Structural topic modeling for corporate social responsibility of food supply chain management: evidence from FDA recalls on plant-based food products

Jiyoon An

Abstract
Purpose – The rising number of food recalls has raised concerns about complexity, globalization and weak governance in the food supply chain. This paper aims to investigate the recall of plant-based products with data from the US Food and Drug Administration.

Design/methodology/approach – Introducing the structural topic modeling method allowed us to test theories on recall in the context of sustainable food consumption, enhancing the understanding of food recall processes. This approach helps identify latent topics of product recalls and their interwoven relationships with various stakeholders.

Findings – The results answer a standing research call for empirical investigation in a nascent food industry to identify stakeholders’ engagements for food safety crisis management for corporate social responsibility practices. This finding provides novel insights on managing threats to food safety at an industry level to extend existing antecedents and consequences of product recall at a micro level.

Practical implications – For practitioners, this empirical finding may provide insights into stakeholder management and develop evidence-based strategies to prevent threats to food safety. For public policymakers, this analysis may help identify patterns of recalls and assist guidelines and alarm systems (e.g. EU’s Rapid Alert System for Food and Feed) on threats in the food supply chain.

Originality/value – Two detected clusters, such as opportunisms of market actors in the plant-based food system and food culture, from the analysis help understand corporate social responsibility and food safety in the plant-based food industry.

Keywords Food supply chain, Product recall, Plant-based food, Structural topic modeling, US Food and Drug Administration

Paper type Research paper

Introduction
Food is of living organisms (e.g. animals), by living organisms (e.g. producers) and for living organisms (e.g. consumers), which provides a venue to demonstrate the complex interactions to understand social responsibility. Ensuring food safety is one of the social responsibility practices to make food free from biological, chemical or physical hazards under the supervision of the US Food and Drug Administration (FDA) (Machado Nardi et al., 2020). Food innovation (e.g. plant-based food) is important as it acts as a change agent to the status quo and redirects the corporate social responsibility (CSR) practices at the operational (e.g. supply chain) and strategic (e.g. marketing) level (Modak et al., 2020).

Food innovation for sustainability is increasingly popular. Abrahamse (2020) has noted that individuals are motivated to involve in sustainable eating practices because they become...
more aware of environmental degradation from conventional food practices and seek health benefits from the alternatives. Elhoushy (2020) suggested that sustainable food choices can be made by striking a delicate balance between self-interest (e.g. personal gain from a cheaper, less sustainable choice) and morality (e.g. societal well-being of others). From this perspective, sustainable eating practices have resisted animal-based food culture.

A firm has invested in this eating practice as a strategic growth opportunity, proposing plant-based substitutes for animal-based food culture. Take Oatly and Beyond Meat as examples. Nasdaq-listed Oatly, an alternative to dairy culture, has grown its revenue to US $643m in 2021, more than tripled from US$204m in 2019 (Oatly, 2022). Nasdaq-listed Beyond Meat, a meat substitute, has shown a similar growth record, rising to US$465m in 2022 from US$298m (Beyond Meat, 2022).

Although plant-based food has provided alternatives to conventional animal-based food, Fuentes and Fuentes (2017) have questioned whether the production methods of plant-based products assure sustainability. They argue that, like conventional products, plant-based products use the industrialized manufacturing system with a complex supply chain network from farm to folk. Askegaard et al. (2014) agreed with this problematization because plant-based food has successfully criticized animal-based food. However, it remains similar power dynamics between individuals and food due to the shared industrialized food supply chain system. As a sustainable food practice shares commonalities in product methods with conventional products, the challenges of environmental degradation and exploitative resource management are still unresolved (Beverland, 2014).

