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A Multi-Criteria Approach for Quantifying the Impact of Global Megatrends on the Pulp and Paper Industry: Insights into Digitalization, Social Behavior Change, and Sustainability

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Abstract: *Background:* The pulp and paper industry (P&PI) is undergoing significant disruption driven by global megatrends that necessitate advanced tools for predicting future behavior and adapting strategies accordingly. *Methods:* This work utilizes a multi-criteria framework to quantify the effects of digitalization, changes in social behavior, and sustainability as three major megatrends transforming the P&PI industry, with a specific focus on hygiene tissue products. Thus, the research combines a comprehensive literature review, insights from a Delphi study, and topic modeling to qualitatively and quantitatively assess the present and future impacts of these global megatrends. *Results:* The findings suggest an urgent need to identify alternative raw materials to prevent potential supply chain disruptions. Moreover, due to shifts in social behavior, it becomes critical for businesses to substantiate their sustainability claims with hard data to avoid the risk of a “greenwashing” perception among consumers. *Conclusions:* This study provides decision support for strategic planning by highlighting actionable insights, quantitative predictions, and trend analysis, alongside the examination of consumer and market trends. It aims to incorporate diverse stakeholder perspectives and criteria into decision-making processes, thereby enriching the strategic planning and sustainability efforts within the P&PI industry.

Keywords: pulp and paper industry; global megatrends; digitalization; social behavior; sustainability; Delphi study; topic modeling

1. Introduction

Megatrends can be defined as large-scale, transformative, and long-term shifts that affect various aspects of our lives, including society, economy, culture, and technology [1]. Two examples of significant global disruptions are the Ukraine war and the COVID-19 pandemic, both of which have profound and wide-reaching effects on global stability. The Ukraine war brings about effects such as trade and economic sanctions, affecting not only the local economies but also the global market by increasing the cost of energy. This, in turn, affects the cost of transportation and leads to supply chain disruptions across all sectors [2]. The COVID-19 pandemic has distinguished itself as one of the most far-reaching trends, impacting health, economics, and social structures. High mortality and morbidity

rates led to the global collapse of healthcare systems, affecting all aspects of life, including the increasing demand and shortages of hygiene tissue products. It has also resulted in lockdowns, travel restrictions, and changes in consumer lifestyles and behavior, leading to an increase in electronic purchasing [3] and consequently, the production of secondary packaging for product delivery [4].

Although megatrends have been popularized since 1982, they are inherently complex in nature, without consensus on how they are defined and developed [5]. This research focuses on three specific megatrends affecting the hygiene tissue industry:

- The digitalization megatrend refers to the integration and advancement of digital technologies that shape a new reality in which information, communication, and transactions take place digitally [6].
- The changes in social behavior megatrend reflects the evolving societal norms and attitudes that influence how people engage, consume, and interact with products and services (in the context of consumers) in an ever-changing global landscape [7].
- The sustainability megatrend involves global efforts to preserve the environment, achieve social equity, and ensure economic prosperity for current and future generations [8].

As sustainability concerns continue to increase globally, people's behavior is shifting towards greater health consciousness and environmental awareness [9], thereby driving up the demand for eco-friendly products [10]. Sustainability, along with digitalization, rapid urbanization, and social changes, among others [11], are global megatrends pressing industries to change and adapt to current and future challenges [12,13]. Demographic reports indicate that, as of 2023, more than half of the U.S. population comprises younger generations, including millennials, Gen Z, and Gen Alpha [14]. These generations tend to be more sustainability-focused consumers, favoring products and services labeled as sustainable or eco-friendly and supporting companies that promote environmental and social change [15]. Consequently, as the proportion of younger and sustainability-conscious generations is projected to reach 64% by 2030 [16], industries must prepare for a growing demand for sustainable products in the coming years.

Sustainability, as a megatrend, has driven changes in the business models of global industries to focus more on environmental and social impact improvements to align with consumer expectations toward more sustainable practices [17]. This megatrend has also offered some opportunities for differentiation and additional revenues, as some consumers are willing to pay a premium for socially responsible products and services, yielding synergistic benefits in the stock valuation of companies that adhere to social and environmental policies [18].

The pulp and paper industry (P&PI), focused on manufacturing fiber-based products such as packaging and hygiene tissue, among others, is not an exception in regards to this phenomenon [19]. Particularly, the hygiene tissue sector, which includes popular consumer goods like toilet paper, paper towels, napkins, and facial tissue, is forecasted to see a 3% annual revenue growth from 2021 to 2026, both in the U.S. [20] and globally [21]. Companies within this industry are intensively working to overcome significant controversies concerning the sustainability aspects of their products [22]. These aspects include deforestation, utilization of virgin wood fibers, and their single-use, as well as high water and energy consumption, among others [23,24]. In response to these challenges, companies are making efforts to decrease their carbon footprint, improve perceived sustainability, and meet consumer expectations [25,26].

Simultaneously, the trend "from paper to paperless", as part of the digitalization megatrend, is severely affecting the hygiene tissue industry [27]. This shift has prompted people to cut down on paper usage, limiting printing to essential items only [28], leading to a noticeable reduction in the production of printing and writing paper [29]. As the production of these commodities decreases, there is a corresponding decrease in the availability of recovered paper (RCP). In the U.S. alone, one-third of hygiene tissue is produced from recovered paper (RCP), such as recycled printing and writing paper. As another

reference, RCP constitutes around 93% of the raw material for the hygiene tissue industry in Mexico. Consequently, digitalization is causing a significant decrease in the generation of traditionally used recycled fibers, resulting in a shortage in the supply of these raw materials for hygiene tissue production [30,31].

Multi-criteria decision making (MCDM) has emerged as a crucial analytical tool in various sectors, facilitating the ability of organizations to evaluate and prioritize options that involve conflicting criteria [32]. Its utilization spans from healthcare, assisting in optimizing resource allocation and treatment decisions, to energy, where it supports the strategic development of renewable energy projects and policy decisions [33,34]. However, its application within the P&PI is limited [35], as only six published articles were found regarding its use in this field, and these are summarized below.

Singh et al. (2022) devised a novel genetic algorithm-enhanced rank aggregation model within a hybrid multi-criteria decision making (MCDM) framework to assess India's pulp and paper industries. Using data from annual reports, numerical criteria were derived with expert guidance. By applying various methods such as MOORA, COPRAS, TOPSIS, VIKOR, TODIM, SAW, and GRA, the model produced consistent and accurate results. This versatile approach supports decision making in diverse contexts, including location selection and addressing environmental sustainability in the face of global warming challenges. The study provides valuable insights for policymakers in shaping pollution regulation norms for a sustainable business environment [36].

Darestani, Palizban, and Imannezhad (2020) propose an MCDM-based approach for selecting maintenance strategies in the paper production industry. Through extensive literature review and insights from industry experts, all maintenance factors were identified as criteria. The best-worst method (BWM) was used to prioritize factors, followed by TOPSIS method application. High-priority criteria in cost (C) and added value (A) dimensions should be prioritized for maintenance strategy implementation, ensuring stable company success and development. The authors suggest localizing this model in all factory departments, according to environmental conditions for optimal application [37].

Yousefi et al. (2023) have developed a multi-criteria decision making (MCDM) framework for sustainable production planning of paper recycling systems, aiming to minimize waste. The authors incorporated sustainability criteria and uncertainty considerations to construct the evaluation criteria for the production plan, further weighting these criteria using the best-worst method (BWM) technique. By applying the analytic hierarchy process (AHP) method, they devised a decision support framework (DSF) to assist managers and practitioners in making more accurate decisions regarding production planning. The proposed DSF also addresses weaknesses in existing approaches, thereby increasing their effectiveness, and results in significant savings of approximately 75% in terms of human resource time [38].

Feng et al. (2023) developed and evaluated a multi-tier supply chain sustainability framework applied to the Chinese pulp and paper industry. The authors conducted an extensive study, combining literature review and expert interviews to identify factors influencing multi-tier supply chain sustainability. They employed a TOE and HOT-fit framework to classify these factors, using AHP methodology to determine their relative importance. Their findings highlight the critical role of institutional and technological factors in achieving sustainability. The study offers practical insights for industry practitioners and sets the stage for further research on supply chain sustainability across industries [39].

Anupam, Goley, and Yadav (2022) developed a model to optimize O₂ delignification (O₂D) using a hybrid approach that integrates the entropy weight-coupled novel-modified technique TOPSIS method with central composite design (CCD) as a response surface method. The input factors include temperature, time, and NaOH dose, while the output factors consist of pulp yield, kappa number, intrinsic viscosity, and brightness. The optimized values for input factors were determined, resulting in a good overall process desirability. A comparison with literature values indicated higher desirability and a lower NaOH dose

requirement, demonstrating the efficiency of the proposed optimization method for the O₂D process [40].

Preethi and Shanthi (2023) evaluated raw materials using the PROMETHEE method based on bipolar fuzzy sets. The criteria were established considering properties such as brightness, durability, moisture content, and smoothness. Subsequently, they applied the multi-criteria decision making (MCDM) method to rank the raw material alternatives. Their analysis, covering paper made from wood pulp, rag pulp, grass, bagasse, and hemp, concluded that paper made from rag pulp emerged as the best option [41]. Hence, the MCDM approach proves to be a versatile tool for effective decision making to address specific concerns and access any particular needs in the pulp and paper industry.

However, the impact of global megatrends on the paper and pulp industry is still uncertain; indeed, the gap in the literature becomes more significant in the context of the hygiene tissue industry. Most existing studies related to the hygiene tissue industry focus on the technical and experimental aspects of pulping and papermaking, without analyzing broader trends in the industry (market) and its stakeholders. This study takes a unique approach by investigating the effects of specific global megatrends on the hygiene tissue industry. It bridges different fields such as supply chain management, environmental and social governance (ESG) practices, manufacturing, sustainability, and marketing. By doing so, it offers valuable insights and applicable strategies to help the industry transition amid challenges resulting from megatrends.

In response to this gap, this research endeavors to utilize a multi-criteria framework to assess and quantify the impact of three significant global megatrends—digitalization, changes in social behavior, and sustainability—on the paper and pulp industry, with a specific focus on hygiene tissue products. To achieve this aim, a combination of qualitative and quantitative analyses was employed, leveraging techniques such as a literature review, a Delphi study, and topic modeling. Hence, the goal is to pioneer the generation of knowledge in this domain and open the door for the future application of multi-criteria decision making (MCDM) models, providing a comprehensive understanding of how these global megatrends are shaping the industry and identifying actionable strategies to address these changes.

