International Food and Agribusiness Management Review
Volume 25, Issue 2, 2022; DOI: 10.22434/IFAMR2020.0065

Received: 30 April 2020 / Accepted: 17 July 2021

Traceability in food supply chains: a systematic literature review and future research directions

REVIEW ARTICLE

Xiongyong Zhou[a,b] and Zhiduan Xu[ⓘc]

[a]*Postdoctoral fellow, Antai College of Economics & Management, Shanghai Jiao Tong University, 1954 Huashan Road, Xuhui District, Shanghai, 200030, China P.R.*

[b]*Visiting PhD, Logistic Operations Management, Cardiff Business School, Cardiff University, Cardiff, United Kingdom*

[c]*Professor, School of Management, Xiamen University, No. 422, Siming South Road, Siming District, Xiamen, Fujian, 361000, China P.R.*

Abstract

The food traceability system (TS) provides visual services for consumers by recording every operation procedure of food supply, processing, marketing as well as distribution throughout the supply chain. This study aims to review the academic papers which are related to food supply chain traceability (FSCT) and proposes a framework for future research. To do this, we carry out a systematic literature review of 278 peer-reviewed scientific literature published between 1994 and September 2019. By classifying the FSCT into pre-study and post-study of TS implementation, this study reveals a number of future research directions of FSCT based on thematic findings and points out that the focus on such issues has shifted to the post-adoption study of TSs. This study further categorizes nine specific research topics from past literature and identifies specific opportunities of each theme for future research.

Keywords: food supply chain, traceability, tracking, systematic literature review
JEL code: Q18

ⓘCorresponding author: zhiduanx@xmu.edu.cn

1. Introduction

Since the mad cow disease broke out in Europe in the late 1990s, consumers' concerns about food safety have continued unabated. In February 2019, Sanquan soup dumplings, a well-known food brand in China, was detected carrying an African Swine Fever infection. A nationwide panic broke out afterwards and nearly caused the breakdown of the company's supply chain. Incidents like these have created a negative image of food quality and negatively affected consumers' confidence in their daily consumption (Aung and Chang, 2014). Increasing evidence indicates that food quality assurance not only depends on safety technological advancements, stronger regulation, and governance mechanisms but is also very crucial to reduce product information asymmetry and quality risk (Zhou *et al.*, 2021). Such governance should be the whole-process monitoring of the food supply chain (FSC), instead of focusing solely on the quality in a particular node, such as the production or distribution. In response, the traceability system (TS), which is information technology to identify, capture, record, and display all the physical entities and locations throughout the entire supply chain, has been suggested and adopted in Europe, North America, and other highly developed regions (Regattieri *et al.*, 2007). Properly designed TSs improve information visibility across the supply chain and help to minimize unsafe or inferior products (Zhou *et al.*, 2021). In addition, such systems provide possibilities for actions to achieve a sustainable supply chain (SSC) that creates economic, environmental, and social benefits (Mol and Oosterveer, 2015). Food supply chain traceability (FSCT) has become a major concern as was also evidenced at the start of the Covid-19 pandemic and there is a dearth of research investigating this topic. With the spread of the Covid-19 pandemic accelerated, in addition to human-to-human, the spread of material-to-human has also emerged in the cold supply chains. To reduce the risk of human or material infection, the TS has been further advocated and promoted. Through the timely collection of upstream and downstream data in the cold supply chains, the unknown origin of the cold product can be quickly discovered, and potential contamination risks can be identified.

Research on FSCT dates back to the early 1990s, which can be generally divided into pre-study and post-study based on the timeline of TS adoption. The behavioral study has been a well-formulated field in the pre-adoption theory. By contrast, the post-adoption approach mainly involved how supply chain companies use TSs and extend their functions, as well as examine the impact of TSs' experimentation or implementation on their operations management. Overall, existing FSCT literature predominately focused on the pre-TS adoption study but paid limited attention to the post-adoption study. However, many common problems and issues are still worth summarizing and discussing (Karlsen *et al.*, 2013). For example, the theoretical lens was rarely mentioned or not even adequately used in traceability research, leading to an insufficient academic contribution that cannot be generalized and extended. In addition, the research object predominately focused on traceability at the organizational level, whereas less attention was paid to supply chain traceability (SCT) or external traceability. Moreover, no common theoretical framework in the existing literature can tease out current findings and inspire new research opportunities (Karlsen *et al.*, 2013). Thus, reviewing and reorganizing past documentation through a systematic view and creating a framework that identifies and illustrates gaps in future traceability research seem necessary and significant.

