may be unwilling to attempt carbon labeling due to cost and benefit consideration, including the certification cost, market risk, governmental policy orientation, etc. [15,16]. For instance, China currently has not put a carbon labeling policy into wide practice, which exerts limited influences on market prospect [11,17].

In such context, it is implied that the carbon labeling scheme is still in dispute. A comprehensive review regarding its progress is essential, through which the research hotspots can be identified to lay out foundation for future study. Common literature review is based upon deliberate screening, which may not fully address the advances in a specific research area [18]. This study provides a holistic review on the research progress of carbon labeling schemes in the period 2007–2019 by using a bibliometric analysis. A number of selected indicators, e.g., number of publications, countries, authors, institutions, highly cited papers, and keywords have been incorporated into the analysis to highlight the research hotspots. Moreover, CiteSpace software package is employed to visualize the structures and connections in the retrieved scientific literatures [19]. The scope of this work is to define a comprehensive and holistic review on the development of carbon labeling schemes, through which research hotspots can be identified to lay out a foundation for future study. It is expected that this study may provide insight into the future development of carbon labeling schemes. The specific contributions of this study are: providing an alternative approach to review the research progress of carbon labeling based on bibliometrics, identifying the research trends through an analysis of descriptive statistics on the bibliometric indicators, laying out a foundation for future development of carbon labeling schemes.

The rest of the paper is given as follows: Section 2 introduces the data sources and method for data cleaning, Section 3 presents the results regarding bibliometric indicators, including number of publications, countries, subject categories, published journals, distribution of institution, highly cited papers, and keywords. Section 4 summarizes the paper, discusses the challenges towards carbon labeling schemes, and presents implications.

2. Data and Methods

The literature data were obtained by a predefined information retrieval from the Web of Science (WOS) Core Collection database in the period of 2007–2019, specifically from the sub-databases of Science Citation Index Expanded, Social Sciences Citation Index, and Arts and Humanities Citation Index. The predefined entries were wet based upon the “carbon label*” and the highlighted words in its associated definition, e.g., environmental impact, life cycle assessment, product, service, etc. There were 2016 records at the retrieval time 14/5/2020, and their document types were confined to Article or Review in English, as shown in Table 1. However, most of the publications focus on analytical chemistry, physical chemistry, biochemistry molecular biology, microbiology, etc., which are apparently not conform to the research topic. After removal of the duplicated and irrelevant publications, there were 175 articles finally identified for further bibliometric analysis.

The retrieval results were performed by descriptive statistics corresponding to a set of bibliometric indicators, such as number of publications, country, category, journal, institution, authors, highly cited papers, and keywords, to investigate the attentions to the carbon label related studies. Specifically, Microsoft Excel and bibliometric online analysis platforms were applied to implement the statistical

analysis. The values corresponding to journal impact factors were from Journal Citation Reports in 2018. CiteSpace software package was used to visualize the underlying connections among keywords by generation of a co-occurrence network.

Table 1. Criteria for literature data retrieval.

Set	Results	Search Criteria
#6	2016	(#5 OR #4 OR #3 OR #2 OR #1) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article OR Review) Indexes=SCI-EXPANDED, SSCI, A&HCI TIMESPAN=2007-2019
#5	210	(TS=(carbon label*) AND TS=(environmental impact)) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article OR Review) Indexes=SCI-EXPANDED, SSCI, A&HCI TIMESPAN=2007-2019
#4	378	(TS=(carbon label*) AND TS=(consume*)) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article OR Review) Indexes=SCI-EXPANDED, SSCI, A&HCI TIMESPAN=2007-2019
#3	68	(TS=(carbon label*) AND TS=(life cycle assessment)) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article OR Review) Indexes=SCI-EXPANDED, SSCI, A&HCI TIMESPAN=2007-2019
#2	68	(TS=(carbon label*) AND TS=(service)) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article OR Review) Indexes=SCI-EXPANDED, SSCI, A&HCI TIMESPAN=2007-2019
#1	1601	(TS=(carbon label*) AND TS=(product)) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article OR Review) Indexes=SCI-EXPANDED, SSCI, A&HCI TIMESPAN=2007-2019

3. Results

3.1. Number of Publications

As shown in Figure 1, there were 175 publications in the period of 2007–2009 with a gradual increase. Particularly, there was a peak in 2016. Less than five papers published annually during the period of 2007 to 2009, which highlighted the infancy of carbon labeling scheme, as it was firstly issued by UK in 2006. From 2009 to 2011, the number of publications increased rapidly. During 2011–2013, it had remained unchanged as 10 publications annually. From 2014, the growth was significant towards a peak in 2016, which had an increase of 15.5 times comparing with the publications in 2007. A possible reason might be that the Paris Climate Agreement drives structural transformation of the global carbon markets, which calls for effective market-based policy tools, e.g. carbon labeling schemes, eco-labeling schemes, carbon trade mechanisms, to promote emissions reduction and energy transformation [20–22]. Since 2017, the number of publications had decreased to 20 and remained at a slow growth until 2019.