Product recall in plant-based food can be seen as a pressure point to reveal food safety failure, posing a threat to CSR practices at the micro (e.g. organization), meso (e.g. industry) and macro (e.g. country) level (Molthan-Hill et al., 2020). Scholars have examined the antecedents and consequences of product recall at a micro level. Li et al. (2021) have examined a firm’s proneness to food recalls due to rising complexity, globalization and lack of strong governance. Zhang et al. (2020) have investigated a firm’s challenges in managing product recall capability in the food supply chain because of the dominance of large corporations and multiple checkpoints to manage suppliers’ qualifications. Wowak and Boone (2015) have noted the importance of recalls in the emerging industry due to their negative impact on finance and spillover effect on the nascent industry.

Existing literature is instructive at the microlevel, but it lacks broader perspectives to contextualize CSR practices. As Wowak and Boone (2015) noted, investigating product recall incidents in the nascent industry can provide insights because they negatively affect finance and cause collateral damages to “innocent” bystander firms due to spillover effects in the industry. This paper aims to conduct an empirical investigation using the structural topic model (STM) method to investigate food recall in the plant-based food supply chain. The following research questions will be investigated.

**RQ1.** What are the emerging topics of plant-based food recall processes to identify stakeholders in the food supply chain system?

**RQ2.** How are the topics interwoven to manage recall processes for food safety crisis management?

The recall incidents in the plant-based food industry will be investigated to expand the findings from existing literature to examine food safety threats in the emerging food innovation landscape. This paper is structured as follows. The literature review will provide a theoretical background for empirical investigation. In the methods section, data collection and analysis will be discussed. Theoretical and managerial implications will be discussed.
Literature review

Antecedents of product recall: a firm-level perspective

Existing literature views a firm as a focal point to examine the antecedents and consequences of product recall. Zhang et al. (2020) have noted the challenges of managing product recall capability in the food supply chain driven by the dominance of large corporations and multiple checkpoints to manage suppliers’ qualifications. Managing recall capability is central for the nascent industry as their negative impact on finance and a spillover effect on the nascent industry (Wowak and Boone, 2015). Marucheck et al. (2011) have investigated recall incidents and voluntary or nonvoluntary removal of products from the marketplace to contextualize the challenges of the food supply chain, including recall management through supplier relationships with regulations and standards (e.g. FDA).

Ketchen et al. (2014) have developed product recall scenarios (precise recall, incomplete recall, cascading recall and overkill recall) associated with different levels of product recall capability, operationalized with two dimensions: resource endowment and resource orchestration. Precise recall reflects high resource endowment and orchestration, which allows identifying sources of harm as the best scenario. Conversely, overkill recall indicates the inability to locate the harms due to a lack of resource endowment and resource orchestration as the worst scenario. Incomplete recall occurs from inadequate resource orchestration with multiple phases of recall incidents. Similarly, cascading recall is driven by the lack of resource endowment to handle recalls completely, creating mistreatment of recall procedures and outcomes.

Consequences of product recall: a consumer perspective

Scholars have investigated what factors influence consumer responses to product recall. Turgeon et al. (2015) have suggested two pillars for recall analysis: recall type (voluntary vs nonvoluntary) and recall severity (magnitude of the harm). Existing literature has examined recall severity as a moderator for consumer responses. To examine the consumer responses to a product recall, Liu and Shankar (2015) found that the negative responses to product recall increase when the incident involves high-quality products, high media attention and high-severity product harm. Germann et al. (2014) have examined the moderating effect of brand commitment on negative consumer responses to product recalls, as committed consumers are more forgivable for low-severity product harm but less forgivable for high-severity harm.

Laufer et al. (2005) have investigated how individuals drive product harm severity assessment and found that their decreased tolerance for ambiguity is positively associated with high perceived severity of product harm. To examine the firm’s responses to the product recall, Hora et al. (2011) have examined deployed strategy type to address the recalls and analysis of attributing the product defect in the supply chain. Muralidharan et al. (2022) have researched the firm’s response to the product recall is delayed when the incidents involve a high revenue-generating product, a firm with previous recall records and a design defect in the supply chain.