There are alternative methodologies available to quantify trends, including regression analysis, time series analysis, econometric models, and social media analytics [42–44]. However, the choice of methodology depends on the specific research question, data availability, and the desired level of precision and accuracy. The main existing limitation prompting this research is the scarcity of literature available to explain the effects of trends on the hygiene tissue industry. Therefore, it becomes essential to utilize alternative methodologies, such as the Delphi study and topic modeling, to overcome this limitation and gain a comprehensive understanding of the industry's dynamics in response to trends. Such a methodological approach is needed to analyze the various dimensions of megatrends in the hygiene tissue industry. This is primarily because there is no study addressing this topic, and the limited literature available in regard to this industry makes it impossible to rely solely on literature reviews to gather information. To overcome this, a Delphi study and topic modeling can be used to gather insights from the field. The Delphi study can help reach a consensus among industry experts concerning uncertain aspects, such as sustainability [45,46], while topic modeling can employ a large volume of textual data to track the evolution of key themes in sustainability reports for U.S. hygiene tissue companies [47]. Integrating these methodologies can help achieve a more comprehensive understanding of the complex dynamics of global megatrends within the hygiene tissue industry.

2. Methodology

The research methodology involves integrating the principles of multi-criteria decision making (MCDM) to identify and quantify the impacts of trends that could disrupt the hygiene tissue industry. This methodology encompasses a comprehensive and critical literature review, along with growth rate estimations. Additionally, it integrates two scientific

research methods, a Delphi study and a latent Dirichlet allocation (LDA) topic modeling, to provide a holistic analysis of the industry's current challenges and future prospects.

Firstly, we conducted a Delphi study, engaging with market experts in the hygiene tissue industry. This method facilitated an iterative process of collecting and refining expert opinions to gain insights and build a shared understanding within the field. The Delphi technique, known for its systematic and interactive forecasting approach, aligns with the MCDM principle of analyzing expert knowledge to inform decision-making processes.

Secondly, we utilized latent Dirichlet allocation (LDA), an advanced topic modeling technique, to systematically identify the main topics present in sustainability reports published by hygiene tissue companies over the past decade. The utilization of LDA enables the extraction of themes and trends from large volumes of text data, reflecting the MCDM principle of integrating diverse data sources to enhance the comprehensiveness and reliability of the analysis.

The integration of these methodologies—particularly the Delphi study and LDA topic modeling—is employed to assess the perceived impact of global megatrends on the industry, as perceived by industry experts and evidenced through sustainability reports. This combined approach was designed not only to validate the findings of the initial literature review but also to incorporate multiple perspectives and criteria into the research process as part of MCDM.

2.1. Literature Review Methodology

We conducted a comprehensive literature review to identify the trends affecting the hygiene tissue industry. The literature review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [48]. The search utilized the keywords “digitalization”, “social behavior”, “sustainability”, and “pulp and paper industry”. The focus was on peer-reviewed journal articles and non-peer-reviewed sources published between 2012 and 2023. We examined 91 publications from the Scopus and Dimensions digital libraries, removing duplicates, and conducting preliminary screening based on abstracts, the collection of relevant full articles, and a detailed evaluation of each selected publication [49]. Each document was rigorously analyzed for specific information, including the title, authors, publication year, context, methodology, and its relevance to the study. The bibliographic data collected were analyzed according to the number of publications per year, indicating a significant increase since 2020, with the number of publications found before 2016 being around one per year. On the other hand, we used the VOSviewer text analytics module, enabling us to create a visual map that illustrates the bibliographic relationships among the utilized keywords (Figure 1). In this visual representation, the size of the circles and the thickness of the lines denote the volume of publications, the citation frequency, the extent of collaboration, and the overall impact of the research. Three clusters can be identified:

- Climate change, innovation, and the economic and developmental aspects of sustainability (red cluster).
- The practical application of sustainable technologies and processes (green cluster).
- The management, business, societal impact, and market aspects of sustainability (blue cluster).

As a preliminary analysis, these three axes constitute key aspects of the current landscape in industries related to pulp and paper.

2.2. Growth Rate Estimation

To assess current performance and predict the future production capacity of a particular industry, growth rate estimates were calculated. Two commonly used methods for estimating growth rate include evaluating the arithmetic average growth rate (AAGR) and the compound annual growth rate (CAGR) [50]. The CAGR method, which is based on the geometric average, is generally considered to be a more accurate estimate of growth over a specified period, as it indicates the composition of the growth rates [51]. In this study, the CAGR method was employed and performed using the following equation:

$$CAGR = \left(\frac{Value_n}{Value_0} \right)^{\frac{1}{n}} - 1$$

where n is the number of years, $Value_n$ is the value in the final year, and $Value_0$ is the value in the initial year.

2.3. Delphi Study

The methodology employed to obtain insights from market experts regarding sustainability trends and aspects of hygiene tissue products was the well-established Delphi study method, which comprised three surveys or interviews [52,53]. This consensus-building technique is widely recognized and has been extensively utilized to achieve a common understanding of complex topics displaying uncertain, contradictory, or limited evidence [45,46]. It is applicable for exploration, forecasting, and decision making [54]. Furthermore, this methodology has also been widely applied in the identification of criteria to be further used in the development of multi-criteria decision making approaches [37,39,55].

A Delphi study gathers input through a structured feedback process involving the use of multiple rounds of anonymous questionnaires aimed at achieving the desired consensus, which is recommended to be greater than 70% [46]. The consensus can be evaluated using different estimations. For binary questions with only two possible answers (yes or no), a kappa factor is used, but for Likert scale questions, the standard deviation is the preferred measure [53,56]. Standard protocols were followed, as discussed in previous studies [52,53,57]. To reach consensus, the Delphi study was carried out over three rounds of questionnaires (Figure 2A), with each round taking six weeks to complete.

2.3.1. Recruitment Process and Socio-Demographic Profile of the Participants

In a Delphi study, the incorporation of participants with expertise in the topic ensures meaningful insights [54]. Accordingly, the study involved the recruitment of a group of market experts with significant experience within the hygiene tissue industry to participate in discussions on sustainability-related topics. To comply with ethical standards, the study received approval from an institutional review board (IRB) under the protocol number 24,392 prior to the involvement of any human subjects. Following IRB approval, market experts were invited to participate through a LinkedIn poll and email invitations. The invitations included comprehensive information about the study, such as the IRB approval, as well as the study's objectives, process, rounds of questionnaires, and timeline, in order to ensure full transparency and secure informed consent from the participants. The participant selection criteria were defined according to the participants' roles in managing and developing strategies for sustainable products within their organizations, their possessing at least two years of professional experience, and their demonstrating a willingness to participate in the study [58,59].

While there is no established standard for the size of the panel, a minimum of 10 experts is considered acceptable for a Delphi study [54]. In this Delphi study, 19 market experts were successfully recruited, each with well-documented socio-demographic information (Figure 2B).

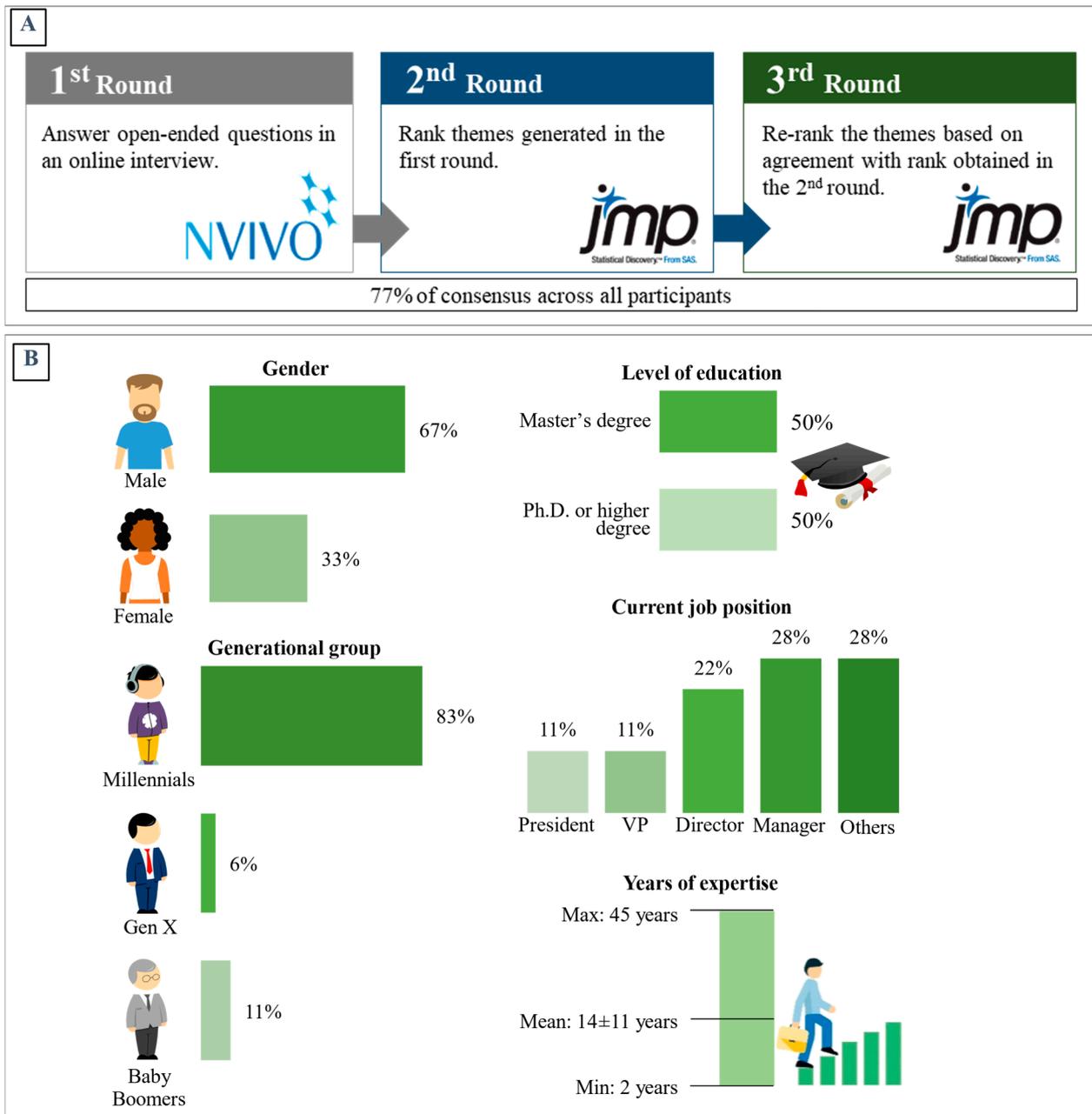


Figure 2. (A) Rounds of questionnaires developed in the Delphi study; (B) socio-demographic profile of market experts who participated in the Delphi study.

