

Article

Product Recalls in European Textile and Clothing Sector—A Macro Analysis of Risks and Geographical Patterns

Vijay Kumar

The Swedish School of Textiles, University of Borås, Allégatan 1, 501 90 Borås, Sweden; vijay.kumar@hb.se;
Tel.: +46-(0)-33-435-45-72

Abstract: Textile and clothing (T&C) products contribute to a substantial proportion of the non-food product recalls in the European Union (EU) due to various levels of associated risks. Out of the listed 34 categories for product recalls in the EU's Rapid Exchange of Information System (RAPEX), the category 'clothing, textiles, and fashion items' was among the top 3 categories with the most recall cases during 2013–2019. Previous studies have attempted to highlight the issue of product recalls and their impacts from the perspective of a single company or selected companies, whereas limited attention is paid to understand the problem from a sector-specific perspective. However, considering the nature of product risks and the consistency in a higher number of recall cases, it is important to analyze the issue of product recalls in the T&C sector from a sector-specific perspective. In this context, the paper focuses on investigating the past recalls in the T&C sector reported RAPEX during 2005–2021 to understand the major trends in recall occurrence and associated hazards. Correspondence Analysis (CA) and Latent Dirichlet Allocation (LDA) were applied to analyze the qualitative and quantitative recall data. The results reveal that there is a geographical pattern for the product risk that leads to the recalls. The countries in eastern part of Europe tend to have proportionately high recalls in strangulation and choking-related issues, whereas chemical-related recalls are proportionately high in countries located in western part of Europe. Further, text-mining results indicate that design-related recall issues are more prevalent in children's clothing.



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Keywords: product recall; product risk; textile and clothing; correspondence analysis; Latent Dirichlet Allocation

1. Introduction

The Textile and Clothing (T&C) sector plays an important role in the European manufacturing industry, which generates a turnover of about EUR 180 billion annually [1]. Over the last few decades, it has emerged as a sector where the supply chain stakeholders located globally are involved in one supply chain [2]. The European T&C supply chain has seen a migration of labor-intensive and low-value-addition manufacturing activities towards locations with less expensive labor and available resources [3]. As a result, the T&C supply chain has become a long and complex network of stakeholders with increased difficulty for the lead firms, such as retailers and fashion brands, to coordinate and track the suppliers, which makes the supply chains prone to faults and non-compliance. A product-harm crisis is one such situation where the product does not comply with the regulatory requirements—such as mandated safety standards or poses an unreasonable risk to the user or environment [4]. While the product-harm crises result in negative publicity for the brands, many of them result in product recalls [4].

A product recall, in general, refers to a remedial step that requests to return products, usually due to the discovery of defects, safety issues or failure to meet the mandatory safety standards that could lead to substantial harm to the user, public or the environment [5]. A single product recall may lead to the withdrawal of millions of products from the market, with incurring logistics and replacement costs and reputation damage [6]. In the past, T&C

brands made product recalls on different occasions due to various issues including design issues that create safety concerns for the wearer, an excessive quantity of dyes and other chemicals, not meeting safety standards related to textile flammability, etc. [7]. Recent product recalls include 400,000 pieces of infant and toddler clothes due to snaps breaking and detaching [8,9]. According to the Rapid Exchange of Information System (RAPEX), which monitors the non-food items recalls for countries in the European Union (EU) and other participating countries, a total of 2220 unique recalls were notified in the year 2020, among which ~6.5% of the total recalls were related to the product category ‘clothing, textiles, and fashion items’. Out of the 34 listed categories for product recalls in RAPEX, the category ‘clothing, textiles, and fashion items’ was among the top 3 categories with most product recall cases for the years 2013–2019 [10–16]. As product recalls are related with public safety, they are often governed by the local regulations/law on consumer safety/protection, where the manufacturer or distributor may be penalized for failure to make a recall or take necessary action for the products that are identified to have an issue. Many apparel brands or retailers either outsource their production or have manufacturing facilities strategically located to reduce production cost. Therefore, it is important for them to track the manufacturing activities to ensure product compliance and avoid product recall situations [17]. Similarly, it is important for the monitoring authorities to understand the product recall trends from a holistic perspective to formulate suitable policies and action strategies to efficiently control the non-complying textile products. Based on the analysis of the children’s textile and apparel product recalls, Norum and Ha-Brookshire [18] propose that product safety should be a part of the study curriculum to ensure that the future workforce is well-aware of the issues to handle or prevent product recalls and to ensure brand and public safety. Even though the T&C sector contributes significantly to product recalls, a limited number of studies have investigated it as a sector-specific issue. Most of the studies are either focused on product recalls that have specific users (e.g., children product recalls [18,19]) or selected companies from one or more sectors (e.g., [20–23]) where there is either no company from T&C sector or the focus is not to understand the problem from T&C sector perspective. Renata et al. [24,25] have investigated textile product safety from recall data; however, their aim was focused on analyzing the recalls from policy aspects. In addition, the majority of the studies have focused on the company perceptive or consumer perspective, whereas the studies on developing a comprehensive understanding of the nature of product recalls, particularly in the T&C sector, have remained elusive.

As product recalls in the EU’s T&C sector have consistently remained high, one way to understand the problem is by macro-analysis of the past recall data to understand how recalls have emerged over the past and understanding the trends in the nature of the hazards. Therefore, the purpose of this paper is to investigate the product recalls in the T&C sector where the focus is to develop an understanding from a holistic perspective by analyzing the past product recalls in the T&C sector notified between 2005 and 2021 by the EU’s RAPEX. With specific focus on the T&C sector in the EU, the study investigates “how the past recalls are related in terms of the product risks or hazards with the country of origin (i.e., where the product was manufactured) and country of destination (i.e., where the product was recalled)?”. In addition, to understand recalling factors, the study investigates “what are the main reported non-compliant aspects of the recalled product?”.

The rest of the paper is organized as follows. Section 2 discusses the related literature, and Section 3 discusses the empirical data used in this study and the process and methods followed to analyze the empirical data. Section 4 presents and discusses the findings. Finally, Section 5 presents the conclusions and Section 6 presents the future research.

2. Related Literature

Product recall is a situation when a manufacturer or distributor removes or recalls a product from the market or the users. The reasons for the product recall are associated with the non-compliance of the product with the required safety standards or the issues, such as design flaws or defects, which can cause substantial harm to the users or envi-