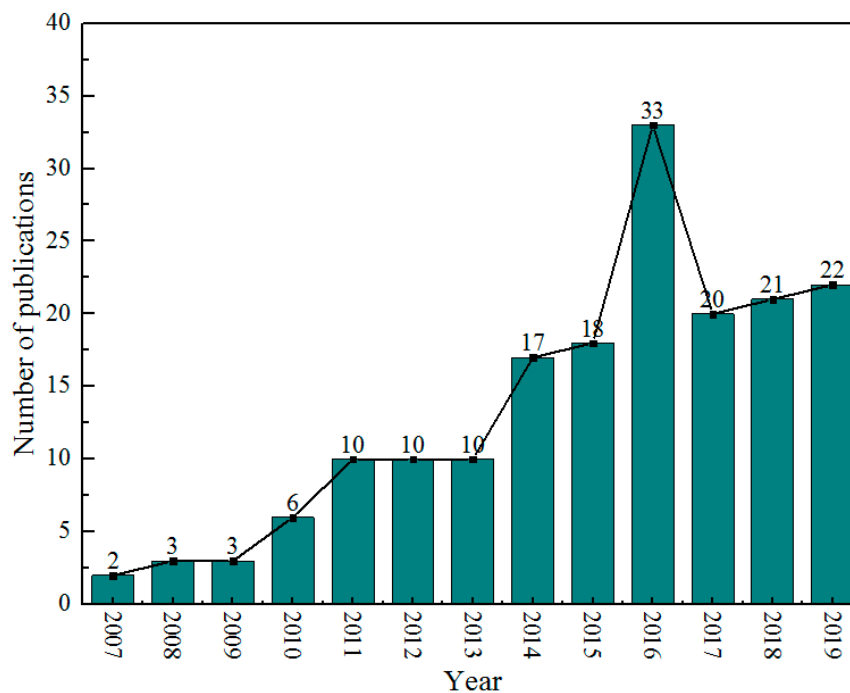


Figure 1. Output of publications during 2007–2019.

3.2. Countries of Publications

A total of 43 countries have contributed articles in carbon labeling related research areas. Table 2 shows the top 10 countries in terms of their publications during 2007–2019. It is apparent that U.S. ranks first, China as second, followed by UK, Germany, Australia, and Italy. In particular, European Union (EU) countries contributed most of the publications, indicating a regional spillover effect due to their close collaborations in economics and politics.

Table 2. Top 10 countries with the most published articles from 2007 to 2019.

Country	Centrality	TP	Percentage (%)
USA	0.98	41	23.43
China	0.21	27	15.43
UK	0.38	23	13.14
Germany	0.19	16	9.14
Australia	0.19	14	8.00
Italy	0.92	13	7.43
Netherland	0.70	10	5.71
Sweden	0.08	10	5.71
France	0.61	9	5.14
South Korea	0.82	7	4.00

TP: total publications.

Figure 2 shows the variation of publications regarding the top five countries, where there is a peak occurred between 2015 and 2018. United Kingdom and United States are the pioneers of carbon labeling schemes and have been involved in such studies for 12 years, indicating a remarkable spillover effect in policy design on low-carbon consumption and production. Carbon label related studies were still in progress in developing entities, e.g., China engaged in such issues until 2012. However, China makes great contribution in low-carbon development due to great pressure on its energy structure [23]. In such context, China calls for such a labeling system to change the consumption patterns while upgrading the supply chain to further improve product/service quality [24].