Although previous findings are instructive, they are not without limitations. The consumer response researchers have mainly used scenario-based lab experiments, reducing external validity. The researchers on firm responses have obtained data in the traditional manufacturing industry (e.g. toy), which differs from the agri-food supply chain system. The empirical contexts of existing research include a well-established industry, which is different from an emerging industry with food innovation (e.g. plant-based products) to involve various relationships with stakeholders.

Food innovation for sustainability

Plant-based food has gained popularity in proposing plant-based substitutes for animal-based food culture. Modak et al. (2020) view this innovation as a change agent to the status
quo by modifying the CSR practices at the operational (e.g. supply chain) and strategic (e.g. marketing) level. Nasdaq-listed Oatly and Beyond Meat are proposed as milk and meat substitute and have grown by 300% and 50% from 2019 to 2021, respectively (Beyond Meat, 2022; Oatly, 2022).

Although a plant-based product may progress in sustainable eating, it is not immune to the existing issues in food safety associated with the conventional food supply chain. The existing system involves storing, handling and distributing food products, including vulnerabilities with easy-to-contaminate perishable ingredients and intervening global supply chains (Whipple et al., 2009). Food innovation for alternative food movements and sustainable eating practices rise to fight against the food safety issues from the traditional food supply chain system.

Fuentes and Fuentes (2017) have raised a question about the production methods of plant-based products. They argue that plant-based products use the industrialized manufacturing system with a complex supply chain network from farm to folk. Askegaard et al. (2014) support this problematization because plant-based food has successfully criticized animal-based food. However, it remains similar power dynamics between individuals and food due to the shared industrialized agri-food supply chain system.

Existing literature has highlighted the importance of recalls in the emerging industry due to their negative impact on finance and a spillover effect on the nascent industry (Wowak and Boone, 2015; Zhang et al., 2020). A recall incident, documented by the US FDA, may serve as a pressure point to demonstrate the dynamics in the nascent agri-food supply chain system, which gives an empirical context to examine product recall capability in the food supply chain.

Methods

Data collection

Data collected by the FDA from 2012 to 2022 was used for analysis. Seventy-two recall cases were selected as the product description includes the target word, vegan. Figure 1 summarizes the distribution of recall data across severity levels and time. According to FDA
Class I recall indicates the product recall with serious adverse health consequences/death with a reasonable probability. Class I and II recall suggest temporally/medically reversible adverse health ramifications with a remote probability and the ramifications with a slim probability, respectively. Figure 1 shows the spread of Class I and II recalls across time. However, the rising trend of the Class I recall with the highest severity and the resurgence of the Class III recall may invite further investigation.

**Data analysis**

STM method has been used to analyze details of recall (e.g. recall reasons) in the data set. This approach provides the following advantages (Roberts et al., 2014). The topic model is grounded on latent Dirichlet allocation (Blei et al., 2003), which helps identify latent patterns of topics by examining the distribution of topics across texts. This bottom-up unsupervised machine learning method helps uncover hidden relationships with the concept, leading to a greater understanding of a phenomenon in an inductive manner. The identified relationships can be visualized as the topic network to investigate how various topics are interwoven, which may represent the various market actors in the agri-food supply chain system.

Conducting STM requires a series of data processing procedures (see Table 1) with the interpretive programming language R. As details of the recall are text data and unstructured data without predetermined format, this data needs preprocessing. As described in Step 1, text data is processed with stemming and stop word removal to identify root forms of the words and remove stop words to prepare topic modeling. Then, processed text constructs a corpus to represent a set of textual documents to represent the latent topics (Step 2). Finally, the STM estimates topic parameters to discover topic clusters and assess the topic prevalence (Step 3).

Table 2 summarizes ten topics with the most frequently occurring keywords.