ronment [5]. A product recall may result in a significant cost to the companies, damage the brand image in the short and/or long run [26,27], and can even lead to bankruptcy. Studies in the past have focused on investigating the impact of product recalls, and various handling strategies [20,26–31]. Besides other organizational and functional reasons, studies have identified globalization as a major reason for the increasing number of product recalls [30,32,33]. As products and supplies in the global supply chains move across geographical and national borders, it creates multiple barriers among the supply chain stakeholders [33]. Consequently, it poses challenges in keeping track of all aspects of the products. In this context, the study by Steven et al. [32] reveals that offshore outsourcing, e.g., manufacturing by a third party in another country, has a stronger effect on product recalls as compared to simple offshoring, i.e., manufacturing in another country. Interestingly, when comparing domestic outsourcing with offshoring, the former results in lesser recalls as the cultural barrier created in the latter case may negatively impact the product quality and result in more recalls [32]. In addition, Luo [34] highlights that the overseas manufacturers in the supply chain are mostly highlighted as responsible for the issues associated with the product recall, and linked to the factors associated with the manufacturing country such as corruption, lax law enforcing, lack of government supervision, and increasing cost-cutting pressure as a responsible factor for the lack of attention for the design/product quality and safety attributes from the manufacturers. From the consumer aspect, Byun et al. [35] reveal that while the loyal customers stay with the brands even after the recall notification, they delay the purchasing of the affected products. Nonetheless, Vassilikopoulou et al. [36] found that the consumers were likely to perceive a product as less dangerous a few months after the product was marked for recall. Therefore, time acts as an important factor on consumers' attitude, as consumers tend to forget the crisis of a product recall and become engaged with the same company to continue purchasing [36]. In addition, a recent study by Kuang et al. [37] reveals that in case of a failure, including harm crisis and product recalls, customers who were acquired through a referral reward program would likely form a more positive overall post-consumption evaluation than those who were acquired through advertising. Besides mitigating the adverse impact of unsafe products, product recall may also occur in case of consumer fraud resulting from organizational misconduct [38]. The misconducts may not only prompt the customers to take actions that negatively impact the organization or brand, but also influence other customers, which may damage the brand severely [39].

In context of T&C sector, several studies have investigated the product safety aspects and investigated the product recalls for product analysis as well as the impact on organizations. As the appropriate design and use of the right materials is important for safe apparels, a stream of research (e.g., [40–42]) has focused on understanding the role of various chemicals and garment design on health hazards, and the development of systems or frameworks to systematically develop safe garments. In addition, a few studies have focused on exploring the product recalls from system perspective and investigated the textile product recalls [24,25].

While the problem of product recalls in the T&C sector has been highlighted by many studies in the past, very few studies have investigated them as a broader issue. Kumar and Ekwall [43] investigate how various macro-indicators explain the frequency of T&C product recalls in the EU and conclude that many socio-economic parameters have a significant impact on the T&C product recalls. Interestingly, Kothari and Mathews [44]—which investigate the retailers awareness of kidswear safety regulation in India—found that 50% of the retailers in the organized sector and 97% of the retailers in the unorganized sector were not aware of the product recalls of the unsafe kidswear. In this context, Norum and Ha-Brookshire [18] focus on a descriptive analysis of product recalls for children's textiles in the US, highlighting the need for education on product safety in order to tackle the challenges of product recalls. While there is a substantial literature on product recalls within the T&C field, most of the studies have focused on understanding the design, material, and related aspects of T&C products and have delimited to certain recall cases. As a result,

a limited attention is paid to develop a holistic understanding. Such an understanding is particularly relevant to the T&C sector in the EU, not only to improve the public safety but also to tackle the issue of relatively higher number of recalls among all reported categories.

3. Empirical Data and Methods

3.1. Empirical Data

The Rapid Exchange of Information System or RAPEX is the system that notifies the dangerous non-food products identified or discovered in the EU member states. The database consists of all notifications since 2005, published under different product categories. The empirical data used in this paper contains all notifications made under the category “clothing, textiles, and fashion items” (referred to as TCF items or products hereafter) from the year 2005 to 2021. The raw data consists of attributes such as risk type, product, notifying country, countries where the recalled product was found, risk legal provision, risk, (product) description, alert number, brand name and model, barcode number, and if the recalled product is identified as counterfeit. There were a total of 4859 recall notifications included for analysis in this paper that are publicly available on RAPEX portal (<https://ec.europa.eu/safety-gate-alerts/screen/search> (accessed on 8 August 2022)). It must be noted that the UK is included in this analysis, as it was the part of the EU for most of the duration for which the product recall data was analyzed in this study.

3.2. Methods

To understand product recalls on a broader level in the T&C sector, it is important to consider at least two aspects of the recalls, i.e., the occurrence or trend of the product recalls and the reasons behind the product recalls. The analysis of the occurrence of the product recalls relates with quantitative data analysis where the pattern of recalls such as recall location, risk category, etc., can be a focus for analysis. On the other hand, the analysis of the reasons behind the product recalls relates with the qualitative data analysis aspect where the analysis of the text description of the recalls can help in developing a better understanding of the recalls. In this direction, the paper follows two analyses, i.e., first, an analysis of the occurrence of TCF product recalls from the recalling country and product origin country perspectives, and second, analyzing the recall descriptions through text mining. For the former analysis, correspondence analysis has been employed, which is an exploratory data analysis technique used to find the association between two or more categorical variables. For text mining, Latent Dirichlet Allocation (LDA) is followed to analyze the text and identify the emerging themes based on the text description or risks of the product recalls. Data fields ‘Risk legal provision’ and ‘Risk’ fields of each recall notification obtained from the RAPEX database were analyzed for LDA. A brief overview of the research process is shown in Figure 1.

For the analysis of recall occurrence, first, the recall data were extracted from the RAPEX database and then converted into the occurrence frequency. This includes calculating the frequency of the TCF products recalled with respect to the destination countries—i.e., where the recalled products were found, reasons for recalls—e.g., hazard associated with the product, country-of-origin of the recalled products—i.e., where the recalled product was manufactured. The obtained data from the RAPEX database consists of description or text details with each recall labeled under ‘risk legal provision’ and ‘Risks’. For the text analysis of the recalls, the ‘Risk legal provision’ and ‘Risk’ data fields were extracted for each recall. If these fields contain the relevant information required to understand the recall risks, they were joined together for each recall before further processing. The extracted descriptions were first tokenized, i.e., converted into separate words, and then the unnecessary words that carry no substantial meaning in text mining were removed. These words include, articles, auxiliary verbs, etc. (e.g., ‘the’, ‘a’, ‘an’, ‘is’, ‘was’, ‘were’, ‘has’, ‘have’, ‘had’. etc.). Further, the filtered words were then converted into the inflected form—e.g., the term ‘recalled’ is converted into ‘recall’ (i.e., words were converted into their corresponding inflected or ground form)—to make the text or words comparable in all recalls. Some

additional words were removed from the recall description text, which is explained later. The preprocessed data were then analyzed using correspondence analysis and LDA, as explained in the following sub-sections.