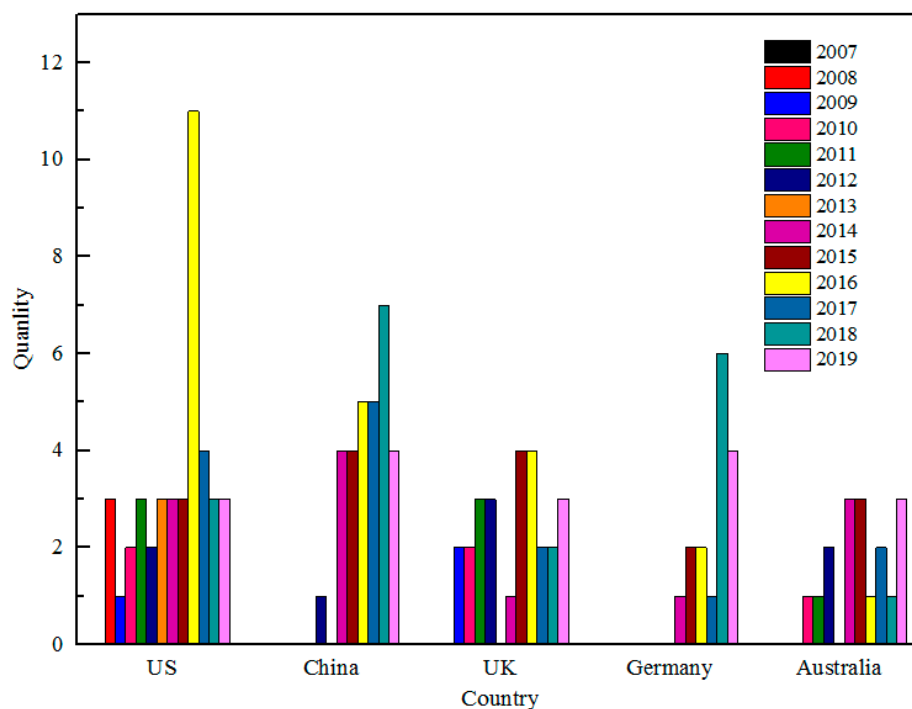


Figure 2. Number of publications regard the top five countries.

The national collaboration provides a new perspective to assess the academic impact of countries in carbon label related studies. Figure 3 shows the network of national collaboration, in which each country is denoted by a circle. The size of the circle represents the frequency of collaboration. The higher the frequency, the larger the circle. The thickness of the purple circle represents the centrality. The higher the centrality, the thicker the purple circle. The centrality is used to indicate the international status of a country in the carbon labeled studies. The US has the largest degree of centrality (0.98), implying a comparative high international influence in this research field. Italy, in spite of only 13 articles being published, its centrality ranks the second (0.92), indicating great potential in development of international cooperation. For instance, there were at least two authors from other countries in these 13 published papers. China, whilst ranked as the second in the number of publications, its centrality was relatively low, which further required reinforcement of international cooperation to share the research findings.

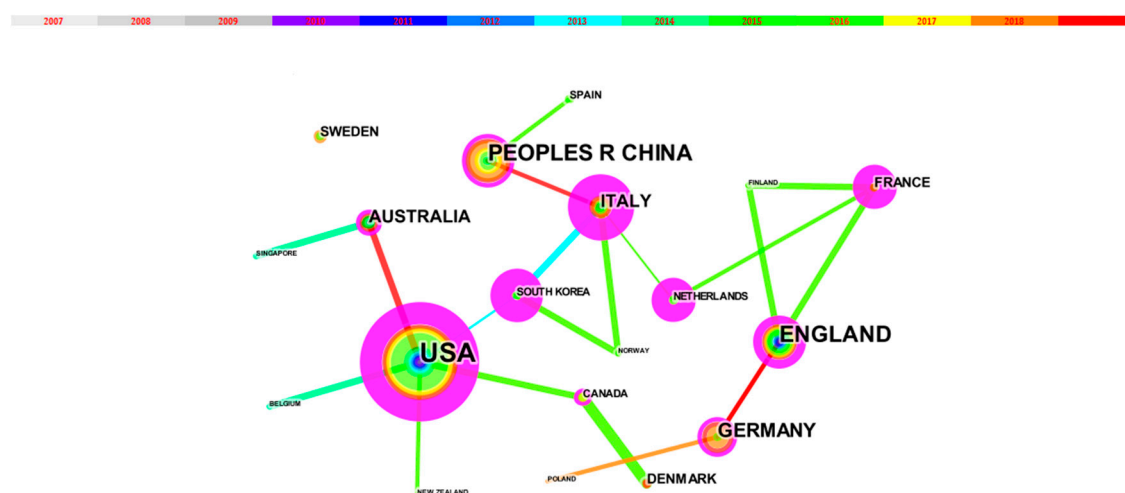


Figure 3. National cooperation network.

3.3. Subject Categories and Published Journals

There are wide topics involved in the studies of carbon labeling schemes during the period 2007–2019, which are subject to 44 categories. Figure 4 shows the top 10 categories, and the most common category is “Environmental Sciences”, accounting for 23.1%. The subject categories are mainly related to environment, economy, food, and business, which demonstrate that carbon labeling related studies have a multidisciplinary field.