2.3.2. Data Collection and Analysis

To determine a common understanding among all participants, the following topics were systematically addressed across three questionnaires:

- The definition of sustainability and metrics employed within the hygiene tissue industry.
- The attributes and visual characteristics of self-labeled sustainable products.
- Barriers to purchasing sustainable products.
- The type of fibers used in the product.
- The color of finished products.
- The perception of sustainability across the stages of the product life cycle.

Round I: Qualitative Research Analysis

The first round of questionnaires consisted of individual online interviews conducted via Zoom [54]. Each participant responded to a series of 11 open-ended questions during a one-hour interview session. These questions, detailed in Appendix A.1 at the end of the manuscript, covered various aspects related to sustainability in the hygiene tissue industry. Overall, participants demonstrated the ability to effectively address all questions within the allotted time frame. Once the transcripts of the interviews were extracted and cleaned, a thematic analysis of the qualitative data was conducted using NVivo 16 Pro. This analysis aimed to identify the most relevant (higher frequency) themes representing the collective responses of the group to each question. The identified themes were further evaluated during the second round [56].

Round II: Quantitative Research Analysis

The second round of questionnaires consisted of an online survey hosted on the Qualtrics platform and shared via email through an anonymous link [52,53]. Participants were invited to assess the themes of the 11 questions generated in round I, employing a five-point Likert scale for their responses. The survey was designed to be completed within an average time frame of 10 min. A total of 17 experts contributed their input, meeting the minimum criteria established for the study [60]. The data were analyzed by performing a descriptive statistics analysis using JMP Pro software V.15. The calculation of the mean, mode, and standard deviation for the responses allowed for the ranking of themes and the assessment of the agreement among participants for each question [52,53].

Round III: Quantitative Research Analysis

The final round of questionnaires involved another online survey facilitated via the Qualtrics platform and shared with participants by email through an anonymous link [57]. Participants were requested to reconsider their ratings of the themes identified in round I, taking into account the collective opinions obtained in round II [61]. The average completion time was 15 min, and 14 experts participated. The findings were analyzed using descriptive statistics in JMP Pro V.15, following a similar process to round II. This statistical software enables the calculation of mean, mode, and standard deviation for the responses. These values were used to rank the themes and assess the consensus reached within the round. This round was considered conclusive for the Delphi study, as the consensus achieved among participants reached 77%, surpassing the recommended threshold of 70% [46,53,54]. The complete results of the Delphi study are presented in Table 1.

Table 1. Results of the Delphi study.

Questions	Themes	Mean	Standard Deviation
1. Based on your experience, how would you define sustainability in your industry?	It is about climate change and its consequences	4.45	0.69
	It is a carbon footprint comparison	3.91	1.22
	It is a market trend	3.36	0.92
2. Are there specific metrics you want to use in your definition of sustainability?	Responsible use of resources (energy, water, land)	4.71	0.61
	Lower carbon footprint	4.27	1.01
	Source and type of feedstock	4.09	0.83
	Waste disposal management	4.07	0.83
	Lower use of chemicals	4.07	0.92
	Certifications	3.73	0.90
	Social aspects	3.50	0.85

Table 1. Cont.

Questions	Themes	Mean	Standard Deviation
3. What are those attributes frequently related to sustainable products in your industry?	Responsible feedstock sourcing	4.43	0.94
	Recycled content	4.20	1.03
	Biodegradability	4.20	1.03
	Energy efficiency	4.20	0.79
	Water efficiency	4.10	0.74
	Certifications	4.00	0.82
	Recyclability	4.00	0.96
	Lower carbon footprint	3.93	0.92
	Lower use of chemicals	3.79	1.19
	Social impacts	3.71	0.91
	Compostability	3.36	1.22
	Waste disposal management	3.00	1.11
	Country of manufacturing	2.80	0.79
4. Based on the life cycle stages of your products, what stages could cause a major impact on consumer perception if it can be improved from a sustainable perspective?	Raw materials	4.67	0.50
	Manufacturing	4.33	0.87
	Utilization (Less consumption and exposure to chemicals)	4.31	0.85
	After-use disposal	3.78	0.97
5. What are those visual characteristics (color and figures on packaging/labels) usually related to sustainability?	Packaging material (plastic, paper, cardboard)	4.60	0.70
	Certifications, labels, or claims	4.29	0.91
	Product color	3.90	0.57
	Amount of packaging used	3.90	0.88
	Main packaging color	3.80	0.92
	Sustainability phrases (marketing)	3.70	0.82
	Recycling logo	3.50	1.18
6. What are those main packaging colors usually related to sustainability?	Graphics	3.14	0.77
	White	5.00	0.00
	Green	4.57	0.51
	Blue	4.11	0.78
	Brown	2.78	0.83
7. What color of finished products might relate better with sustainable products within your industry?	Natural color	4.56	0.73
	Brown	4.22	0.97
	Mocha	4.00	0.71
	Undyed	3.63	1.30
	White	2.57	1.09
	Yellow	2.43	1.02
8. What are those graphics usually related to sustainability?	Triangles	5.00	0.00
	Trees or plants	4.78	0.44
	Water or ocean	3.07	1.07
	Circles	2.89	1.05
	Animals	2.80	1.23

Table 1. Cont.

Questions	Themes	Mean	Standard Deviation
9. What do you think are the main challenges or barriers to purchasing a sustainable product (as experienced by consumers)?	Price	4.56	0.73
	Be unfamiliar with certifications, claims, or labels	4.22	0.67
	It is confusing to identify a sustainable product	4.22	0.67
	Brand loyalty	3.92	0.95
	Be unfamiliar with the product itself	3.69	0.85
	Lack of confidence in the product	3.62	1.04
10. How do you think the growth of e-commerce will affect the pace of adoption of sustainable products?	Lower performance	3.54	1.33
	Improves product accessibility	4.78	0.44
	Improves product availability	4.78	0.44
	Makes purchasing process easier	4.78	0.44
	Increases information about products	4.67	0.71
11. From a consumer perspective, what kind of fiber do you think would be perceived as more sustainable (recycled, non-wood fiber, virgin fiber)?	Improves product traceability	3.44	1.01
	Recycled fibers	4.69	0.48
	Fibers from residues/wastes (e.g., agricultural)	4.22	0.44
	Non-wood fibers	3.78	0.67
	Virgin wood fibers from planted forests	3.54	0.88
12. How do certifications influence consumers' perception and purchase behavior in your industry?	Virgin wood fibers from natural forests	2.23	1.09
	Increase confidence in products	4.22	0.67
	Increase willingness to buy	3.56	1.01
13. Based on your experience, what will be the significant attributes related to sustainable products in your industry in the next ten years?	Water efficiency	4.78	0.44
	Environmentally friendly processes	4.67	0.50
	Performance	4.62	0.51
	Responsible feedstock sourcing	4.56	0.53
	Lower carbon footprint	4.56	0.73
	Bio-based content	4.46	0.66
	Recyclability	4.44	0.53
	Recycled content	4.44	0.73
	Biodegradability	4.15	0.90
Social impacts	4.00	0.93	
Compostability	3.69	1.11	
Waste disposal management	3.56	1.13	

2.4. Topic Modeling: Latent Dirichlet Allocation (LDA)

Topic modeling is an unsupervised machine learning technique that facilitates the analysis of large sets of documents and datasets simultaneously [62]. This technique's algorithm scans and overlaps documents to identify clusters of words that represent a theme and best characterize those documents [47]. LDA is a form of topic modeling that represents themes based on word probabilities, where words with the highest probability within a theme usually provide an accurate description of that theme [63]. To conduct LDA topic modeling, reports of 16 hygiene tissue companies with higher market shares [20] were collected, covering the years 2012 to 2021. Table 2 summarizes the reports available (free access) per company each year within the established time horizon (10 years). A total

of 123 reports were collected from the companies' websites and were analyzed using R programming language. Specifically, the topic model was fitted using the "LDA" (latent Dirichlet allocation) function from the "topicmodels" package. Since the number of topics is not fixed, it was determined by exploring a range of values and selecting the number of topics that resulted in the most interpretable, independent, and meaningful topics supporting the research study question [64].

Table 2. U.S. hygiene tissue companies' sustainability report availability from 2012–2021.

Company	Years Available	Number of Reports
Procter & Gamble	2012–2021	10
Kimberly-Clark	2012–2021	10
Georgia Pacific	2020–2021	2
Walmart Inc.	2012–2021	10
Kroger Co.	2016–2021	6
Walgreen Co.	2015–2021	7
Target Corp.	2012–2021	10
Costco Corp.	2018–2019	2
Clorox Co.	2012–2021	10
CVS Health Corp.	2012–2021	10
Albertson Cos Inc.	2016–2021	6
Edgewell LLC	2017–2021	5
Johnson & Johnson	2012–2021	10
Reckitt Benckiser Inc.	2012–2021	10
Essity AB	2016–2021	6
Seventh Generation	2013–2021	9
Total reports available		123

Prior to fitting the LDA topic model, sustainability reports issued in the same years were combined and used to create a corpus of 10 text documents. The data preprocessing, including stemming and combining words, lowercase conversion, and removing stop words, numbers, symbols, and misspellings, was executed using the "tm_map", "content_transformer", and "removeWords" functions from "tm" package [62,64].

Once the LDA topic model was created, a beta matrix (the probability of each word is within each topic) and a gamma matrix (probability of each topic within in each text document) were executed, both using the "tidy" function from the "tidytext" package. The beta and gamma values were plotted to explore the following two approaches: (i) evaluating relevant topics found across the sustainability reports and (ii) assessing how these relevant topics lost or gained importance over the years.

In LDA topic modeling, topic naming is primarily based on the beta value of the terms contained within each topic and their human-understandable meaning. The beta value serves as an indicator of the term's probability to effectively capture the essence of the topic. Thus, a higher beta value corresponds to a higher likelihood of that term effectively controlling the thematic content of the associated topic (Table 3) [65].

Table 3. Distribution of the top 10 words and their probabilities within each topic in the LDA topic model.

Topic	Term	Beta
1	Social impacts	0.0123
	Environment	0.0038
	Corporate social responsibility	0.0036
	Emissions	0.0018
	Responsible sourcing	0.0013
	Packaging	0.0013
	Water	0.0009
	Energy	0.0007
	After-use disposal	0.0006
	Waste	0.0005
2	Corporate social responsibility	0.0071
	Social impacts	0.0069
	Environment	0.0026
	Responsible sourcing	0.0014
	Emissions	0.0012
	Water	0.0007
	Packaging	0.0007
	Materials	0.0006
	Energy	0.0006
Workplace	0.0006	
3	Social impacts	0.0153
	Corporate social responsibility	0.0092
	Environment	0.0032
	Responsible sourcing	0.0016
	Emissions	0.0015
	Data	0.0012
	Packaging	0.0010
	Waste	0.0007
	Water	0.0007
Energy	0.0007	

Simultaneously, to observe changes in the use of some relevant words over time, the frequency of these words across the 10 text documents from 2012 to 2021 was calculated and plotted.