Topic 1 is labeled as a gluten issue because some recalled products with gluten-claim include more than 20 ppm glutens. Patagonia recognized as an environmental-friendly brand (O’Rourke and Strand, 2017), is involved with Topic 1. Topic 1 is classified as Class II recall as it would affect patients with celiac disease (approximately 1% of the US population, King et al., 2020) in a medically adverse manner. Topic 2 is salmonella contamination. Recalls executed as powders, mostly sourced from a supplier, used to produce a plant-based product may be contaminated. This incident is a Class I incident, as salmonella may lead to death in some cases. Topic 3 is labeled as a dairy-based food culture. Eggs, milk and food with dairy products have received critical attention from the plant-based culture supporting egg, milk and meat substitutes. Traditional sweet dessert recipes consume dairy products, which makes a plant-based dessert product vulnerable to the risk of path dependency. Topic 4 is a voluntary recall. Reported voluntary recalls were mixture-type food (e.g. burgers, tamales and peanut butter) and all Class I types with severe consequences. Topic 5 is nonvoluntary recall, as the authority has inspected the product and enforced the recalls. All the recalled items failed to declare allergen

<table>
<thead>
<tr>
<th>Process Name</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stemming and stop word removal</td>
<td>Identify root forms of the words (e.g. contamination and contaminated can be reduced to contaminated) and remove stop words (e.g. the, is, at)</td>
</tr>
<tr>
<td>Building a corpus</td>
<td>Construct a set of textual documents to represent the latent topics</td>
</tr>
<tr>
<td>Estimating topic parameters</td>
<td>Discover topic clusters and assess the topic prevalence</td>
</tr>
</tbody>
</table>

Table 1: Data processing steps for structural topic model

Source: Author’s own creation
ingredients, and most are classified as Class I types. Topic 6 is labeled as food fraud. Scholars define food fraud as economically motivated food adulteration, which causes direct food fraud risk, indirect food fraud risk and technical food fraud risk with immediate material risk, long-term exposure risk and misrepresentation (e.g. country-of-origin) (Spink and Moyer, 2011).

The purposeful mismatches between the plant-based product and the product delivery (e.g. nutrition facts panel and ingredients list) were documented. Whole Foods Market, an Amazon company supporting the whole food initiative, is one of the perpetrators. Topic 7 is labeled as a plant-based agri-food supply chain system issue because the source of the food safety issue originated from an upstream supplier in the system. The firm engaging with the downstream market actors was notified of food safety issues and executed recalls, preventing negative effects. Topic 8 is Listeria monocytogenes contamination. These incidents are the Class I type recalls, but very little information was documented to explain how or why contamination occurred. Topic 9 is the soy lecithin issue due to the lack of disclosure. Soy lecithin is a food additive from soy (e.g. soy oil), as it should be disclosed as an allergen for food safety. Topic 10 is labeled as a chocolate snack issue as the traditional chocolate snack recipes include amalgams of allergen materials, such as wheat/flour, chocolate (associated with milk protein) and tree nuts.

Topic network analysis (Figure 2) visualizes how topics are related (i.e. cluster community). Topic 10 is the central node with the highest degrees as it directly connects to Topics 5 and 6 toward the downside (Cluster 1) and Topics 3 and 9 toward the upside (Cluster 2). Conversely, Topics 1 and 2 are the least central nodes with the lowest degrees as they only connect to Topics 7 and 8, respectively. We may identify two cluster communities via Topic 10. One is the downside community Topic 5-Topic 6-Topic 7-Topic 1, and the other is the upward community Topic 3-Topic 9-Topic 4-Topic 8-Topic 2.