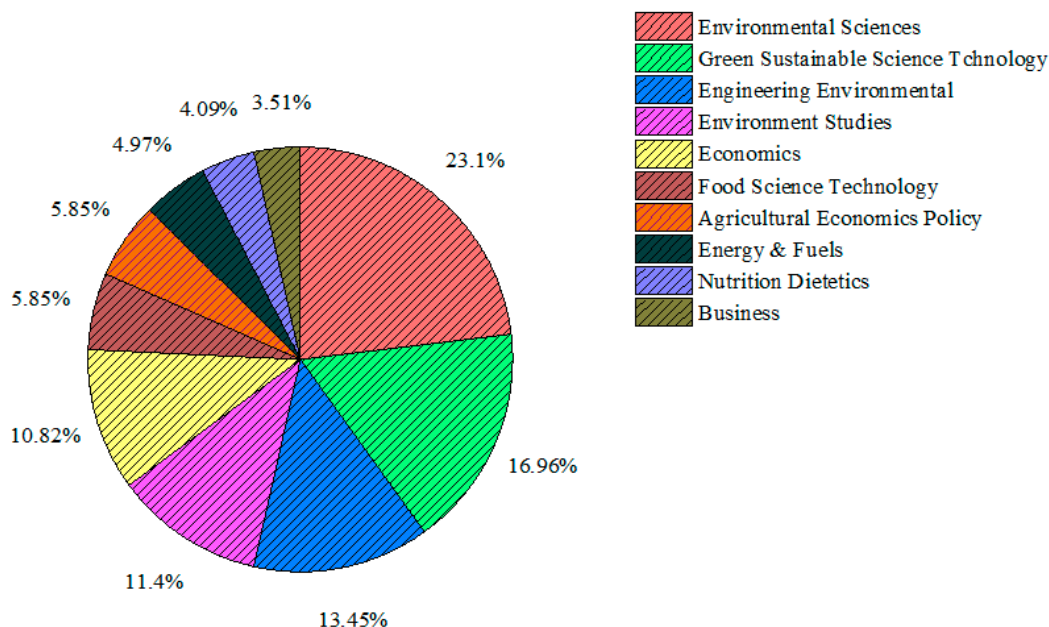


Figure 4. Top 10 subject categories.

Carbon label related studies were published in 85 journals. Table 3 shows the top 10 journals, where 86 articles are published, accounting for 49.14%. Most of the journals were from the publisher Elsevier. The *Journal of Cleaner Production* is highlighted by both of the maximum publications and the total citations. The *Journal of Renewable and Sustainable Energy Reviews* has the highest impact factor, and the *Journal of Food Policy* has the highest average number of citations.

Table 3. Top 10 journals with the most published articles.

Journals	IF(2018)	EP	Percentage (%)	TC	ACP
<i>Journal of Cleaner Production</i>	6.395	37	21.14	149	4.03
<i>Food Policy</i>	3.788	10	5.71	91	9.10
<i>Sustainability</i>	2.592	10	5.71	1	0.10
<i>Energy Policy</i>	4.880	6	3.43	3	0.50
<i>International Journal of Life Cycle Assessment</i>	4.868	5	2.86	7	1.40
<i>British Food Journal</i>	1.717	4	2.29	24	6.00
<i>Appetite</i>	3.501	4	2.29	19	4.75
<i>Renewable & Sustainable Energy Reviews</i>	10.556	4	2.29	14	3.50
<i>Environmental Science & Policy</i>	4.816	3	1.71	26	8.67
<i>Energy Economics</i>	4.151	3	1.71	21	7.00

EP: entire publications, TC: total citations, ACP: average citation per paper.

3.4. Distribution of Institutions

Table 4 shows the top five institutions ranked by their affiliated first author’s publications. There were 287 institutions involved in the carbon label related studies during 2007–2019. Southwest Jiaotong University was identified as the institution where most of the publications contributed, followed

by Central Queensland University, Swedish University of Agricultural Sciences, Eidgenössische Technische Hochschule Zürich (ETH), and Korea University. Southwest Jiaotong University published six papers in the area, where it mainly focused on application of system dynamics and game theory to investigate the interaction among consumer, enterprises, and government in implementation of the carbon labeling scheme to provide insightful policy implications on sustainable consumption and production [25,26]. Central Queensland University proposed carbon labeling scheme as an indicator to reflect the environmental impact of building materials in order to promote green design [27,28]. Swedish University of Agricultural Sciences was ranked as the fourth, where they paid close attention to measurement of uncertainties in carbon labelled food product [29,30]. ETH and Korea University gave emphasis on consumers' preferences and willingness to pay for carbon labeled products, by which the possible influencing factors were explored [31–33].

Table 4. Institutions with the most publications.

Institution	Country	TP
Southwest Jiaotong University	China	6
Central Queensland University	Australia	4
Swedish University of Agricultural Sciences	Sweden	4
Eidgenössische Technische Hochschule Zürich	Switzerland	4
Korea University	Korea	3

TP: total publications.

3.5. Highly Cited Papers

The top 10 highly cited papers in the field of carbon labeling schemes during the period 2007–2019 are given in Table 5. These papers were distributed in seven journals, and three of the highly cited papers were published on *Journal of Food Policy*. The article published by Grunert et al. [34] was ranked the first with 267 citations. In these highly cited papers, some focused on comparing utilities of various sustainable labeling schemes, including carbon, environmental, and ethical labels [31,35]. Most of the citations related to these highly cited papers were mainly from methodological perspectives, focusing on public attitudes towards organic foods, by means of choice experiments, structured interviews, and questionnaire survey [36,37]. The co-citations were highlighted by exploration of consumer preferences and willingness to pay for organic foods by using Schwartz's value theory combined with the planned behavior theory [38,39]. However, several studies firmly believed that carbon labels may provide a signal to help consumers change their purchasing behaviors if they can fully understand the associated labeling information [40,41]. In such context, Rugani et al. [42] argued if the underlying method for carbon labeling, i.e., the life cycle assessment, could be improved to be more transparency. In summary, these highly cited papers had addressed the challenges in application of carbon labeling schemes, to lay out a foundation for their future development.