3. Results and Discussion

In this section, we present and discuss the integrated results obtained from the methods employed in this study. By combining the existing literature with the insights from market experts and company sustainability reports, our aim is to provide a detailed analysis of the trends and impacts within the hygiene tissue industry. While we focus on the hygiene tissue sector, insights from this work represent a large segment of the pulp and paper industry.

3.1. Global Megatrends and the Hygiene Tissue Industry

It is crucial for businesses to identify, analyze, and adapt to megatrends to remain competitive and relevant in the years ahead [11]. Moreover, it is worth recognizing that these megatrends are interdependent, and their effects differ across sectors, emphasizing the necessity for a multi-criteria decision making (MCDM) approach to effectively investigate these complexities [66].

The hygiene tissue industry has experienced significant changes over the years in response to consumer trends [13]. To align with shifting preferences, the industry has transitioned from items created through the use of harsh bleaching processes towards products that are multi-layered, bulkier, softer, and, depending on the product category, more absorbent [29,31,67,68]. Currently, the industry faces new challenges brought about by current megatrends such as digitalization, changes in social behavior, and sustainability [69]. In the following sections, these challenges will be explored in detail.

3.2. Effect of Digitalization

Digitalization has guided the adoption of new digital technologies, creating a new reality in which information, communication, and transactions are achieved digitally [70]. This shift has increased convenience, efficiency, and engagement for consumers. However, the hygiene tissue sector is being impacted by digitalization specifically related to the supply of the raw material used [71].

3.2.1. Shortage of Recycled Paper Supply

The move towards digitization has forced people to reduce paper consumption and limited them to printing only essential items [28]. This trend has driven a considerable reduction in printing and writing paper production, causing a decrease in the availability of recycled paper [72]. This constitutes a concern, since recycled paper accounts for one-third of the raw materials used in hygiene tissue operations in the U.S. [30].

Between 2000 and 2018, the production of printing and writing paper decreased by half, from approximately 30 million tons to 15 million tons (Figure 3A). The COVID-19 pandemic further accelerated this trend, causing an additional 5 million ton reduction within two years (2020–2021), with several printing and writing paper-producing facilities retrofitting to produce paperboard for packaging [73].

Correspondingly, the future availability of recycled fibers is expected to face further disruptions. A forecast for the period of 2022–2032 has been constructed using future value calculations, taking into account compound growth rates based on various periods: 2010–2020 (CAGR-10y), 2015–2020 (CAGR-5y), and 2017–2020 (CAGR-3y) (Figure 3A). These projections provide solid insights into the impact of digitization on the availability of recycled printing and writing paper by 2032.

Estimates suggest that over the next decade, the production of printing and writing paper and thus, the availability of its post-consumer material, will steadily decline, falling to levels between 50–75% with respect to 2020 (Figure 3A). This intriguing finding underscores a pressing reality: this situation may be further exacerbated by the adoption of recycled fibers as a substitute for virgin fiber in different products, a result driven directly by the sustainability megatrend. There are indications from the market that this is already happening, as the cost of recycled material has continued to rise in some Latin American countries, and the quality of recycled material has also been compromised, affecting the yield of usable fibers obtained after contaminant removal [30,74].

This finding indicates the urgent need to identify suitable feedstock to replace recycled printing and writing paper, potentially through the exploration of alternative fibers or other recycled fiber sources.

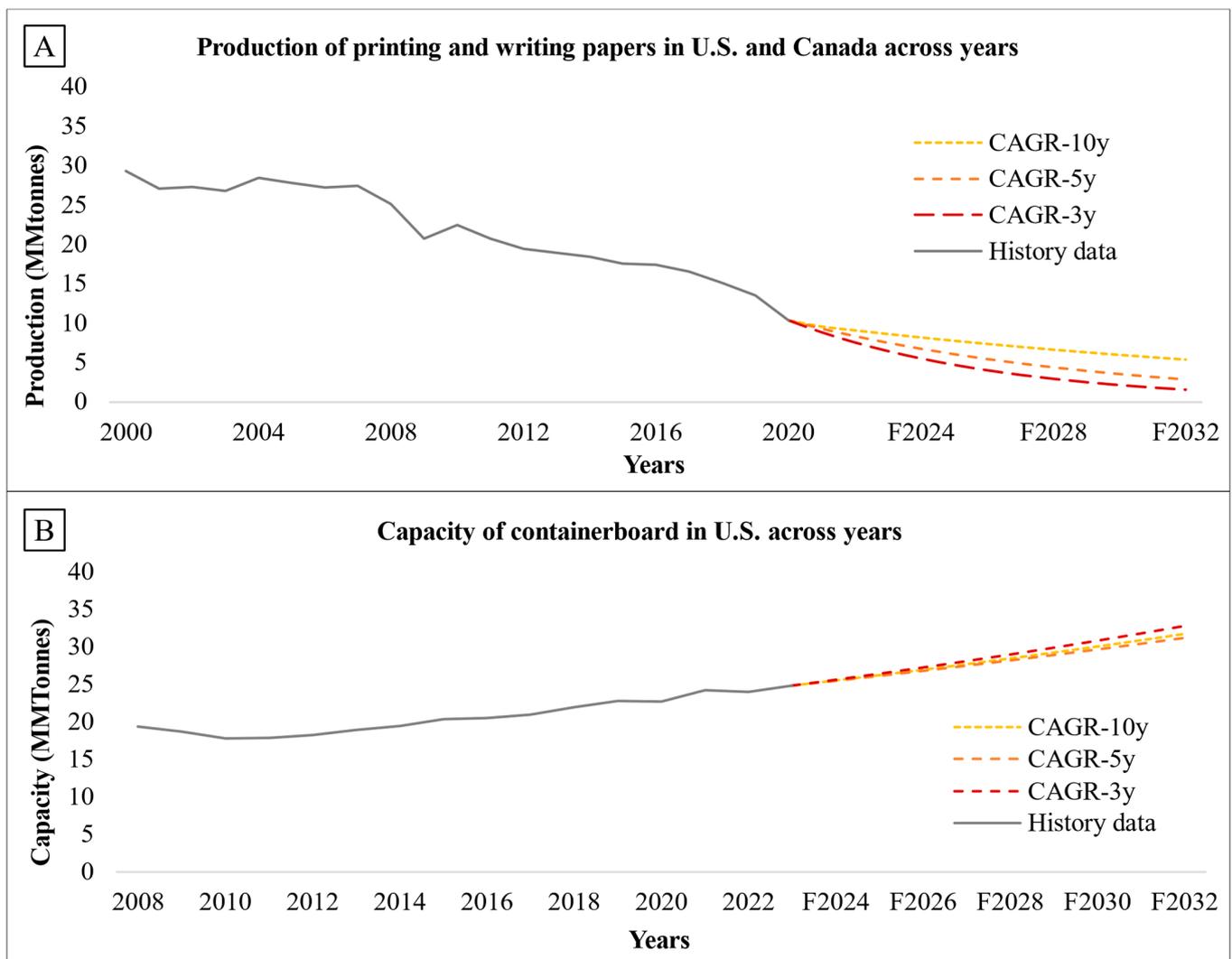


Figure 3. (A) Production of printing and writing papers in the United States and Canada across years [13]; (B) the capacity of containerboard production in United States across the years [30].

3.2.2. The Recycled Fiber of the Future Is Brown

Digitalization is also transforming shopping behaviors [70]. Online shopping, a trend that began years ago and which was intensified by the COVID-19 pandemic, is growing as a current behavioral shift [75]. In just the years between 2019–2021, an increase of 50% in e-commerce sales was reported in the United States, where e-commerce sales represent 13.2% of total retail sales, with expectations for continued growth [76,77].

The expansion of e-commerce, along with the conversion of multiple printing and writing paper production facilities to produce containerboard, and the growing emphasis on eco-friendly paper-based packaging have collectively driven a marked increase in the production of secondary packaging [30,78]. From 2008 to 2022, containerboard production expanded by 32%, equivalent to an approximately 6 million ton increase (Figure 3B). Forecasts for 2023–2032, based on various periods of CAGRs, project an ongoing capacity expansion of 15–30% by 2032.

In 2021, nearly 39 million tons of old corrugated containers (OCCs) were produced in the United States, with 91% of this amount being recycled [79]. OCCs, sourced from industrial and consumer packaging, have been considered as a potential substitute for recycled paper in the manufacture of hygiene tissue products [31]. Given their high production and level of recyclability, OCC fibers are considered to be a viable alternative that could be utilized over an extended period of time. However, using OCCs to produce hygiene tissue

products presents challenges, including their brown color and the reduced softness of the fibers contained in OCCs [72]. Some hygiene tissue companies have introduced products featuring natural color fibers, such as mocha, which are perceived by more consumers as more eco-friendly [80]. Nevertheless, the low adoption rate of these products can be attributed to the fact that white tissue products remain the preferred choice for most consumers [81]. This claim was supported by the findings from the Delphi study, where market experts agreed that unbleached finished products with yellowish and brownish tones may be perceived as sustainable. However, some consumers may reject these products due to hygiene, cleanliness, and purity concerns. Consequently, these products require bleaching, and in the context of the sustainability megatrend, companies in the hygiene tissue sector must explore environmentally friendly bleaching methods [72,82]. This result highlights OCCs as a potential alternative to recycled fibers obtained from printing and writing paper, given its the high likelihood of its continuous availability and its performance, despite the challenges previously discussed [30]. Interestingly, while OCCs are already utilized in away-from-home hygiene tissue products, their use in consumer hygiene tissue products has been limited, e.g., last year, the WEPA company introduced the first consumer tissue product containing OCC [83]. Incorporating OCCs into this industry segment could be facilitated due to the low cost, compared to market pulps, of this recycled fiber [30], even with the addition of some improvement stages.

Furthermore, the Delphi study revealed market expert perspectives regarding the impact of e-commerce growth on the adoption of eco-friendly options (Figure 4A). They stated that the rise in e-commerce may benefit the industry by simplifying the purchase process of sustainable hygiene tissue products, increasing awareness about the products' sustainability credentials, and improving product availability, accessibility, and traceability.

3.3. Changes in Social Behavior

Social behaviors have changed dramatically over the last few decades due to various social trends, reshaping lifestyles and behaviors with far-reaching implications for the future [11]. One particular trend impacting social behavior is growing environmental awareness and the urgency of climate change. People are more aware of the environmental impacts of their actions as the effect of climate change is worsening [84,85]. Several studies reveal that a consumer segment is increasingly using its purchasing power to address societal concerns and decrease its environmental footprint [10,86]. This shift in consumer behaviors span across the six generational groups, which can be divided into two sub-categories: three older generations (traditionalists, baby boomers, and Gen X) and three younger generations (millennials, Gen Z, and Gen Alpha) [87,88]. While all generations may share a common thread of environmental awareness, each group exhibits distinct priorities, behaviors, preferences, and spending patterns [89,90].