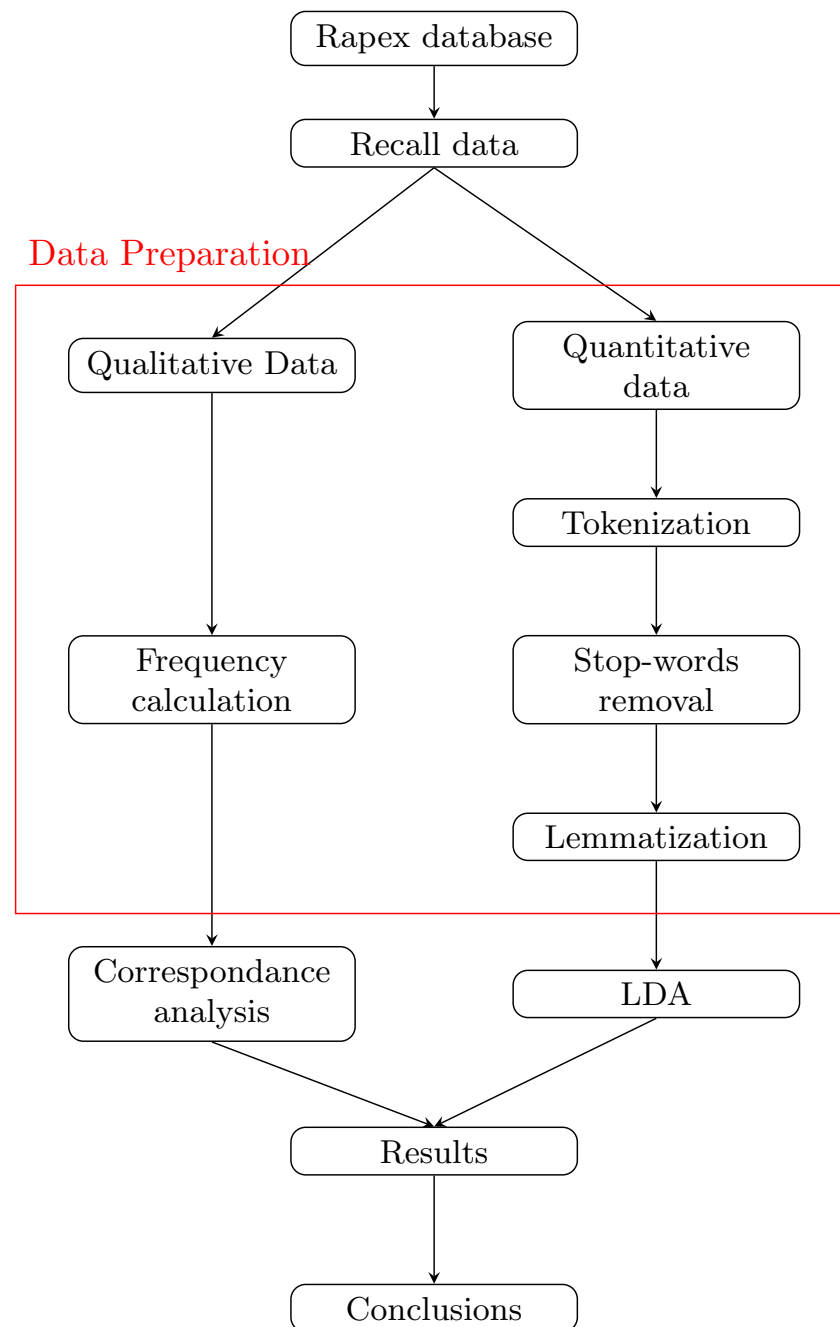


Figure 1. Research process.

3.2.1. Correspondence Analysis

Correspondence analysis (CA) is widely used in data mining to investigate the relationships among two or more categorical variables [45,46]. It is an exploratory data technique that explores the data without any predefined hypothesis and is used for dimensional reduction and perceptual mapping. The computational process for CA is as given below for two categorical variables, i.e., variable a with total n categories and variable b with p categories. Consider a contingency table or matrix $\mathbf{X} = \{x_{ij}\}_{n \times p}$ of size $n \times p$ where n is the number of rows, i.e., representing n levels of a categorical variable a and p is the number of columns, i.e., representing p levels of another categorical variable b . Further, x_{ij} represents

the element in i th row and j th column, which measures the frequency of observations for i th level of variable a , and j th level of variable b .

$\mathbf{X}$ is converted into a correspondence table or matrix $\mathbf{Z}$ as,

$$\mathbf{Z} = \{x_{ij}/N\}_{n \times p}$$

where $N = \sum_{i=1}^n \sum_{j=1}^p x_{ij}$

Further, the row profile, $\mathbf{r}$, and column profile, $\mathbf{c}$, can be calculated as,

$$\mathbf{r} = \mathbf{Z}\mathbf{1}_p$$

$$\mathbf{c} = \mathbf{Z}^T\mathbf{1}_n$$

where $\mathbf{Z}^T$ represents the transpose of $\mathbf{Z}$, and $\mathbf{1}_x$ represents a column matrix of elements as 1, of size $x \times 1$.

We can calculate the standardized residual matrix $\mathbf{S}$ as [45],

$$\mathbf{S} = \mathbf{D}_r^{-1/2}(\mathbf{Z} - \mathbf{r}\mathbf{c}^T)\mathbf{D}_c^{-1/2}$$

where, $\mathbf{D}_r = \text{diag}(\mathbf{r})$, and $\mathbf{D}_c = \text{diag}(\mathbf{c})$, $\mathbf{c}^T$ represents the transpose of $\mathbf{c}$.

In order to display the data in lower dimensions, the residual matrix $\mathbf{S}$ is decomposed using the singular value decomposition (SVD), as shown below,

$$\mathbf{S} = \mathbf{D}_r^{-1/2}(\mathbf{Z} - \mathbf{r}\mathbf{c}^T)\mathbf{D}_c^{-1/2} = \mathbf{U}\mathbf{D}_\alpha\mathbf{V}^T$$

where, $\mathbf{U}\mathbf{U}^T = \mathbf{V}\mathbf{V}^T = \mathbf{I}$, and $\mathbf{D}_\alpha = [\lambda_1^2, \lambda_2^2, \dots, \lambda_q^2]^T$, $q = \min(n-1, p-1)$ and $\lambda_1^2 \geq \lambda_2^2 \geq \dots \geq \lambda_q^2$.

Further we can calculate the standard row coordinates, $\mathcal{F}$ and standard column coordinates, $\mathcal{G}$ as,

$$\mathcal{F} = \mathbf{D}_r^{-1/2}\mathbf{U}$$

$$\mathcal{G} = \mathbf{D}_c^{-1/2}\mathbf{V}$$

Similarly we can calculate the principal row coordinates $\mathbf{F}$ and principal column coordinates $\mathbf{G}$ from $\mathcal{F}$ and $\mathcal{G}$, as shown below,

$$\mathbf{F} = \mathcal{F}\mathbf{D}_\alpha = \mathbf{D}_r^{-1/2}\mathbf{U}\mathbf{D}_\alpha$$

$$\mathbf{G} = \mathcal{G}\mathbf{D}_\alpha = \mathbf{D}_c^{-1/2}\mathbf{V}\mathbf{D}_\alpha$$

The data can thus be visualized into lower dimensions by selecting an appropriate number of columns of $\mathbf{F}$ and $\mathbf{G}$ (or $\mathcal{F}$ and $\mathcal{G}$) [47]. For example, for visualizing data in 2D, the first two columns of each matrix are selected and plotted on 2D scatter plots for visualization and interpretation. The variance explained by the k th dimension or component among total q dimensions/components can be written as,

$$\mathcal{V} = \frac{\lambda_k}{\lambda_1 + \lambda_2 + \dots + \lambda_q}$$

To analyze the association between the row and column variable, an asymmetric CA-biplot is used, in which the standard coordinate of one variable and the principal component of another variable are plotted in a single scatter plot [45].

3.2.2. Latent Dirichlet Allocation (LDA)

Latent Dirichlet Allocation (LDA) is an unsupervised machine learning method that is used for modeling a text corpus. LDA works on the principle that the text documents

can be represented by mixtures of underlying (latent) topics where each topic is characterized by a probabilistic distribution of the words in the vocabulary [48]. Therefore, each document—which involves one or more topics—is conceptualized to be written by drawing the words from the distributions of words from each connected topic. The process of identifying the structure of latent topics is carried out by calculating the posterior distribution of words for the selected number of latent topics by analyzing the occurrence of the words in the vocabulary, i.e., the available text in all available documents.