3.6. Keywords

Keywords can be used to reflect the hotspots and topics of research interest in a certain time period [18]. CiteSpace software package was employed to produce a keywords co-occurrence network [43]. In such a process, a number of synonymous keywords were sorted by merging, such as "Carbon label" and "Carbon labeling", "greenhouse gas" and "GHG", "life cycle assessment" and "LCA", etc. Table 6 shows the frequency regarding the keywords occurred during 2007 to 2019. There were 98 keywords obtained, among which 22 keywords appeared above 10 times. During the time period of retrieval, "carbon footprint", "willingness to pay", and "food", were the top three keywords, indicating that surveys on consumer attitudes towards carbon labeled products had aroused widely academic concerns in the past 12 years.

Table 5. Top 10 cited papers.

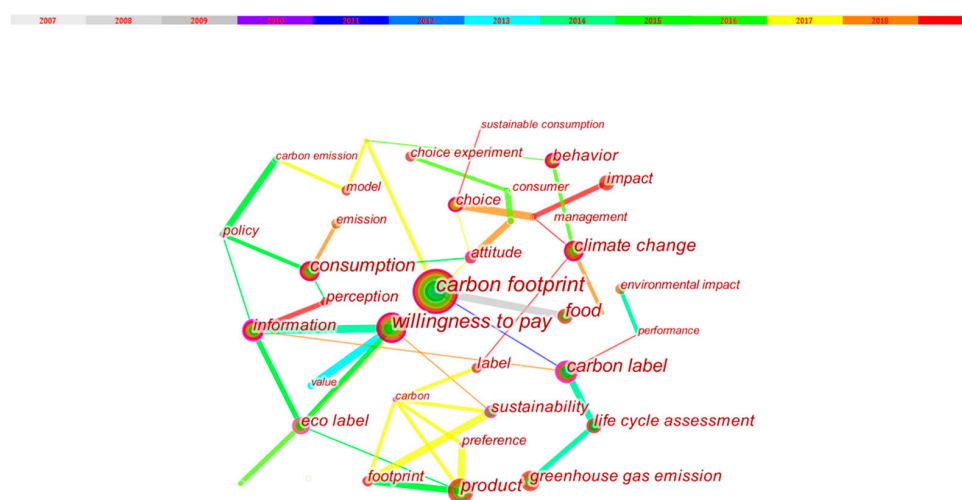
Title	Author	Country and Institution	Journal and Year	TC	ACP
Sustainability labels on food products: Consumer motivation, understanding and use	Grunert, K.G.; Hieke, S; Wills, J.	Denmark, Aarhus University	<i>Food Policy</i> (2014)	267	44.50
Does local labeling complement or compete with other sustainable labels? A conjoint analysis of direct and joint values for fresh produce claim	Onozaka, Y.; McFadden, D.T.	Norway, University Stavanger	<i>American Journal of Agricultural Economics</i> (2011)	144	16.00
the use and usefulness of carbon labeling food: A policy perspective from a survey of UK supermarket shoppers	Gadema, Z.; Oglethorpe, D.	England, Northumbria University	<i>Food Policy</i> (2011)	112	12.44
Carbon labeling of grocery products: public perceptions and potential emissions reductions	Upham, P.; Dendler, L.; Bleda, M.	England, University Manchester	<i>Journal of Cleaner Production</i> (2011)	108	12.00
Consumers' valuation of sustainability labels on meat	Van Loo, E.J.; Caputo, V.; Nayga, R.M.; Verbeke, W.	South Korea, Korea University	<i>Food Policy</i> (2014)	85	14.17
Product-level carbon auditing of supply chains Environmental imperative or wasteful distraction?	McKinnon, A.C.	Scotland, Heriot Watt University	<i>International Journal of Physical Distribution & Logistics Management</i> (2010)	68	6.80
The potential role of carbon labeling in a green economy	Cohen, M.A.; Vandenberg, M.P.	USA, Vanderbilt University	<i>Energy Economics</i> (2012)	67	8.38
Finnish consumer perceptions of carbon footprints and carbon labeling of food products	Hartikainen, H.; Roininen, T.; Katajajuuri, K.M.; Pulkkinen, H.	Finland, MTT Agrifood Research Finland	<i>Journal of Cleaner Production</i> (2014)	64	10.67
Vulnerability of exporting nations to the development of a carbon label in the United Kingdom	Edwards-Jones, G.; Plassmann, K.; York, E.H.; Hounsome, B.; Jones, D.L.; Canals, L.	Wales, Bangor University	<i>Environmental Science & Policy</i> (2009)	64	5.82
Challenges of carbon labeling of food products: a consumer research perspective	Roos, E.; Tjarnemo, H.	Sweden, Swedish University of Agricultural Sciences	<i>British Food Journal</i> (2011)	51	5.67

TC: total citations, ACP: average citation per paper.