By 2023, the United States reported that the proportion of older and younger generations reached nearly equal values [14]. However, this demographic balance is anticipated to undergo a dramatic transformation, with younger generations projected to constitute 64% of the population by 2030 [16]. Given the significant shift in generational group composition and the impact of global megatrends, this underscores the critical importance of comprehending consumer behavior and perceptions of sustainability across various generational groups.

3.3.1. Social Changes Affecting Consumer Behavior

Older generations are known for their strong brand loyalty and a preference for in-person shopping experiences. They place a high value on personal interaction and the ability to physically touch, feel, and try out products before making a purchase [91,92].

Conversely, younger generations are more inclined to use digital technologies for researching products, comparing prices, and making purchases [87]. They prioritize convenience, accessibility, and the availability of a broader range of products offered online at competitive prices [91]. Additionally, younger consumers are also more likely to rely on

recommendations from friends, influencers, and online reviews when making purchasing decisions [93]. Given these trends and the projected growth of younger generations, it is imperative to emphasize that hygiene tissue marketers must elevate their online presence to effectively reach and engage these market segments. Strategies may include enhancing the responsiveness and design of their digital channels, as well as crafting compelling content to captivate attention and stimulate sales.

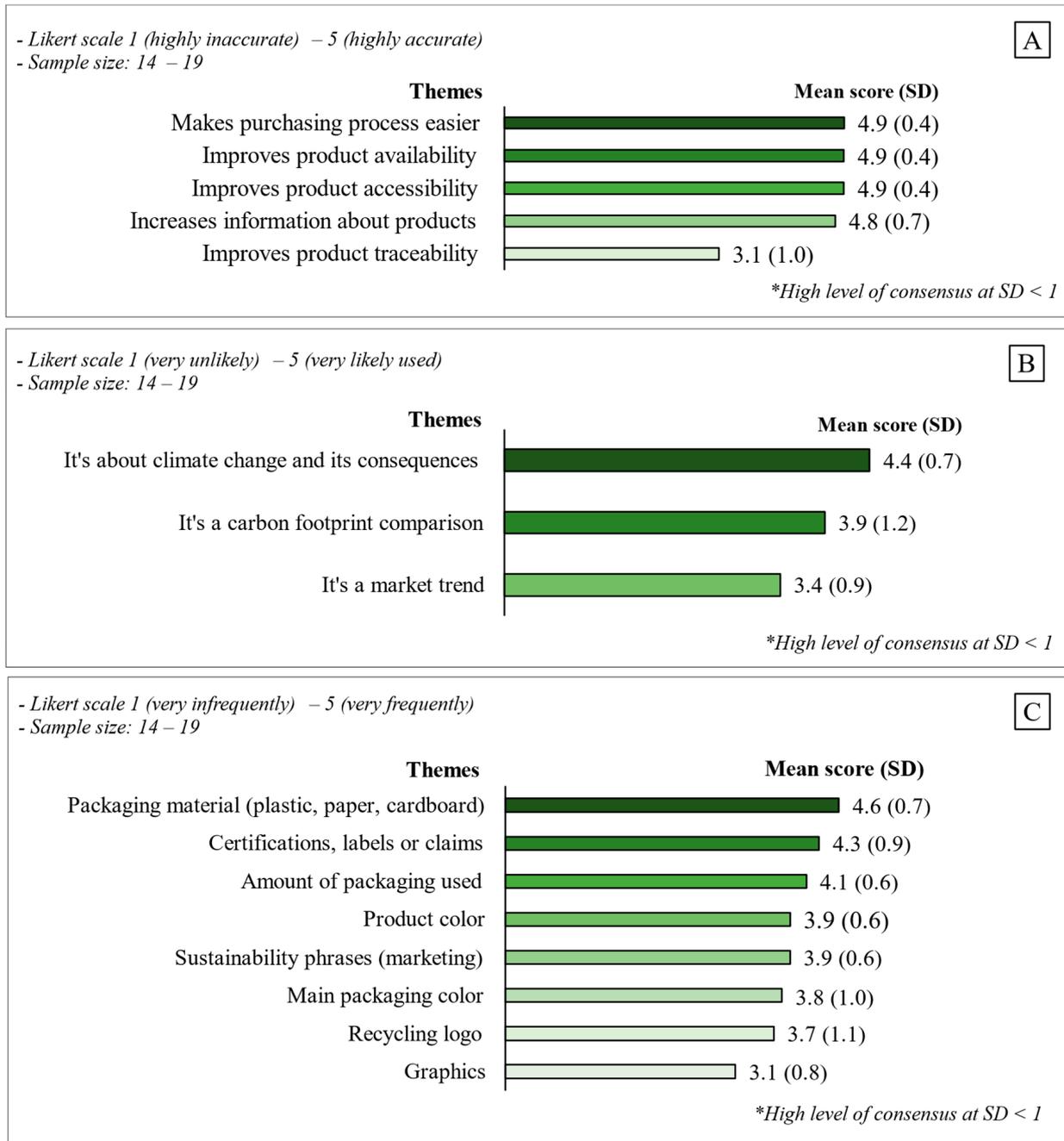


Figure 4. Market expert ratings from Delphi study of (A) effects of the growth of e-commerce on the pace of adoption of sustainable products; (B) themes used by market experts to define sustainability; (C) visual characteristics frequently related to sustainability.

3.3.2. Social Changes Affecting Sustainability Perception

Even though the perceptions of sustainability may vary across generational groups, defining the word “sustainability” remains a challenge. Within our Delphi study, the

concept of sustainability was explored among hygiene tissue market experts. Our findings highlight the complexity of defining sustainability, revealing that it can be interpreted as an ambiguous “trend similar to climate change” or as a precise measurement, such as comparing carbon footprints between products (Figure 4B).

Indeed, when consumers look for sustainable products in the market, they often struggle to identify them based on their sustainability attributes, leading to uncertainty in their purchasing decisions [94]. According to a survey conducted by Essity, a global hygiene and health company, approximately 50% of the respondents expressed a lack of clear understanding regarding the sustainability of products, finding this topic overwhelming [95]. According to insights from the Delphi study, market experts identified certain visual characteristics of products to be indicative of sustainability. These characteristics include the type and quantity of packaging materials, certifications, product color, sustainability declarations, packaging color, and graphics on the label (Figure 4C). Despite these indicators, experts believe that consumers may still lack confidence in making informed purchasing decisions [96].

Even though there is no well-established relationship between specific demographic characteristics (e.g., age, gender, income, education) and sustainable consumer behavior [93], older generations tend to be more concerned about social impacts like human health and rights, leading them to favor products that emphasize these aspects [87]. Conversely, younger generations are more inclined to adopt a sustainable lifestyle and support companies with good environmental reputations [97]. As of 2022, it was reported that over half of the younger generation in the U.S. believed that companies should take a stand on current environmental and social issues [98]. Younger consumers show a preference for e-commerce and are willing to make trade-offs between price and quality [99]. In line with this trend, there is growing tendency among this consumer segment to rely on hard data, rather than marketing claims, when making purchasing decisions due to their awareness of greenwashing [100,101]. As this demographic segment grows and gains more purchasing power [97], it signals a significant possibility that the demand for sustainable hygiene tissue products will likely increase substantially in the coming years. To capitalize on this growing trend and drive the adoption of eco-friendly options, companies must provide readily available information about the sustainability metrics of their products, supported by hard data. This approach empowers consumers to make informed choices that resonate with their sustainability-oriented preferences. Consequently, understanding the evolving preferences and behaviors of different generations will be paramount for success in the rapidly evolving retail and online landscape of the hygiene tissue industry.

3.4. Sustainability Megatrend

Hygiene tissue companies have been progressively incorporating sustainable options in their product portfolios [19]. The Tissue Pack Innovation Lab at NC State University has been tracking the evolution of self-labeled sustainable hygiene products in the U.S. from 2017 to 2023. During this period, a rise in the offering of these products has been observed, with an increase of 30% for bath tissue and 25% for kitchen towels [102]. It is important to mention that self-labeled sustainable hygiene tissue products were included in this category according to a variety of sustainability attributes, such as the use of alternative fibers, recycled fibers, or fibers sourced from responsibly managed forests, in addition to features like compostability, biodegradability, recyclability of the packaging, and eco-friendly manufacturing processes, among others. Additionally, Figure 5 summarizes and ranks market expert insights collected in the Delphi study regarding several sustainability-oriented aspects in the hygiene tissue industry.