Let us consider a corpus D consisting of M product recall descriptions, where each description represents the details of a product recall, and description $d \in 1, 2, \dots, M$, having N_d words. Considering that there exist topics $\{1, 2, \dots, K\}$ and each topic k draws a distribution over given words or vocabulary of size V , $\beta_k \sim \text{Dir}_K(\eta)$, where $\text{Dir}_K(\eta)$ is a K -dimensional symmetric Dirichlet distribution with a scalar η . It is considered that for each description d , draw topic proportion $\theta_d \sim \text{Dir}_V(\alpha)$, where $\text{Dir}_V(\alpha)$ is a V -dimensional Dirichlet distribution with a positive K -vector parameter α . Further, for each word $i \in \{1, 2, \dots, N_d\}$ in each document $d \in \{1, 2, \dots, K\}$:

- Draw a topic assignment, $z_{d,i} \sim \text{Mult}(\theta_d)$, $z_{d,i} \in \{1, 2, \dots, K\}$
- Draw a word $w_{d,i} \sim \text{Mult}(\beta_{z_{d,i}})$, $w_{d,i} \in \{1, 2, \dots, V\}$

where Mult represents a multinomial distribution.

Blei and Lafferty [49] (p. 74) presented the abovementioned arrangement in a directed acyclic graph, as shown in Figure 2. This can be further written into a joint probability distribution as [50,51],

$$p(\mathbf{W}, \mathbf{X}, \Theta, \mathbf{B} | \alpha, \eta) = p(\theta | \alpha) p(z | \theta) p(\beta | \eta) p(\mathbf{W} | \mathbf{Z}, \beta)$$

where $\mathbf{W}$ is a matrix with assigned words, $\mathbf{Z}$ is a matrix with assigned topics, $\Theta = [\theta_1, \theta_2, \dots, \theta_K]$, and $\mathbf{B} = [\beta_1, \beta_2, \dots, \beta_V]$. Hence, we can calculate a posterior distribution for each topic, i.e., $p(\mathbf{Z}, \theta, \beta | \mathbf{W}, \alpha, \eta)$ using collapsed Gibbs sampler [52], which can be used to determine the probabilistic association of a recall description for the given topic.

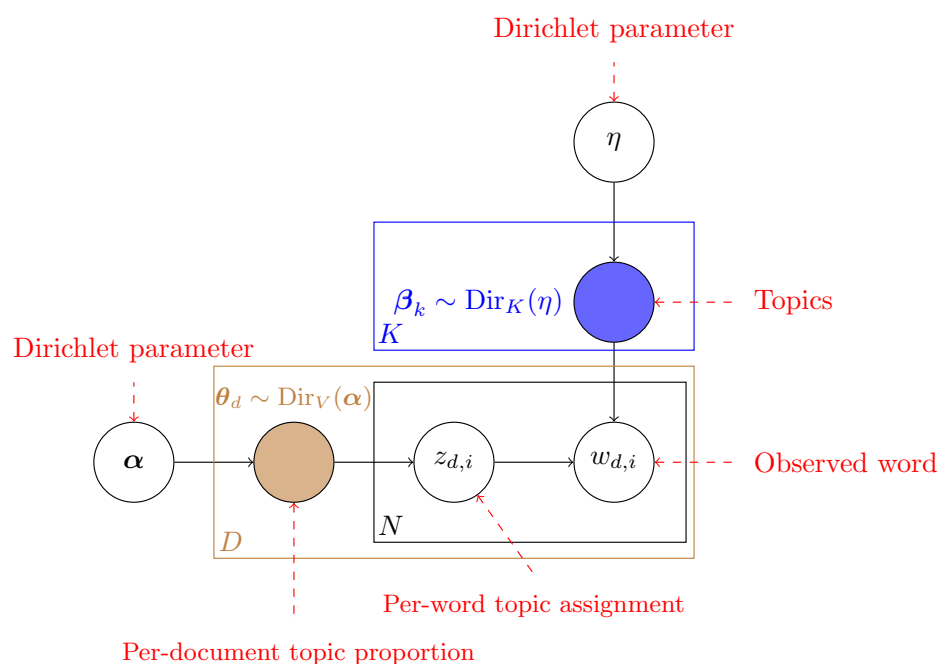


Figure 2. Latent Dirichlet Allocation in plate notation. Adapted from Blei and Lafferty [49].

Python 3.8 and open-source python package Gensim [53] (Github repository (<https://github.com/RaRe-Technologies/gensim>, accessed on 8 August 2022)) were used for fitting the LDA model in this paper. The hyper parameters used for LDA were $\alpha = \beta = 1/\text{No. of topics}$, as a commonly followed approach (e.g., see Refs. [54,55]).

4. Results

4.1. Descriptive Analysis

A total of 4859 unique recall notifications related to TCF products were made from 2005 to 2021, as shown in Figure 3A. There was an increasing trend in the total recall notifications until 2012, and it subsequently decreased afterwards. Strangulation is the most common reported risk type for the recalled TCF products, as Figure 3B reveals. The top four risks, i.e., strangulation, injuries, chemicals, and choking account for a little over 98% of all recalls. It must be noted that some recall notifications were reported with multiple risk types, and Figure 3B shows the frequency distribution for each risk type. In this context, although chemical-related recalls account for about 18% of total recall notifications, the recalls related to environmental issues are less than 0.5%. This indicates that compliance with chemicals that did not meet the required standards was not leading to any environmental issue. Further, Figure 3C shows the TCF recalls made in different countries that are reported in the RAPEX database. Procedure-wise, a recall notification is made when a local authority identifies a non-complying product. After notification of the recalled product made, often the same non-complying products are found in other countries, which were subsequently recalled without registering a new product recall in the RAPEX system. Instead, the additional countries—where the recalled products were found—were added to the data field ‘Found in’ in the original notification on the RAPEX database. In this context, Figure 3C presents the Total TCF recalls in two parts, namely *Notified* and *Found*. *Notified* represents the total unique recall cases *initiated* by a country, whereas *Found* represents the total unique recall cases that were made after a recall notification made by another country. Further, *Total* represents the summation of *Notified* and *Found*. Bulgaria has reported the highest number of total recall cases for TCF products and about 80% of all recall cases were notified by five countries. Greece has the 6th highest number of recalls *notified* to the RAPEX database and the 4th highest in the number of total recall cases, as Greece has made a large number of product recalls, which were notified by the other countries. The origins of recalled products are shown in Figure 3D. The origin of the recalled TCF product can be traced back to China for at least ~48% of cases, whereas ~17% of the recalled TCF products have remained unknown. Interestingly, the top three identified countries (i.e., excluding unknowns) are outside of the EU.