Table 6. Descriptive statistics of the keywords.

Keywords	Count	Centrality	Percentage (%)
Carbon footprint	50	0.18	7.72
Willingness to pay	37	0.18	5.38
Food	28	0.03	4.07
Carbon label	26	0.38	3.78
Consumption	26	0.20	3.78
Product	24	0.07	3.49
Climate change	21	0.10	3.05
Information	20	0.32	2.91
Behavior	18	0.13	2.62
Greenhouse gas emission	18	0.04	2.62
Life cycle assessment	17	0.19	2.47
Eco label	16	0.21	2.33
Sustainability	16	0.23	2.33
Impact	15	0.06	2.18
Choice	14	0.12	2.03
Footprint	14	0.12	2.03
Perception	14	0.05	2.03
Attitude	13	0.20	1.89
Label	13	0.03	1.89
Choice experiment	12	0.08	1.74
Preference	11	0.10	1.60
Policy	10	0.14	1.45

Figure 5 shows the keywords co-occurrence network. The size of the circle represents the occurrence frequency. The lines between the nodes denote their connections. The thicker the lines, the stronger the connection. The lines between nodes are bright in color, indicating that there are a number of research hotspots derived in recent years. The largest circle is “carbon footprint”, by which “carbon label,” “willingness to pay,” “food,” and “attitude” are closed linked. The node with the highest centrality is “carbon label”, by which there are six nodes connected, including “carbon footprint,” “information,” “life cycle assessment,” “performance,” etc. Such phenomenon may imply that life cycle-based assessment is fundamental to the performance of carbon labeling schemes, through which various forms of carbon footprint information is provided. Besides, consumer behavior towards a carbon labeling scheme is full of academic research interests. Consumers are receptors of carbon labeled products or services, and their purchase intentions are critical to implementation of the labeling policy [11,44].

**Figure 5.** Keywords co-occurrence network.

Keywords clustering was conducted to identify the research frontiers of carbon label related studies. There were seven clusters identified, and their corresponding silhouette values were above 0.7 (if above 0.5, the cluster is considered to be reasonable), as shown in Figure 6. The largest cluster (#0) was entitled “categorisation task”, which put emphasis on application of classification to ensure reliable comparisons among similar products with different carbon emissions. The second cluster (#1), was given as “uncertainty analysis”, focusing on uncertainty regarding carbon footprint assessment. The third cluster (#2), as “carbon footprint label”, mainly paid attention to its relative performance, e.g., the environmental impact, energy efficiency etc. The cluster (#3), as “climate change”, indicating public awareness of the implication of carbon labeling scheme.

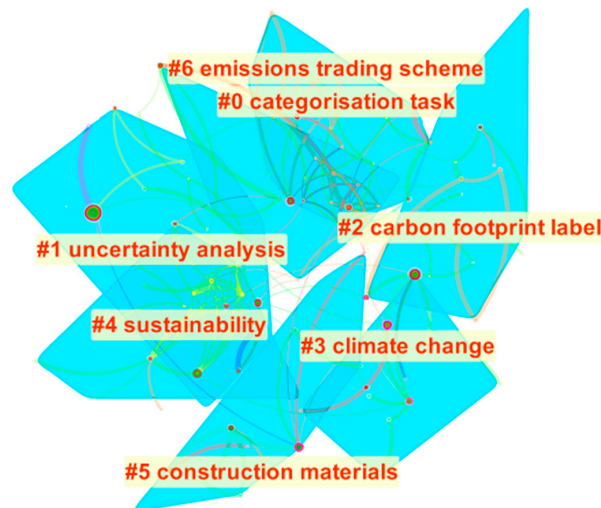


Figure 6. Clusters of carbon label studies related keywords.

Burst detection was used to determine if any change occurred at the research hotspots [45]. The bursting words refer to the keywords that have suddenly emerged or increased significantly in a short period of time, which may provide insight into identification of future research interests [46]. It is detected by an algorithm proposed by Kleinberg (2002), which generates a list of important words in terms of their frequencies in a finite duration of time [45]. The frequency of the word changes implies possible state transition, indicating as burst [47].

In Figure 7, the red rectangle indicates the strongest bursts, since the corresponding keywords have multiple occurrences in the specific time nodes. “Strength” shown in Figure 7, indicates the bursting words that have been mentioned frequently than any other words in a specific time period [19]. There are 15 keywords with apparent bursts in this study. Such phenomenon implies that the carbon labeling studies have been distinguished by three stages: first from 2007 to 2012, as the carbon labeling scheme was in its infancy, and the burst keywords mainly contained carbon footprint, carbon label, carbon emission, food, and energy. In particular, the labeling policy was gradually extended to the household equipment and construction industry to evaluate its energy efficiency. The second stage was from 2013 to 2015, where the keywords were booming, with life cycle assessment, eco label, food consumption, and market contained. In this stage, studies preferred the utility of the labeling policy and its possible impact on production, trade, and export. For instance, the carbon labeling schemes were compared with other eco-labels to highlight the impact on the development of trade and economy [48]. In the third stage (2016–2019), studies placed emphasis on individuals’ behavior towards carbon labeled product or service by conducting surveys to investigate their perception, preference, and willingness to pay, indicating that they were interests of topics in the carbon label studies [49–52]. At the same time, multi-stakeholders’ interaction was gradually involved in the carbon label relevant researches [53]. The application of a carbon labeling scheme was gradually transformed from product to service, e.g., tourism. Carbon labeling may affect the behavior of tourists who purchases low-carbon

tourism services, though tourists may have pro-environmental intent or not, as well as may display environmentally sustainable behavior or not [54].