Cluster 1’s topics may rise from the market actors’ opportunisms in the plant-based agri-food supply chain system. Opportunistic behaviors are conceptualized as active opportunism (e.g. purposeful self-serving conduct at the expense of a counterparty’s loss) and passive opportunism (e.g. passive acceptance). For food fraud, an exchange partner commits intentionally violating the contractual agreement for opportunistic profit at the expense of their exchange partner’s financial loss or harm (Amasiatu and Shah, 2018). To illustrate, plant-based food producers have promoted gluten-free claims by violating the standard and omitting soy lecithin, generating intentionally misleading product delivery practices to seek financial gains. Also, as an agent to market the plant-based product, they merely passed over the adulterating food incidents and executed recalls, showing less covert opportunistic behavior than food fraud. Nonvoluntary recalls have been applied to opportunistic behaviors in the agri-food supply chain system.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Proposed topic label</th>
<th>Topic label</th>
<th>Example keyword</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 1</td>
<td>Gluten issue</td>
<td>gluten, free, ppm, label, test</td>
<td></td>
</tr>
<tr>
<td>Topic 2</td>
<td>Salmonella contamination</td>
<td>powder, organ, supplier, use, salmonella</td>
<td></td>
</tr>
<tr>
<td>Topic 3</td>
<td>Diary-based ingredient issue</td>
<td>egg, milk, contain, peanut, sweet</td>
<td></td>
</tr>
<tr>
<td>Topic 4</td>
<td>Voluntary recall</td>
<td>bag, manufactur, almond, product, voluntari</td>
<td></td>
</tr>
<tr>
<td>Topic 5</td>
<td>Nonvoluntary recall</td>
<td>soy, complaint, declar, inspect, depart</td>
<td></td>
</tr>
<tr>
<td>Topic 6</td>
<td>Food fraud</td>
<td>ingredi, incorrect, mislabel, label, packag</td>
<td></td>
</tr>
<tr>
<td>Topic 7</td>
<td>Vegan agri-food system issue</td>
<td>firm, notifi, affect, determin, food</td>
<td></td>
</tr>
<tr>
<td>Topic 8</td>
<td>Listeria monocytogenes contamination</td>
<td>contamin, recal, listeria, monocytogen, various</td>
<td></td>
</tr>
<tr>
<td>Topic 9</td>
<td>Soy lecithin issue</td>
<td>undeclar, possibl, vegan, lecithin, white</td>
<td></td>
</tr>
<tr>
<td>Topic 10</td>
<td>Allergen issue</td>
<td>wheat, flour, chocol, allergen, walnut</td>
<td></td>
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</tbody>
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Source: Author’s own creation
Cluster 2’s topics may be explained by food culture issues. Topics with relatively high centrality represent diary-based (Topic 3) and soy-based (Topic 9) food culture issues. Plant-based food culture includes substitute initiatives for dairy products (e.g., meat, milk, and eggs) and mimicking animal-based substances (Laakso et al., 2022). Plant-based food producers can prevent food safety threats by building an allergen and adulteration-cautious food culture issues. As historical recall data helps identify vulnerabilities to the agri-food supply chain system, applying information technology for transparency (e.g., blockchain) may help value orchestration by converging interests from various stakeholders (Tan and Salo, 2023).

Discussion
The rising number of food recalls has raised concerns on complexity, globalization, and weak governance in the food supply chain. This paper aims to investigate the recall of plant-based products with data from the FDA. Introducing an STM method allowed us to test theories on recall in the context of sustainable food consumption, enhancing our understanding of food recall capability. This approach helps understand how to recall...
interrelated topics across various stakeholders in a specific nascent market segment, the plant-based food product. This finding answers a standing research call for empirical investigation in a specific food industry segment to identify stakeholders’ engagements (Oliveira et al., 2023).

The STM analysis revealed that the plant-based food supply chain shares threats to food safety with other traditional processed food companies. Many recalled items were plant-based substitutes for animal-based products in an industrial manufacturing supply management system. This plant-based supply chain management faces complex coordination with various suppliers from firm to folk and struggles from the lack of traceability in ingredients and food processing (material and production management) (Jonsson and Holmström, 2016).

The annual report of Beyond Meat (2022) has acknowledged that a nascent player in the sustainable eating landscape is more difficult to compete with the traditional meat-based food players because they are established vertically and horizontally integrated agri-food chain achieves the scale of the economy to keep their market dominance in demand and supply. Rondoni et al. (2022) suggested how competitive landscapes between conventional and plant-based eggs have evolved in the UK and Italy. Basu (2022) has noted that these market dynamics challenge plant-based food marketers to maintain relationship management with existing and potential consumers.