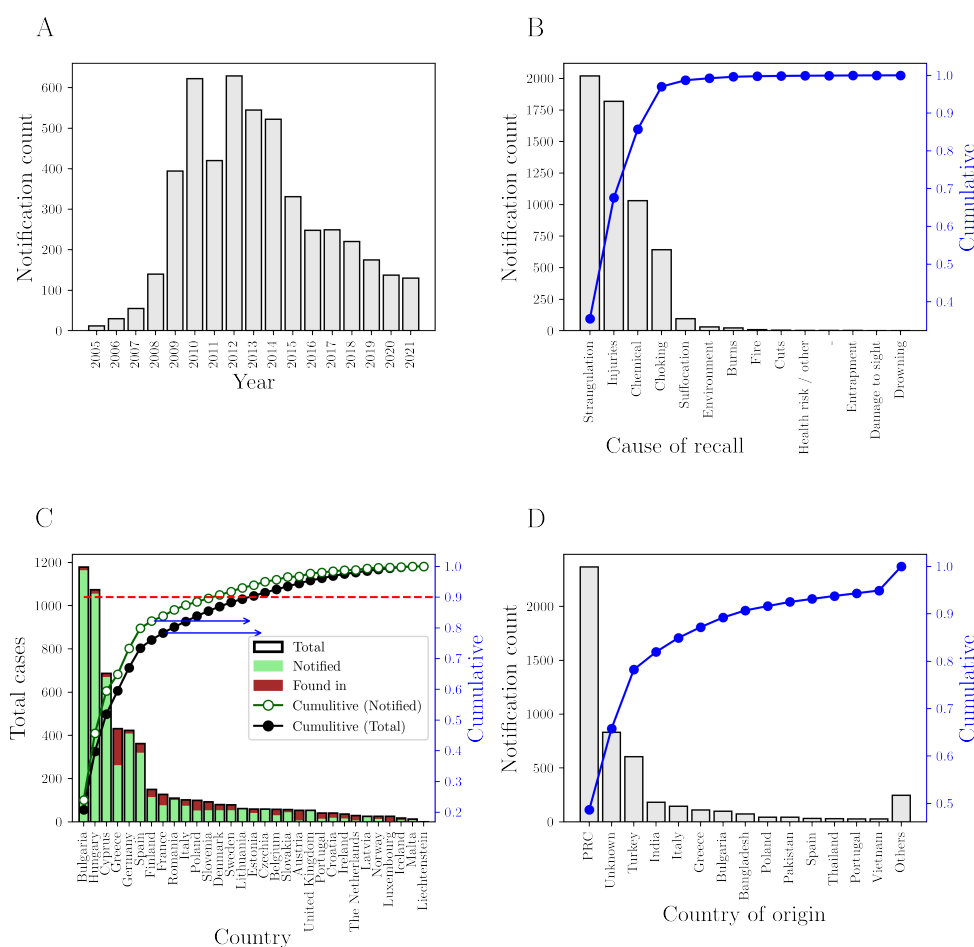


Figure 3. Distributions of (A) product recall notifications over years (B) cause of product recalls (C) countries of product recall and (D) countries of origin for recalled product. PRC: People's Republic of China.

4.2. Correspondence Analysis

Correspondence analysis (CA) reveals the relationships among two or more categorical variables. In order to understand the TCF recalls, CA was carried out to understand the relation between the risk types associated with the TCF recalls with countries where the products were recalled and with the origin of the recalled products. For the analysis, the top four risk types were considered, which account for ~98% of total reported issues in the recall notifications. Similarly, as discussed previously, the TCF items are not recalled uniformly in all countries. Some countries have a high representation when it comes to TCF recall cases reported in the RAPEX database. Therefore, in this analysis, the top countries by total recall cases that account for ~95% of total recall cases were considered. Asymmetric CA-biplot for countries where TCF items were recalled and the risk types are shown in Figure 4A, where the first two components represent ~97% of the total variance (see Figure S1, in Supplementary File). It is evident from Figure 4A that 'Component 1' aligns with the issues related to the top three risks, i.e., 'Chemical', 'Strangulation', and 'Injuries', whereas 'Component 2' aligns with 'Choking'. 'Injuries' and 'Strangulation' are closely related issues, which implies that countries where relatively high 'Strangulation' cases are reported, have a high chance of also reporting the 'Injuries' related issues. From an association perspective, it is interesting to note that, except for Czechia and Estonia, the 'Chemical' risk is strongly associated with countries that are located in the western part of Europe. On the other hand, 'Strangulation' and 'Injuries' risks are more associated with countries located in the eastern

part of Europe. The risk ‘Choking’ is found to be strongly associated with the United Kingdom. Further, Figure 4B shows the correspondence analysis for the country of origin of the TCF products with risk types. Similar to Figure 4A, the analysis was carried out for the top four risks and for the countries that account for the origin of ~95% of recalled TCF cases. The position of the People’s Republic of China—which is identified as the single largest origin of the most TCF recalled items—is close to the origin on asymmetric CA-biplot, which indicates that none of the risks are distinctive for the recalls or no specific risk distinctly differentiates the recalls when the origin is the People’s Republic of China. On the other hand, India, Pakistan, and Vietnam are strongly associated with ‘Chemical’ related risks. Similarly, Thailand is found to be associated with the ‘Choking’ risk. Though the reasons ‘Strangulation’ and ‘Injuries’ are near the origin of the CA-biplot, which indicates that these reasons are not very distinct for the countries, it is interesting to note that the countries are positively associated with these recall reasons—i.e., Greece, Bulgaria, and Italy—are countries in the EU. It can be further noted that Greece and Bulgaria show a negative association with the ‘Chemical’ risk, whereas India, Vietnam, and Pakistan show a negative association with ‘Strangulation’ and ‘Injuries’ risks. Therefore, it can be inferred that the products whose origin is in the EU have a relatively high probability for recalls that relate to ‘Strangulation’ and ‘Injuries’ risks among all risks, whereas the recalled products whose origin is outside the EU have more of a tendency to relate with chemical-related issues.

A

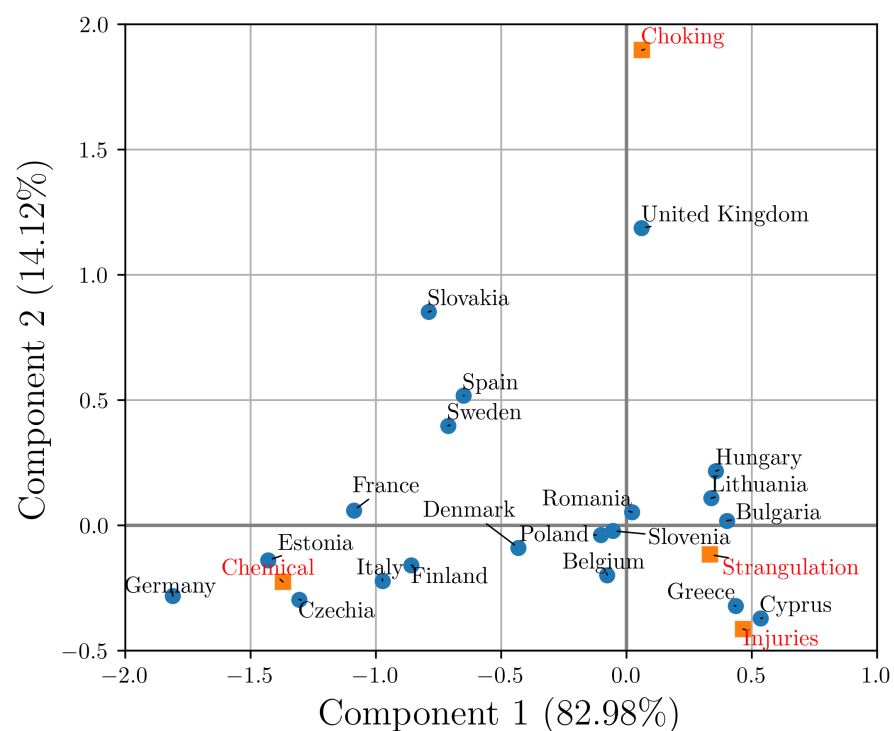


Figure 4. Cont.