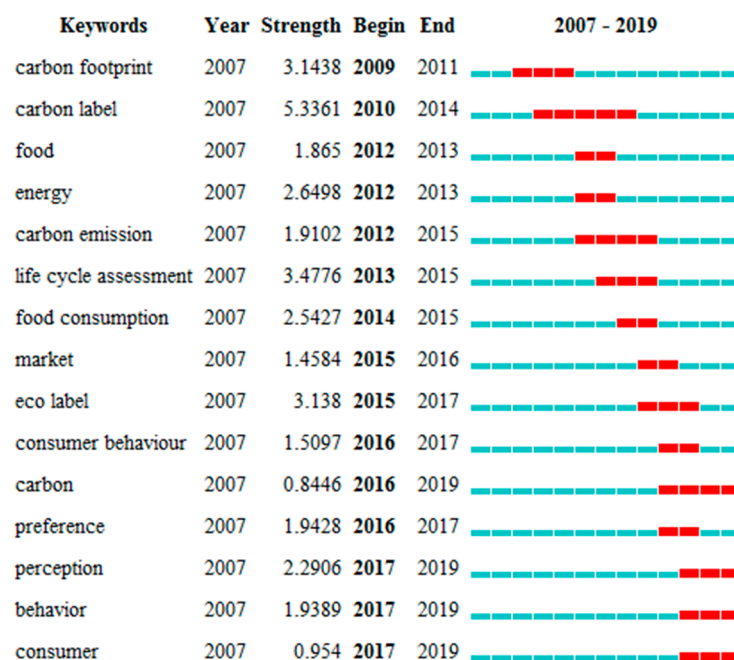


Figure 7. Top 15 Keywords ranked by burst detection.

4. Discussion and Insights

4.1. Discussion

This study highlights the necessity to make clearer the carbon labeling information and introduces a multiple-perspective co-citation analysis for interpreting co-citation cluster dynamics. Moreover, unlike other studies, the research visualizes a geographical as well as a multidisciplinary importance of carbon labeling schemes. The study underlines the novelty of a co-occurrence network among environments, economies, food, and businesses analyzed in different countries within the environmental science scenario. The research turns to improving network visualization to help consumers better understand the utility of labeling scheme.

The development of research hotspots of carbon labeling schemes has been characterized by the alteration of keywords during the time period 2007–2019. The alterations of keywords show that research aims were changing from carbon labeling as a marketing tool to consumption behavior and attitudes helpful for environmental policies. In recent years, academic circles have focused on consumption behavior in order to understand carbon labelling impact.

The study manages a bibliometric analysis with CiteSpace, which visualizes the evolution trend of carbon labeling scheme. The paper presents an upgrading of the pre-existing literature review, which stopped in 2016 [23]. From 2016 to 2019, scientific research paid more attention to consumer behavior, preference, and attitude towards carbon labeling. The keywords co-occurrence network highlights a linkage between life cycle assessment and carbon labeling, mainly for food and energy, showing academia's interest about willingness to pay, life cycle assessment, and carbon labeling. Furthermore, there is a strong connection between consumer attitude and consumption choice as well as sustainability label and eco-label. The burst detection highlighted that the investigation of consumer behavior was a topic of interest in the carbon labeling related research field.

Unlike previous studies, the paper takes into consideration countries, such as the U.S., China, and Italy. The literature on carbon labeling schemes coming from China highlights a renewed interest in this issue. China focuses on application of system dynamics investigating the interaction among

consumers, enterprises, and governments in implementation of carbon labeling [25,26]. In the future, China might improve its carbon labeling policy and put it into wide practice, influencing market prospect, and providing insightful policy implications on sustainable consumption and production.