Before us, a small number of authors have reviewed several issues related to traceability in the food industry. Differences from this study are mainly reflected in the following aspects. First, this review is systematic and not just oriented to a specific subject. Conversely, works, such as Alfnes *et al.* (2018) and Olsen and Borit (2013), only reviewed a particular topic within food traceability, including consumer's preference on food traceability and public regulations about product traceability. In addition, Borit and Santos (2015) and Garcia-Torres *et al.* (2019) only reviewed a specific food product using traceability technologies. Then, Dandage *et al.* (2017) and Sen (2014) conducted reviews on the traceability practice in a certain region. Second, multi-dimensional comparison and criticism of the past literature are made in the present study to escalate the results of Dabbene *et al.* (2014). Third, compared with the narrow scope of databases employed by Bosona and Gebresenbet (2013) and Ringsberg (2014), the current study uses two internationally recognized databases to collect literature. Fourth, this study also selects extended keywords to acquire relevant literature as much as possible, whereas past review papers, such as Ringsberg (2014), only chose few keywords during the literature

collection process. Finally, none of those review papers with regard to traceability has divided the literature from a holistic and systematic perspective. This study therefore applied a systematic review approach and attempts to present a framework for future direction, of which research opportunities are derived from the management of traceability technology and evolution of TS operational patterns in a variety of theoretical and practical applications, making up for the research framework considered by Karlsen *et al.* (2013).

Consequently, this study aims to summarize existing research on FSCT and propose a framework for future research directions. By conducting a content analysis of 278 articles mainly identified in the databases including Web of Science (WoS) and Scopus during 1990 to September 2019, this study examines the research trends and concept development, and synthesizes nine research themes of FSCT, as well as provides recommendations for future study on the basis of research status of each specific theme.

After introducing the background and research questions of this study, Section 2 elaborates the research method and provided descriptive analysis results from multiple perspectives. Thematic analysis is presented in Section 3, while research trends, the relation between the themes, and future directions framework are thoroughly discussed in the next section. Further on, Section 5 concludes this review and points out the limitations.

2. Research method and descriptive analysis

2.1 Research method

The systematic literature review method, which was used in this study can be understood as a type of content analysis that evaluates structural (descriptive) and content (thematic) criteria through quantitative and qualitative perspectives. Before systematic analysis, literature collection is an initial and extremely important process (Mayring, 2003).

Focusing on the issue of FSCM, to minimize the omission of related literature, referring to Yang *et al.* (2018) and Garcia-Torres *et al.* (2019), the review searched all possible combinations among (‘food*’ OR ‘meat’ OR ‘animal’ OR ‘seafood’ OR ‘vegetable’ OR ‘fruit’ OR ‘milk’ OR ‘tea’ OR ‘wine’ OR ‘beverage’) AND (‘supply chain*’ OR ‘alliance*’ OR ‘logistic’ OR ‘procure*’ OR ‘purchas*’ OR ‘supply network*’ OR ‘product*’ OR ‘value chain*’ OR ‘inventory’ OR ‘warehous*’ OR ‘demand chain*’ OR ‘supply*’ OR ‘manufactur*’) AND (‘track*’ OR ‘trace*’ OR ‘country of origin’ OR ‘identification’ OR ‘transparency’) in two most comprehensive databases, that is, WoS and Scopus. Then, we determined the subject areas, language types and document types according to the advanced options provided by two databases, as shown in Figure 1. 35,203 and 8,730 related papers were identified in WoS and Scopus, respectively. Deleting 5,543 duplicates, this study left 38,390 papers for subsequent selection. Titles, abstracts, and keywords of those materials were then quickly scanned following the preset inclusion and exclusion standards.

We found that several studies come from unrelated disciplines, such as biology and chemistry. Although some searching keywords were exited in their abstracts, those papers are not relevant to our research topic. In addition, considerable papers were from the field of food science focusing on how to technically establish TSs and propose solutions, which did not meet our standard. To ensure the effectiveness and reliability of the literature collection, we arranged two researchers to screen the documents individually. In this round, we first classified 38,390 articles and rapidly sorted them according to a scale of ‘very irrelevant, irrelevant, uncertain, relatively relevant, and very relevant’. ‘Very irrelevant’, for example, refers to the title that generally contains biological terms, such as ‘DNA’ and ‘X-ray’. We focused on the literature that was classified as ‘uncertain, relatively relevant, and very relevant’. And after double-checking, we kept 318 potentially relevant articles in the full-text review. Further on, literature including some other highly cited papers that have not existed in the above two databases was also supplemented from Wiley (Hoboken, NJ, USA), Science Direct (Elsevier, Amsterdam, the Netherlands), Springer (New York, NY, USA), Emerald (Bingley, UK), and Tylor & Francis (Milton Park, UK) databases after the full-text analysis. The remaining 278 papers were included in this review.