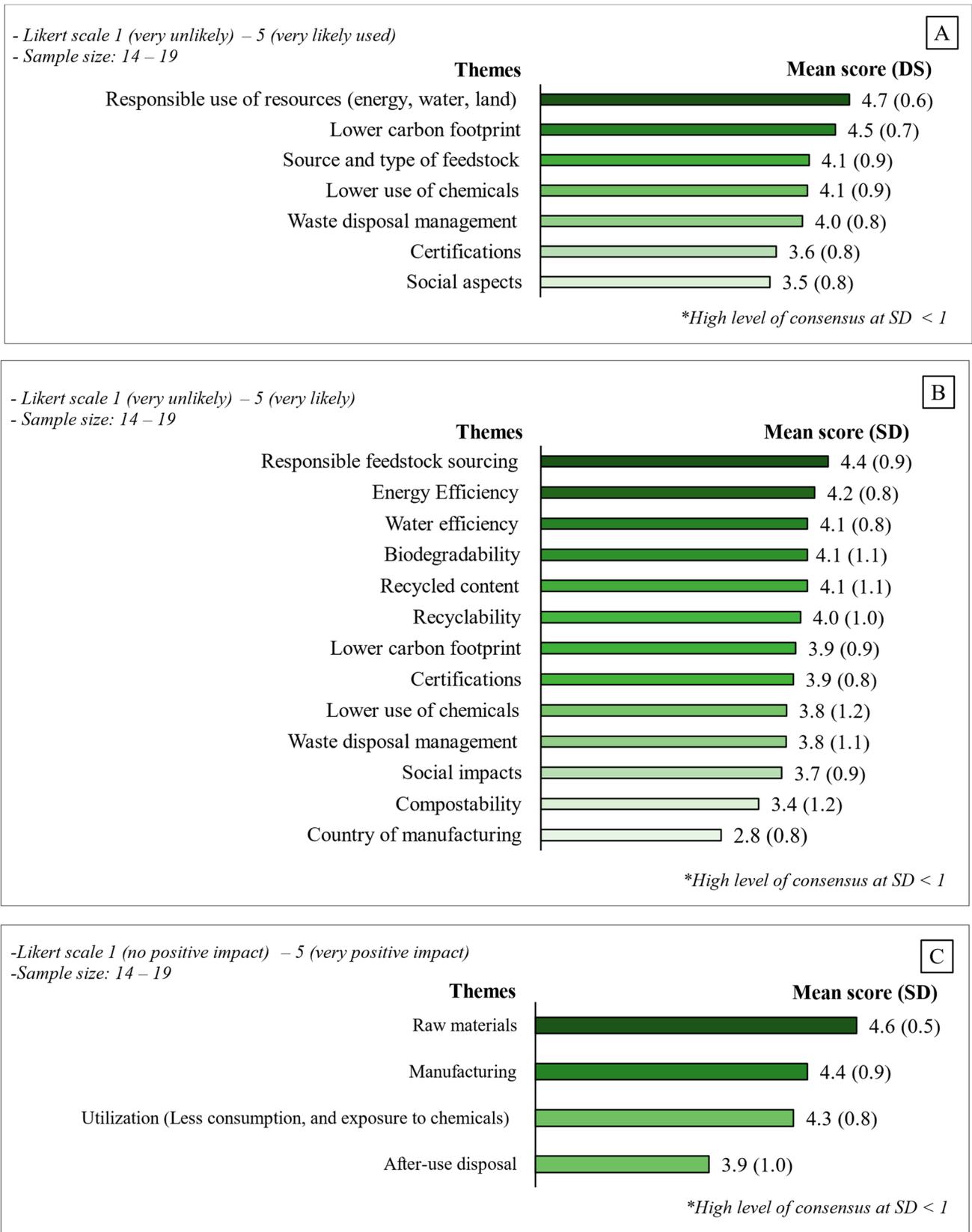


Figure 5. Market expert ratings from Delphi study of: (A) metrics used in the definition of sustainability; (B) product attributes related to sustainability; (C) stages that could cause a major impact on consumer perception, if they can be improved from a sustainability perspective.

Figure 5 shows that market experts agree that the most current product attributes and metrics related to sustainability may be focused on the raw material and manufacturing life cycle stages of these products. Key considerations include the feedstock (fiber) used, how responsibly the feedstock is sourced, and how responsibly and efficiently resources (water, energy) are used during the production process. Lastly, the after-use disposal characteristics of both the product and its packaging play an essential role, including factors such as biodegradability, compostability, and recyclability.

Regarding the visual characteristics of hygiene tissue products (Figure 6), experts consider that the most sustainability-related items may include the use or the amount of alternative packaging material (as opposed to plastic) employed; the presence of certifications; unbleached products; packaging featuring green, white, or blue colors; sustainability marketing; and the presence of triangles and nature-inspired graphics.

- Likert scale 1 (very infrequently) – 5 (very frequently related to sustainability)
 - Sample size: 14 – 19

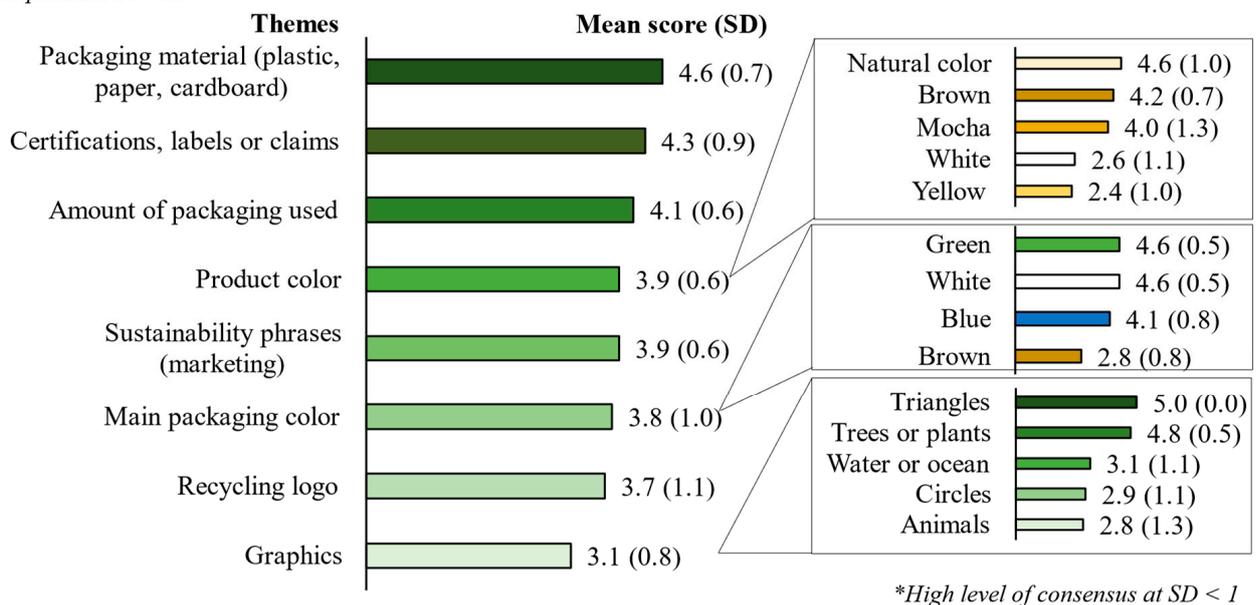


Figure 6. Market expert ratings from Delphi study of visual characteristics related to sustainability.

3.4.1. Past and Current Perspectives of Sustainability in the Hygiene Tissue Industry

By applying LDA topic modeling, this study identifies the key topics that have shaped the industry in recent years. The analysis of the sustainability reports from the 16 leading companies in the industry reveals three relevant topics: the environmental impacts of the product lifecycle, sustainable workplace management, and social responsibility and value chain management (Figure 7). The first topic encompasses the companies’ commitments to reduce carbon emissions and environmental impacts by adopting sustainable practices across the product lifecycle, from raw material sourcing to product and packaging disposal. The second topic highlights the companies’ commitments to promoting diversity, equity, and inclusion throughout the organization and providing a safe, healthy, and supportive workplace for employees. The third topic addresses the companies’ social responsibilities to improve the well-being of nearby and in-need communities, both in terms of health and resource scarcity. Moreover, it also emphasizes the importance of upholding ethical standards in the companies’ supply chain and operations by responsibly utilizing common resources.

Top terms per each topic

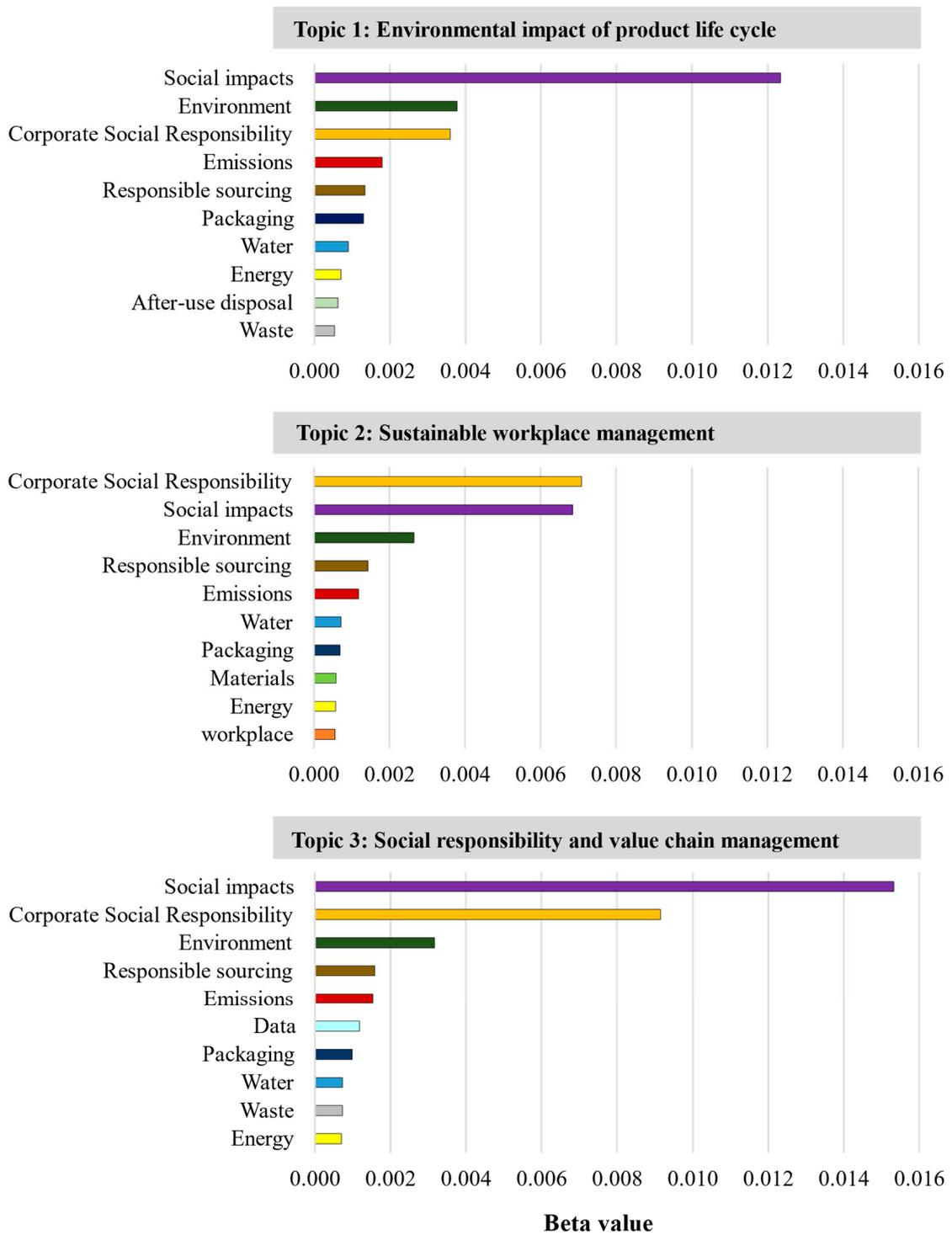


Figure 7. Distribution of the top 10 terms per each topic found in the LDA topic modeling analysis of sustainability-related reports.

In order to investigate the evolution of topics over time using a topic modeling analysis of sustainability-related reports, we examined the gamma values (probability of the topic within each of the selected 10 text documents) across the years 2012–2021 (Figure 8). Our analysis revealed that each year was dominated by a single topic, likely reflecting the interconnected nature of the topics in these reports. Notably, we found that topic 2 has been decreasing in importance over time, while topics 2 and 3 have been gaining prominence.

Additionally, topic 1 was found to be the most dominant topic in 2021, the final year of our time horizon.



Figure 8. Distribution of gamma values from topic modeling analysis of sustainability-related reports across multiple years.