4.2. Insights

Though the analytic review on the 175 carbon label related articles, three main challenges have been identified to lay out foundations for future studies. First, precise accounting for carbon emissions is a prerequisite for the labeling practice [29]. Carbon label is also an entitled carbon footprint label, since most of the carbon labels are presented in a footprint form [6]. As implied in the definition of carbon label, lifecycle-based carbon footprinting is a cornerstone to support the presentation of a carbon labeling scheme [55]. However, the system boundary for a specific product or service is difficult to define, which may cause uncertainty in expression of the accounting results; thus, decreasing credibility of the labeling scheme [28]. For instance, existing studies have shown that the carbon footprint of crops are varied by place of production, due to the different system boundary for lifecycle accounting, giving rise to uncertainty in food carbon labeling practice [30]. Such inconsistency may give rise to the same product that has significantly different numerical values labeled on its package [56]. It, thus, calls for improvement of carbon footprint assessment to ensure fair comparison among similar products or services. Besides, a functional unit is generally followed by the life cycle assessment, which limits comparability among various types of products [29]. There is a call for standardized methods to normalize the carbon footprint (regarding products or services) into a common scale, in order to improve the comparability of various labeling schemes [57].

The second issue with the labeling practice is the poor communication with consumers. A number of studies have identified that consumers are confused by the labeling information, even though they are willing to pay certain premium for carbon labeled product or service [58,59]. In such context, research turns to improving visualization to help consumers better understand the utility of labeling scheme. For example, a traffic light colored system was proposed to indicate intensity of product carbon footprint by using the normalization method [60,61]. Whether such form of label suggested is effective in enhancing communication still needs further validation. Moreover, it is worth noting that consumers may be irrational regarding environmental concerns [62]. Conventional research methods, including questionnaires, focus groups, in-depth interviews, etc., have been widely employed to explore consumer perception and willingness to pay for carbon labeled products [63]. However, they may be limited by capturing responses based on consciousness [64,65]. Neuroscience is insightful to identify the conscious and subconscious responses; thus, to discriminate social consciousness and actual behaviors [66,67]. Such a tool has potentials to investigate consumer behavior towards different forms of labeling presentation.

The third issue is the labeling policy overlapping. Taking food as an example, there are a number of labels presented on its package, such as information regarding organic, food miles, animal welfare, and carbon footprint [68]. Various labels not only add complexity in the packaging design, but also give rise to the issues with respect to information credibility and reliability, even resulting in more confusion when consumers purchase products. Thus, the integration of various labeling policies is essential to ensure information coverage and improve labeling form of presentation [48,69]

5. Conclusion and Implications

This study reviews carbon label related studies in the period of 2007–2019 based on a bibliometric analysis. The number of publications, the countries of publications, the categories, the journals, the authors, the institutions, and the highly cited papers are investigated to have a holistic view on the research progress regarding carbon labeling scheme. There are 175 publications identified in the defined period, which presents an increase trend. The publications cover 44 categories and 85 journals. “Environmental Sciences” is the key subject category, and “*Journal of Cleaner Production*” is the journal

with the most publications. 287 institutions have contributed to this research area. U.S. ranks the first in the number of publications, followed by China, UK, Germany, Australia, and Italy.

The study investigates the research progress of carbon labeling schemes, to provide insight into its future development. The outcomes confirm the necessity to optimize life-cycle assessment for carbon labeling schemes as well as the importance of labeling for better visualization. Moreover, the study gives support to the importance of improving carbon labeling schemes to help consumers change their purchasing behaviors.

Some considerations about the implications of this study are introduced. The first regards the cooperation between developing countries and developed countries. Spillover effects may accelerate carbon labeling scheme implementation. Developed countries may transfer experiences, good practices to developing countries to ameliorate carbon-labeling schemes, so as to standardize the schemes internationally. Carbon labels, in particular, and eco-labels, in general, represent a private governance and may enhance compliance. The standardization of the carbon labeling scheme at an international level may be useful to define a limit for the number of categories, as well as for the variety of labels that sometimes overlap each other [6].

The second implication takes into consideration the consumers and their motivation. It is necessary to define strategies to motivate consumers towards decreasing GHG emissions, and facilitate the knowledge of the labeling meanings. At this purpose, green education programs should be defined, involving both consumers and entrepreneurs, as well as eco-advertising, which, using, for instance, social media, encourage people to purchase environmentally friendly products and services.

The third implication concerns the use of new business models and technologies. The use of eco-branding, such as names and symbols, to distinguish environmentally friendly businesses from environmentally unfriendly competitors. The adoption of carbon-branding implements sustainable business practices leading to a reduction of costs, enhancing corporate social responsibility, attracting new markets, and obtaining higher prices [11]. Technologies, e.g., blockchain, which is a public digitalized ledger, may be used in the carbon labeling process to create more transparency and trust in the relationship between customers and sellers (concerning environmentally friendly purchasing).

There is a connection between carbon labeling schemes and life cycle assessment. Future research, thus, would be the optimization of life cycle assessment for labeling accreditation, improvement of labeling visualization for better expression, and normalization of various environmental labels to promote sustainable consumption. How to implement carbon label standards, as well as homogenizing carbon labeling schemes among different countries should be investigated to provide insightful policy implications on sustainable consumption and production. Moreover, future studies may observe that carbon labeling schemes trigger consumers to take pro-environmental purchasing actions. In such cases, the research might deeply analyze the linkages between consumers and enterprises, as well as between enterprises and governments, to implement carbon labeling schemes.

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