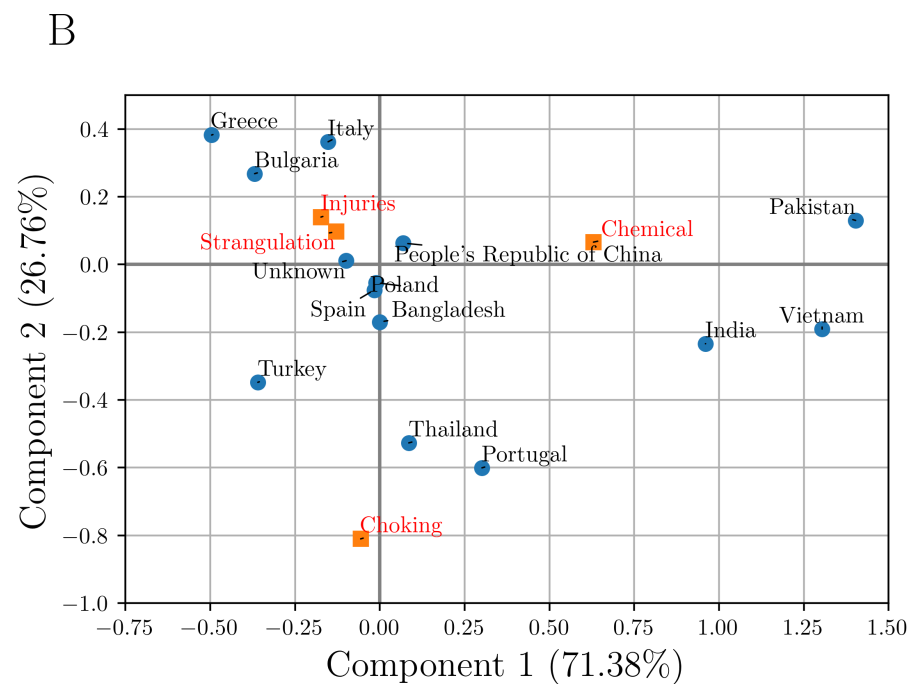


Figure 4. CA-biplot for (A) countries where the TCF products were recalled with reasons/issues for recall, and (B) country of origin of the recalled TCF products with reasons for recall.

4.3. Text Analysis of Recall Description

The text analysis of the description was carried out using LDA analysis. As aforementioned, the data fields ‘Risk legal provision’ and ‘Risk’ from the RAPEX recall notification of TCF products were used in the LDA analysis. Before presenting the LDA, a descriptive analysis of the text is presented. Figure 5 shows the occurrence frequency for the top 20 terms in the top 4 selected risks. It must be noted that the text was cleaned to remove the common words that carry no meaning in text mining. Further, some other words such as ‘strangulation’, ‘choking’, ‘injury’, ‘chemical’, ‘product’, etc., were removed, as these words either carry no meaning or the recall description was already classified in regards to these words. As shown in Figure 5, among the most common words, ‘regulation’ or ‘standard’ are common words that appear in all four categories, indicating the non-compliance of the product with certain national/European standards/regulations. Further, it is interesting to note that the ‘child’ appears in all categories except for ‘chemical’, which indicates that the recall reasons are associated with some children products. In addition, many of the terms relate to attachments to the garments—such as chord, drawstring, decorative, rhinestone, etc., that create risks related to injuries, strangulation, and choking. Further, the recalls with reasons ‘injuries’ and ‘strangulation’ share many common terms, which indicate that the recalled products in these categories share many common characteristics, and possibly notified to recall in the abovementioned issues together.

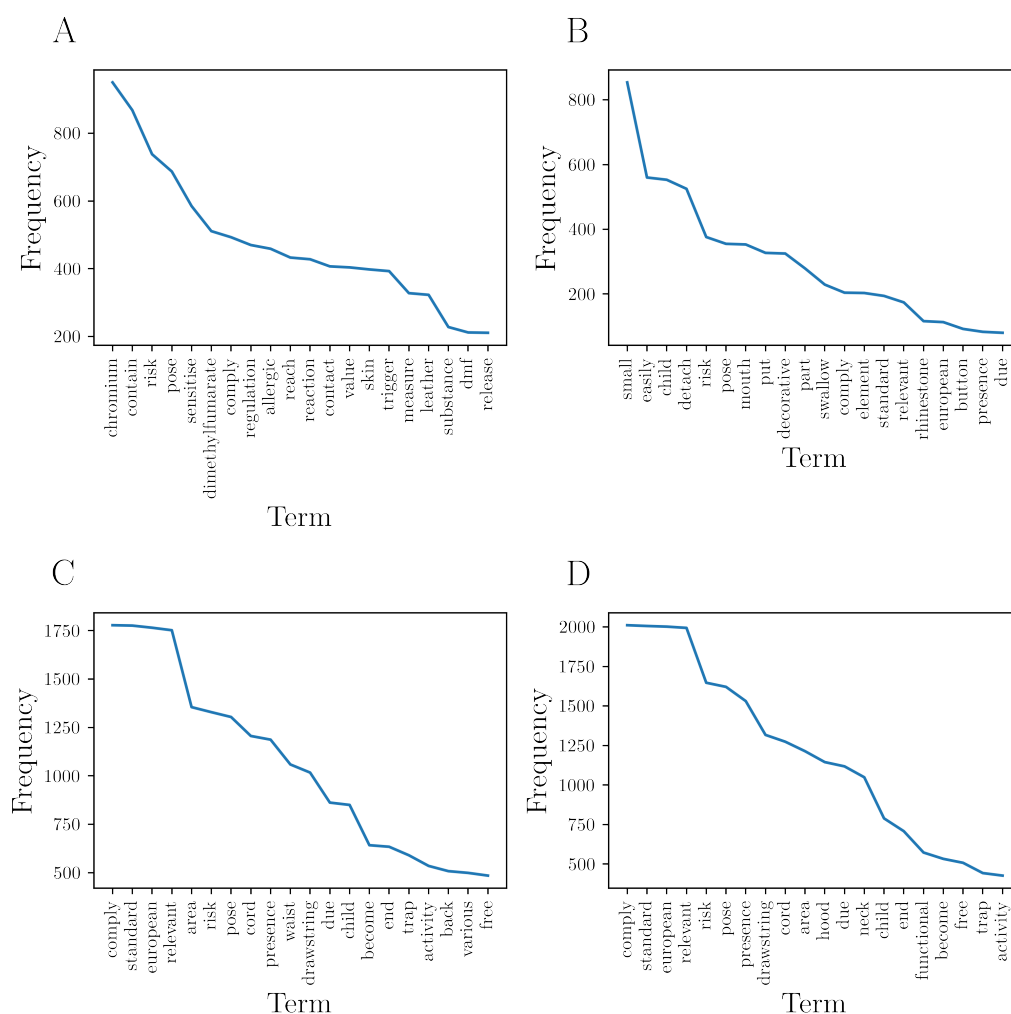


Figure 5. Term frequencies for the recall description in different categories, namely (A) chemical, (B) choking, (C) injuries, and (D) strangulation.