Further research may examine this rising player’s challenge with qualitative methods and test existing theories, such as institutional theory (Brito, 2001) and resource dependence theory (Rogan and Greve, 2015). When product recall is viewed as a crisis to successful CSR practices in an emerging industry, proactive and reactive approaches to the crisis help expand the CSR research paradigm: economic, social and governance risk.

Spatial analysis of recall incidents (Figure 3) indicates how headquarters experiencing product recalls are geographically dispersed across recall incidents over time. The results show proximity to share product recall capacities at the industry level. Stranieri et al. (2019) suggested introducing a revenue-sharing mechanism for supply chain coordination may increase sustainability as a proactive approach to the crisis. Scholars argue that industry-wide resource management for decreasing resource gaps and increasing resource orchestration can be a reactive approach to address the spill-over effect of product recall (Wowak and Boone, 2015; Ketchen et al., 2014). Implementing economic and governance measures may increase the industry-level approach against product recall.

The STM results have revealed the precursors, processes and outcomes of recalls in the context of the plant-based food industry regulated by the US FDA, which is associated with meso- and macro-level. Two topic cluster communities were identified: market actors’ opportunisms in the plant-based food supply chain system and food culture clusters. The identified clusters may expand the findings from microlevel (e.g. firm) research of existing literature.

In future research, scholars may conduct in-depth investigations on the key phases of recalls: precursor, process and outcome (Wowak and Boone, 2015). For the recall precursor phase, scholars may investigate how a firm’s resource allocation and composition of top management affect recall. Organizational culture to navigate complex supply chain relationships can be examined for the recall process phase. Furthermore, for the recall outcome phase, in addition to consumer responses, a firm’s sensemaking and learning from the recall incident can be assessed to advance the scholarship of recall.

This research has contributed to enhancing our understanding of recall but is not without limitations. This paper only includes data from the USA, limiting the findings’ generalizability. Future research may investigate data from different sources to examine the effects of external factors (e.g. cultural differences) on recall’s key phrases. Collaboration with food researchers may help understand the particularities of food recalls inspired by seminal papers (Soon et al., 2020; Potter et al., 2012).
This paper’s analysis unit was a recall incident level, which may limit our understanding of recall in the bigger picture. As the agri-food supply chain system involves complex market actors from the upstream to downstream supply chain, future researchers can adopt a multilevel perspective (Carter et al., 2015) for the recall studies. This may help explore hierarchical and nested relationships with market actors by examining multi data sources and theories to specialize in the specific data source. With this approach, the potential unit of analysis includes observations from individual market actors, functional teams in a specific organization and firms across different levels of supply chains. Big data analytics, handling structured (e.g. sales data) and unstructured data (e.g. Newspaper articles as text data), may be helpful to advance this initiative.

For practitioners, this empirical finding may provide learning opportunities on recalls. Understanding their precursors, processes and outcomes is a source for organizational learning to prevent threats to food safety. For public policymakers, this analysis may help identify patterns of recalls and assist guidelines and alarm systems (e.g. EU’s Rapid Alert System for Food and Feed) on food safety threats to the food supply chain.

Conclusion

For the nascent food supply chain (e.g. plant-based food), building product recall capability would face challenges that would threaten the well-being of stakeholders. This paper has empirically investigated FDA recall data in the nascent plant-based food supply chain.
chain. The analysis revealed that market actors’ opportunisms and sticky conventional animal-based food culture emerged in the topics that threaten food safety in the nascent plant-based food marketplace. For academia, a multilevel perspective investigating various analysis units may shed light on understanding in-depth understanding precursors, processes and outcomes of recall. For practice, technological advancement in food processing and logistics (Wowak et al., 2016) may address the revealed challenges, such as traceability, ingredient perishability, problem discovery lag and food production management (mingling and blending). These endeavors will continue to reduce threats to food safety to practice sustainable food consumption.

References


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