Informed by topic modeling and supported by the review of the relevant literature, the present sustainability landscape in the hygiene tissue industry can be depicted through several key aspects, each of which aligns with the multi-criteria principles applied in the present research to ensure a comprehensive approach. These aspects are:

Responsible Forest Management and Certifications

Wood is the primary source of fiber for pulp production [103]. However, concerns have been raised regarding unsustainable forest management practices and deforestation [22,104]. To address these concerns, third-party certifications are increasingly being used to verify responsible feedstock sourcing by product manufacturers [105]. According to data from the Tissue Pack Innovation Lab, as of 2023, the Forest Stewardship Council (FSC) is the most commonly used certification in the United States, appearing on approximately 40% of toilet paper and paper towel products. This is followed by certifications from the Sustainable Forest Initiative, the Rainforest Alliance, and the Program for the Endorsement of Forest Certification (PEFC), appearing on approximately 20%, 15%, and 10% of tissue products, respectively [102]. The adoption of these certifications may have a positive impact on consumer perception and purchasing behavior by increasing consumer confidence and their willingness to purchase sustainable hygiene tissue products, as concluded by market experts in the Delphi study (Figure 9A).

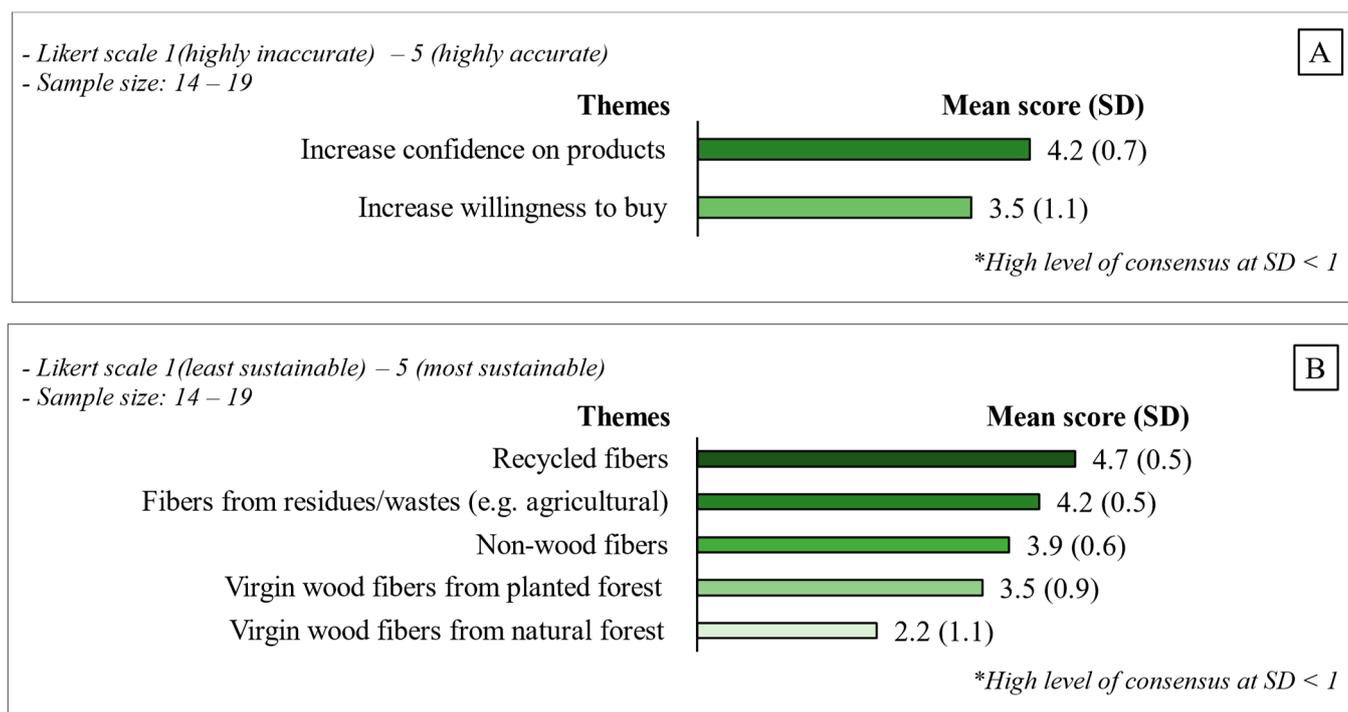


Figure 9. Market expert ratings from Delphi study of: (A) effects of certifications on consumer perceptions and purchase behavior; (B) type of fibers perceived as more sustainable from a consumer perspective.

Recycled Fibers

There has been a growing emphasis on reusing pre- and post-consumer fibers despite their increasing supply chain and quality limitations [71,106]. According to the 2017–2023 tissue benchmarking study conducted by the Tissue Pack Innovation Lab at NC State University, the offering of products made from recycled fibers in the United States has increased by 6% for kitchen towels and 13% for bath tissue [102]. Moreover, in the Delphi study, market experts concluded that from a consumer perspective, recycled fibers may be perceived as more sustainable due to the decrease in the use of virgin fibers and associated reduction in deforestation [107] followed by alternative fiber sources (agricultural residues and fast-growing plants), planted forests, and natural forests (Figure 9B).

Alternative Fibers

Alternative fibers such as bamboo, wheat straw, miscanthus, reeds, sugarcane bagasse, and flax are perceived as more sustainable than wood from trees due to their availability, rapid growth-rates, lack of deforestation risk, etc., [25,26,108]. However, a completed environmental impact assessment regarding switching from woody to non-woody feedstocks is still under evaluation [25,82,109]. Between 2019–2022, the Tissue Pack Innovation Lab found that the offering of products made from alternative fibers in the U.S. market increased by one-fold for both bath tissue and kitchen towels, respectively [102]. While the current production of pulp from non-woody sources remains low, the global capacity for non-wood pulp production is expected to grow by 7.4% in coming years, with North America projected to experience a 54.8% increase over current figures [110]. Evidence of this trend can already be seen in the United States, with hygiene tissue products made from bamboo, as well as in Germany, where major companies have launched hygiene tissue products made from other non-woody sources such as wheat straw, used in Zewa consumer bath tissue produced by Essity [111], and miscanthus, used in BlackSatino GreenGrow bath tissue and professional hand towel paper produced by WEPA [83].

Environmentally Friendly Production Processes

The hygiene tissue industry is committed to achieving net-zero carbon emissions and meeting consumer demand for sustainable products by implementing practices aligned with the UN Sustainable Development Goals. Georgia Pacific, for example, has reported a 79% reduction in solid fossil fuel usage for energy and a 76% reduction in sulfur dioxide emissions since 2013 and 2010, respectively [112]. Cascades has also made strides toward sustainability by reducing water consumption in the tissue-making process by a factor of five, principally through the use of recycled fibers and process water [19]. The industry is working to further reduce its environmental impact by utilizing cleaner energy sources such as biomass fuels, implementing water-saving process technologies, and developing more environmentally friendly bleaching alternatives [31,82].

After-Use Disposal Implications

The Delphi study identified waste disposal management, as well as packaging material type and amount, as key metrics and attributes related to sustainability (Figures 5A,B and 6). In 2023, the Tissue Pack Innovation Lab identified that 92% and 86% of packaging was made from plastic, with 77% and 75% being recyclable for kitchen towels and toilet paper, respectively [102]. Regarding the biodegradability of this type of packaging, it all depends on the type of plastic used [113]. Thus, hygiene tissue companies are exploring the use of renewable and biodegradable materials to achieve more sustainable packaging for their products [25].

Social Aspects

Market experts recognize that a company's social responsibility is a current and future critical metric and product attribute related to sustainability in the industry (Figure 5B,C). In response, companies have taken various actions to promote the well-being of society as a whole, including consumers, employees, and communities [97]. Since the onset of COVID-19, companies have begun focusing on addressing barriers to mental health, as well as on promoting self-care, care for others, and environmental stewardship, as evidenced by sustainability reports from 2012–2021.

3.4.2. Future Perspective of Sustainability in the Hygiene Tissue Industry over the Next 5–10 Years

Despite the growing demand for sustainable products, it is noteworthy that traditional products still dominate the market [20]. This is largely attributed to various barriers that hinder the widespread adoption of sustainable hygiene tissue products among consumers. These barriers, as identified by market experts in the Delphi study (Figure 10A), may include premium pricing, insufficient information about product sustainability and certifications, brand loyalty, lack of consumer confidence, and perceived inferior performance.

The findings uncover a parallel between the influence of price and product identification barriers on consumer purchasing decisions. Remarkably, it suggests that identifying a sustainable tissue product could reduce the significance of price as a purchase barrier. From a consumer perspective, there may be a positive correlation between premium price and superior performance, with higher-priced products believed to offer better performance. However, findings by the Tissue Pack Innovation Lab challenge this assumption, at least in the case of kitchen towels, where water absorbency—a major performance attribute—tends to decrease as the price of the product increases [114]. Interestingly, market experts ranked product performance among the top four sustainability-related attributes that will be significant over the next decade (Figure 10B).