Further, Figure 6 shows the bi-gram analysis of the top 10 most adjacent terms used in the tokenized text of the recalled items. The term ‘comply’ appears with different terms in all bi-grams, indicating that the recalled products did not comply with certain aspects. For example, the chemical risks of the recalls are more related with the EU’s REACH regulations, as indicated by the bi-gram term ‘reach’, whereas injuries and strangulation risks mention the European standards. Furthermore, the products recalled for risks related to injuries and strangulation are associated with product attributes that pose risk or hinder the activities of a child, whereas the products recalled in the choking category are associated with the child’s ability to swallow or put the product’s parts in their mouth.

The LDA analysis of the text description of the recalls is shown in Tables 1 and 2. For each category, the LDA topic modeling was carried out with parameter $K = 3$, i.e., three topics, and the hyperparameters were selected as discussed in Section 3.2.2. As many recalls have the same description, the LDA analysis carried out only the unique descriptions i.e., by removing the duplicate description. Tables 1 and 2 show the words and associated probability with each topic or theme. The higher value of probability implies a stronger association of the word with the topic. For the recalls related to the risk ‘Chemical’, the three identified themes/topics are related to chemicals or chemical derivatives, namely, first, dimethylfumarate or dmf compounds, posing risk to skin; second, phthalate, which leads to health issues; and third, chromium and amine compounds, which relate with allergic reactions. Further time analysis reveals that the majority of the recalls between 2009 and

2010 were noted under Topic 1 (associated with dimethylfumurate or dmf) and, afterwards, Topic 3 (related with chromium and amine) became more prevalent. Nonetheless, the total number of cases under the chemical category has seen an overall decreasing trend, as shown in Figure S1A.

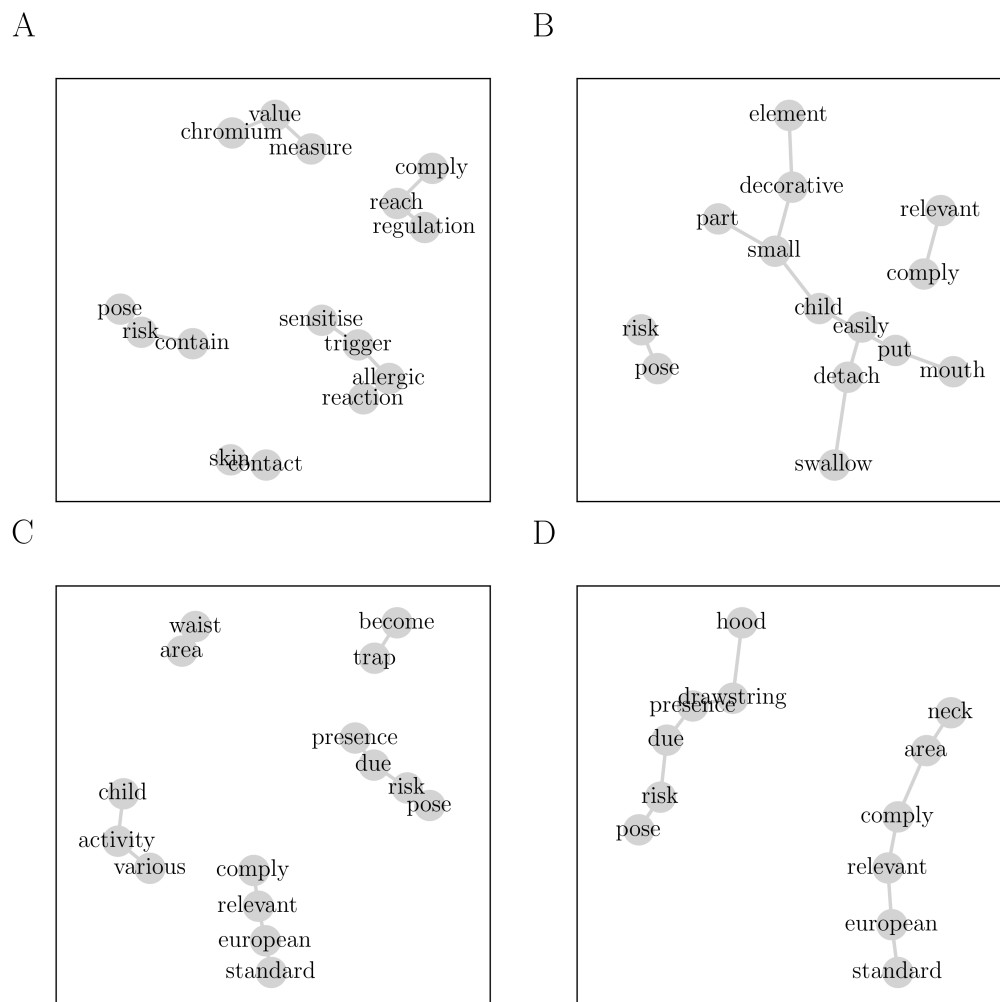


Figure 6. Bigram analysis for recall description in different categories, namely (A) chemical, (B) choking, (C) injuries, and (D) strangulation.

For the risk related to choking, strangulation, and injuries, there are many themes or topics that have overlapping attributes. For example, Topic 1 in the Strangulation category is similar to Topic 2, the Choking category. Similarly, Topic 3 in the Strangulation category has many common terms with Topic 2 in the Injury category. Nonetheless, it indicates that the risks associated with strangulation, injuries, and choking originate from the common product attributes. Within the Choking category, Topic 1 and Topic 2 align with the choking risks associated with a child's ability to put detachable product parts in their mouth, and the choking risks associated with drawstrings that do not follow the prescribed European standard, respectively. Further, Topic 3 aligns with the choking risks associated with plastic components. The majority of recalls are associated with Topic 1, as shown in Figure S1B. For the risks associated with the Injuries category, all three identified themes share common aspects (although to different probabilities) associated with the compliance of European standards, as the terms "European" and "comply" are shared by all topics/themes. Nonetheless, Topic 1 aligns with the injuries risks associated with cords (with garments), whereas Topic 2 aligns with product aspects, which could result in the trapping of the child during the activity. Similarly, Topic 3 aligns with the injury risks

associated with toggles and drawstrings attached to the garments. Further, from Figure S1C it can be inferred that recalls were mostly identified under Topic 1 from 2009 to 2014, and afterwards under Topic 2. For the risks associated with Strangulation category, Topic 1 and Topic 3 deal with the strangulation risks associated with drawstrings, whereas Topic 2 is related to decorative accessories and cords and aligns with products such as a bikini. Further, from Figure S1D, it is clear that recalls in Topic 1 were prevalent till the year 2013 and afterwards, the recalls in Topic 3 were prevalent. While at least one theme in each category has emerged due to European regulations or standards, many themes are related to children products. Further analysis reveals that the word ‘European standard’ appears 3191 times in all recall descriptions, out of which 3036 times it refers to ‘European Standard EN 14682’, which relates to the safety of the children’s clothing.

Table 1. Top 10 terms identified using LDA for recall reason categories ‘Chemical’ and ‘Choking’. (Tr: Term, Pr: Probability).