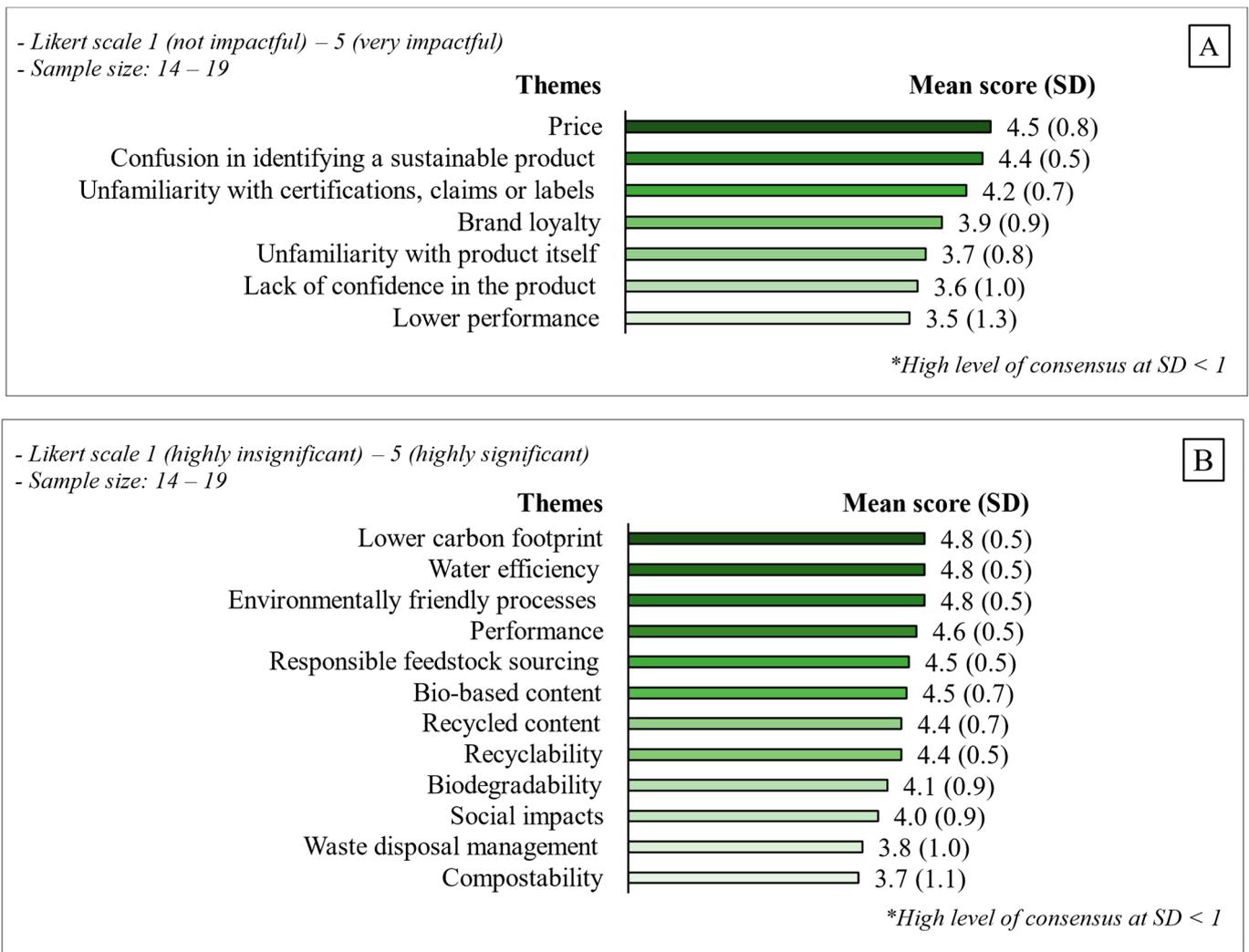


Figure 10. Market expert ratings from Delphi study for: (A) challenges to purchasing a sustainable product; (B) attributes that will be significant over the next ten years.

In order to encourage consumers to purchase sustainable hygiene tissue products at a premium price, tissue companies must prioritize improving product performance, as well as establishing well-defined metrics and information regarding the sustainability of their products. The frequency distribution of the top seven sustainability-related words found in the sustainability reports was analyzed over time (Figure 11). These terms have become increasingly significant, with a growing tendency regarding the occurrence of words such as “emissions” and “packaging”. This indicates that companies are becoming more aware of the need to account for their carbon emissions reduction, packaging materials used, and their after-use implications, which could be part of the future metrics and information concerning U.S. products. By providing transparent and trustworthy information about sustainability, companies can help consumers overcome their hesitation, due in part to a lack of information or the fear of greenwashing, to purchase sustainable hygiene tissue products.

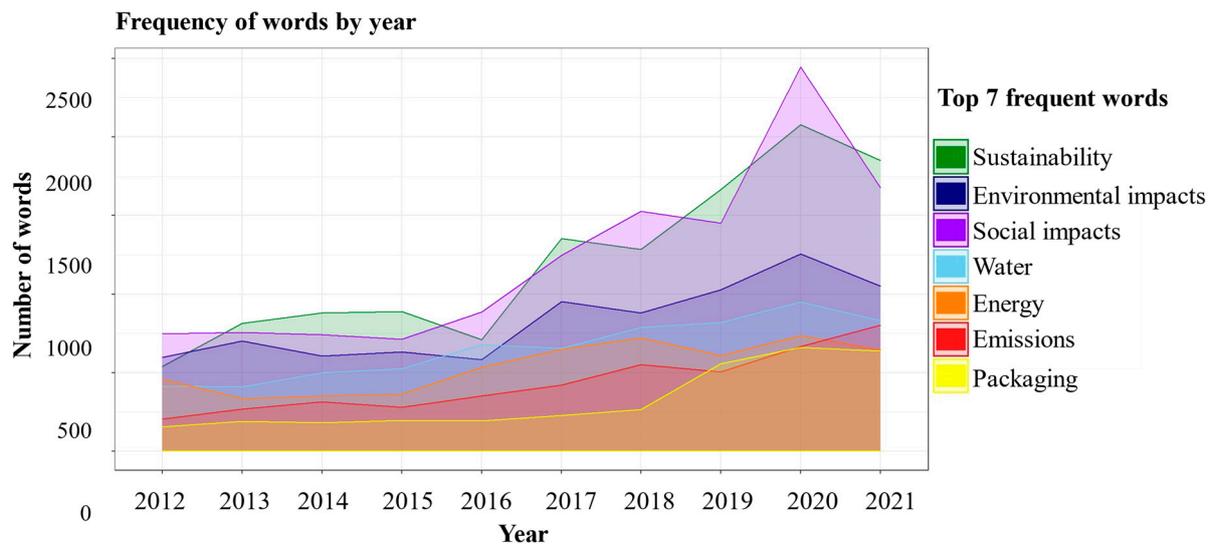


Figure 11. Distribution of the top seven sustainability-related words noted in the sustainability reports over the years.

4. Final Comments and Future Perspective

The utilization of a literature review, a Delphi study, and topic modeling allows for the collection of critical information and the generation of knowledge related to the impact of global megatrends such as digitalization, social behavior change, and sustainability on the hygiene tissue industry. This study pioneers this domain and opens the door for future applications in multi-criteria decision making (MCDM) models. It further assesses the impact and drives decisions to enable an in-depth investigation into global megatrends and their effect on market trends and consumer behavior. By aligning business strategies with the principles of multi-criteria decision making (MCDM), companies can better adapt to evolving market demands, ensuring resilience and competitiveness in an increasingly eco-conscious world. Additionally, the application of the criteria created is not limited to MCDM; they can also inform market research methodologies to further assess other aspects within the industry, such as focus groups, consumer surveys, and more.

Insights from this work will provide a solid foundation for a future research line involving the development of focus groups, as well as a subsequent nationwide consumer survey. Data collected from the Delphi study presented in this work will be significant in future hygiene tissue market research methodologies, particularly in determining which product attributes and levels to consider and in designing the related questionnaires. This future research will aim to evaluate consumer attitudes toward hygiene tissue products labeled as sustainable, with a specific focus on assessing consumer considerations and perceptions regarding products containing conventional fibers (e.g., from both recycled and virgin woody sources), as well as alternative sources (e.g., from agricultural residues and fast-growing plants). This insight will enable companies to align their offerings more effectively with consumer expectations for sustainability and digital convenience.

5. Conclusions

The results of the present research demonstrate the significant influence of global megatrends on the hygiene tissue industry. The digitization megatrend, for instance, is expected to cause a 50–75% reduction in the availability of recycled writing and printing paper in the U.S. and Canada by 2020, urging the industry to explore alternative material sources such as OCCs, as well as non-wood fibers such as wheat straw and bamboo. While incorporating brownish fibers from OCCs can make the finished product appear more environmentally friendly for sustainability-oriented consumers, the development

of low-carbon footprint bleaching process options might be required to cater to diverse consumer preferences.

Consumer behavior, particularly among younger generations, emphasizes the demand for the transparency, quality, and accessibility of sustainability-related information, guiding future product development towards sustainability. The evolution of sustainability metrics, with a notable shift towards specifying key indicators, such as emissions, on corporate sustainability reports and product packaging, points towards an industry trend of providing clear carbon footprint data. This transparency is anticipated to empower consumers to make informed decisions and embrace sustainable hygiene tissue products, potentially at a premium price. Innovations in product development, such as the exploration of alternative bleaching processes and fibers, underscore the industry's commitment to addressing sustainability challenges. The reliance on certifications from entities such as the FSC and PEFC highlights a move towards accountability and trust-building with consumers.

This study also highlights the importance of employing qualitative and quantitative research techniques to assess and measure the impact of industry trends. A critical aspect of this study involved combining a literature review with estimating business production and capacity growth rates. This approach was instrumental in identifying the scale of industry disruptions and predicting their future impact. Concurrently, the Delphi study proved to be an effective qualitative research technique, particularly in building an expertise-based understanding of topics characterized by uncertainty or insufficient evidence, such as sustainability. Additionally, the study utilized topic modeling analysis to explore, discover, and measure the evolution of key topics within a historical text collection. This analysis provided valuable insights into the industry's past, present, and future behaviors.

Furthermore, it is important to emphasize that the changes occurring within the industry have an impact on all stakeholders, both internal and external, throughout the entire value chain. One significant change is the consideration of alternative fibers. Primarily, suppliers face the challenge of sourcing alternative raw materials that not only match availability but also meet the criteria for cost and performance, ensuring that they do not introduce additional disruptions into the value chain. As alternative fibers are incorporated, manufacturers must ensure that their current processes can handle these new materials, or they must make any necessary adjustments to accommodate them. Retailers play a crucial role by collaborating with communities and regulators to smoothly introduce new product attributes into the market, minimizing any negative impacts and potentially enhancing value for consumers, competitors, and society. This highlights the importance of recognizing stakeholder impact when incorporating changes into a business model.

The insights of the present research point towards a growing emphasis on environmental responsibility, consumer-centric strategies, and transparent communication as key pillars for sustaining growth and fostering a more sustainable future in the hygiene tissue sector.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Appendix A.1. List of Questions for Round I (1-1 Interviews) of the Delphi Study

1. Based on your experience, how would you define sustainability within the hygiene tissue industry? Are there specific metrics you want to use in your definition?
2. What are the attributes frequently related to sustainable products in the hygiene tissue industry?
3. What are the visual characteristics (color and figures on packaging/labels) usually related to sustainability?
4. What do you think are the main challenges or barriers to purchasing sustainable hygiene tissue products (as experienced by consumers)?
5. What product attributes drive consumers to purchase sustainable products? Based on your expertise.
6. How do you think the growth of e-commerce will affect the pace of adoption of sustainable products?
7. Based on your experience, what significant attributes do you anticipate will be related to sustainable products in the hygiene tissue industry in the next ten years?
8. From a consumer perspective, what kind of fiber do you think would be perceived as more sustainable (recycled, non-wood fiber, virgin fiber, unbleached fiber)?
9. What color of finished products might relate better with sustainable hygiene tissue products? (e.g., bleach (white), unbleached (yellow, brown, or mocha))
10. Based on the stages of the life cycle of your products (raw materials, manufacturing processes, utilization, and after-use disposal), what stages could cause a major impact on consumer perception if it can be improved from a sustainable perspective?
11. How do certifications influence consumers' perception and purchase behavior in the hygiene tissue industry? (e.g., green seal, FSC, PEFC, USDA certified bio-based products, etc.).

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