Chemical						Choking						
Topic 1			Topic 2		Topic 3		Topic 1		Topic 2		Topic 3	
Tr #	Tr	Pr	Tr	Pr	Tr	Pr	Tr	Pr	Tr	Pr	Tr	Pr
1	dimethylfumarate	0.071	regulation	0.035	chromium	0.049	small	0.131	risk	0.063	risk	0.038
2	risk	0.044	contain	0.033	contain	0.040	child	0.079	pose	0.057	safety	0.030
3	contain	0.044	weight	0.031	comply	0.038	easily	0.075	european	0.045	force	0.025
4	pose	0.041	value	0.027	reach	0.037	detach	0.073	standard	0.044	pose	0.022
5	skin	0.040	human	0.026	regulation	0.037	mouth	0.056	relevant	0.043	pin	0.018
6	contact	0.038	measure	0.026	amine	0.034	put	0.053	comply	0.040	child	0.018
7	substance	0.034	comply	0.024	aromatic	0.033	part	0.050	presence	0.034	cause	0.017
8	dmf	0.032	lead	0.023	release	0.029	decorative	0.034	due	0.032	plastic	0.016
9	sensitise	0.028	health	0.022	risk	0.026	risk	0.022	drawstring	0.028	addition	0.015
10	presence	0.025	phthalate	0.019	allergic	0.026	pose	0.022	area	0.027	upper	0.015

Table 2. Top 10 terms identified using LDA for recall reason categories ‘Injuries’ and ‘Strangulation’. (Tr: Term, Pr: Probability).

Injuries					Strangulation							
Topic 1			Topic 2		Topic 3		Topic 1		Topic 2		Topic 3	
Term #	Tr	Pr	Tr	Pr	Tr	Pr	Tr	Pr	Tr	Pr	Tr	Pr
1	risk	0.069	child	0.063	toggle	0.051	risk	0.074	cord	0.092	child	0.066
2	pose	0.068	become	0.061	drawstring	0.048	presence	0.073	tie	0.043	standard	0.059
3	presence	0.067	standard	0.059	child	0.040	pose	0.071	garment	0.039	european	0.058
4	comply	0.065	comply	0.059	risk	0.038	comply	0.070	halter	0.038	comply	0.058
5	standard	0.065	european	0.058	pose	0.036	relevant	0.070	neck	0.035	relevant	0.057
6	relevant	0.065	relevant	0.056	hood	0.029	standard	0.069	bikini	0.034	become	0.057
7	european	0.064	trap	0.056	cause	0.028	european	0.069	functional	0.030	activity	0.044
8	area	0.055	activity	0.047	relevant	0.026	drawstring	0.047	top	0.027	trap	0.044
9	cord	0.048	area	0.044	european	0.026	area	0.041	decorative	0.027	various	0.043
10	waist	0.043	various	0.044	comply	0.026	due	0.041	area	0.025	drawstring	0.042

The combination of LDA results with the correspondence analysis provides an interesting insight into the recalls. The EU’s REACH regulations and European Standards including European Standard EN 14682 apply to all countries that notify the product recalls on RAPEX. However, the CA reveals that recall cases related to the chemical risks are proportionately higher among all recall risks in the countries located in the western part of Europe, whereas strangulation and injuries are proportionately higher for countries in the eastern part of Europe. This pattern helps create a possible understanding. First, despite having similar regulations, the recalls are influenced by the enforcement of the regulations and other social conditions (as highlighted by Luo [34]) that impact the identification or notification of a few categories of the non-complying products with greater emphasis.

Another possibility stems from the quality or types of the products that may be specifically designed with targeted markets, where the retailers may have focus on certain product aspects or features influenced by cultural aspects or influenced by the local regulations, thus having differential recalls under different categories.

5. Conclusions

The paper deals with the analysis of the TCF product recalls in the EU reported by RAPEX. With a specific focus on T&C sector in the EU, the study investigates how the past recalls are related in terms of the product risks or hazards with country of origin and country of destination. In addition, the study investigates the main reported non-compliant aspects of the recalled product. Therefore, the main contribution to the literature lies in revealing the broader picture of the recalls in the EU, which is based on the analysis of the EU-based TCF product recalls, which are publicly accessible by the notifying agency RAPEX. In other words, the paper presents a holistic view of the product recalls in T&C sector in the EU.

In terms of total recalls, three countries, i.e., Bulgaria, Hungary, and Cyprus, have notified more than 50% of the total recalls, which indicates that the issue of TCF recalling is disproportionately prevalent in these countries. This indicates that there are some national factors that act as facilitators for these recalls. However, as this study uses the recall notifications as statistics—i.e., all recalls are treated equally, and no further information such as the size of the recall, stage of recall, etc., are investigated—the underlying factors for higher recalls cannot be established. Nonetheless, the recall statistics and pattern indicate that some local or regional factors are related to product recalls.

Another interesting finding relates to the recalls that are design-related and create hazards such as strangulation, injuries, and choking, where children's clothing are most commonly recalled under the non-conformance with the European Standard EN 14682. This shows the importance of the know-how of design-related regulations among the designers and product development team, which the organizations must utilize in order to ensure avoiding a recall situation.

In addition, the findings indicate that the TCF recalls that are related to strangulation and injuries-related harms have a positive association with the products of the EU origin, and a negative association with the products that have an origin outside of the EU, whereas the reverse is true to chemical-related recalls. This again proposes an important implication in terms of regulation awareness for the companies which have worldwide sourcing and manufacturing facilities. From the characteristics point-of-view, the strangulation and injury harms relate to the design aspect of the TCF products and these characteristics are tangible in nature. On the other hand, chemical-related characteristics are comparatively difficult to test or perceive since they are, unlike design-related characteristics, intangible in nature. Hence the companies may need to pay more attention to the ready-for-selling products in terms of the conformation of the product's intangible characteristics. This is due to the fact that the findings show that there is a comparatively high possibility for outside-the-EU-origin products to have issues with chemical-related recalls. Similarly, the companies need to focus more on design conformation as per the regulations, if the garments are being manufactured in the EU. This is due to the fact that strangulation and injuries-related recalls have a positive association for products that have origins in the EU.

6. Limitation and Future Work

There are certain limitations associated with this work. While this study focuses on investigating the patterns from the recall occurrence point-of-view and trend from the text mining of the recall descriptions, certain limitations pave the way for future research. In this paper, we rely on the empirical data about the TCF product recalls that are published by RAPEX. The recalls are therefore considered equal without taking into account the size of a recall (e.g., the volume or monetary value of products that are notified to be recalled). From a business point of view, it may be of particular importance to see the recall trends

from the aspects of value or volume, and future studies could attempt to understand the trends or patterns that account for the effect of these parameters. The findings from such studies can help companies to make concrete strategies to handle recall scenarios. Further, to find or establish the reason behind the disproportionately high number of recalls, there is a need to further investigate the market monitoring process. As there are local monitoring agencies that notify the non-conforming products to RAPEX, the differences in their functioning may help to understand the magnitude of the recall notifications in the EU, and the findings may help the policymakers as well. In addition, the LDA model in this study was developed for three topics to develop the initial insights. To develop an in-depth understating of the product recall categories, it is important that the appropriate number of topics are identified with some unbiased analysis (e.g., taking some mathematical measure while selecting the topics). Therefore, future research can also focus on identifying the appropriate number of groups for the LDA and investigate if any pattern exists in the identified topic from geographical and regulatory aspects. In addition, other data analysis and text analysis techniques can be investigated further to understand the nature of the recalls and overall trends.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/stats5040062/s1>, Figure S1: Variance explained by components for (A) countries where the TCF products were recalled with reasons/issues for recall, and (B) the country of origin of the recalled TCF products with reasons for recall.; Figure S2: Distribution of recalls under different identified themes for (A) chemical, (B) choking, (C) injuries, and (D) strangulation.

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