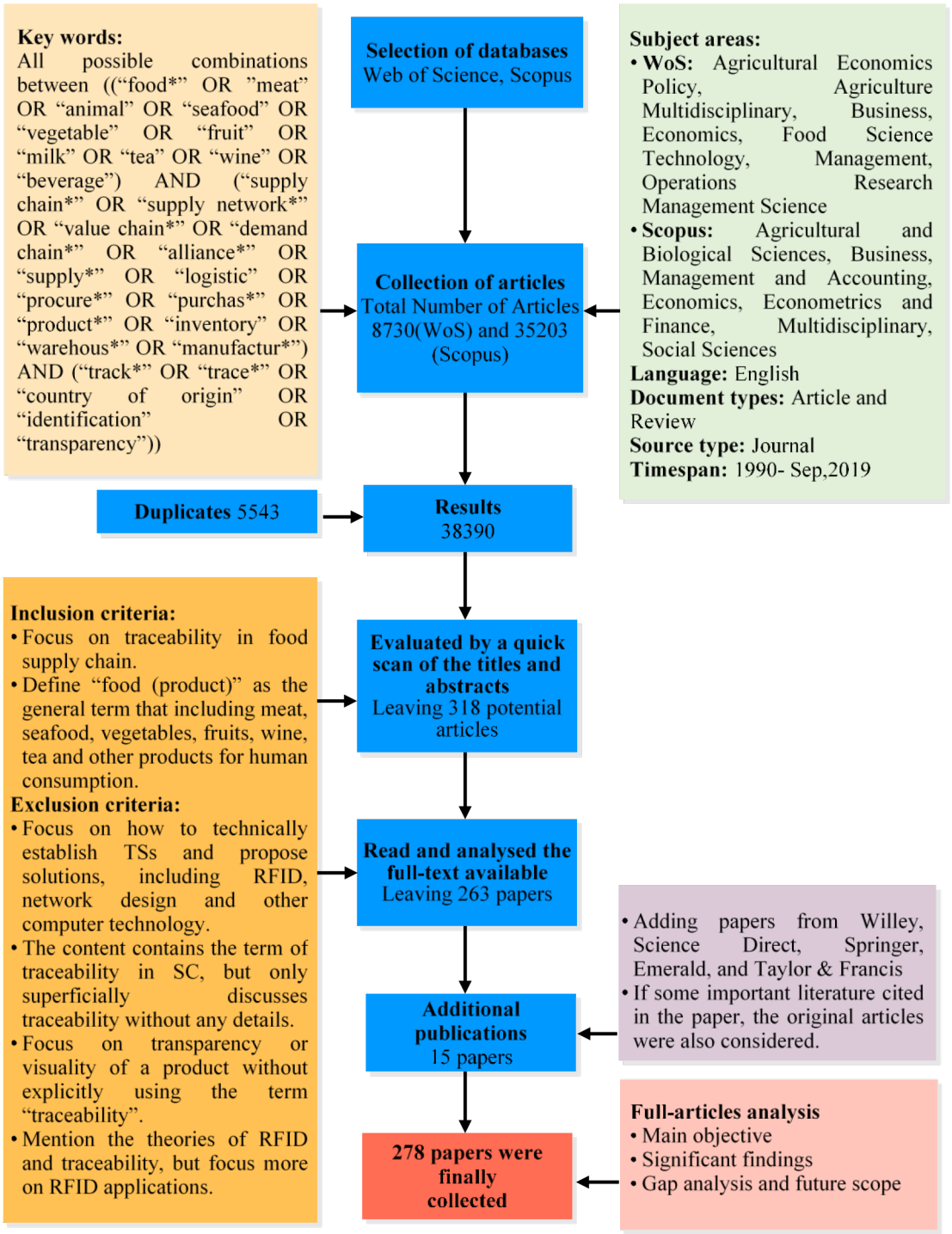

Figure 1. Filter process.

Information of each category was recorded in an Excel (Microsoft, Redmond, WA, USA) spreadsheet to ensure validity and reliability. The coding was performed by two independent researchers to reduce the risk that the content of the literature can be understood by the judgment of only one researcher.

Before coding all documents, we performed a pilot review, comparing the pre-coding results of the first 50 papers to assess the quality of the search database and verify the coding strategy based on the research questions, which is critical to insure the rigor of research. The inclusion of any disputed literature was verified through group discussion. If still unable to make a decision, senior researchers will be invited to conduct further review.

2.2 Descriptive analysis

A clear and extensive overview of collected literature was presented in accordance with published year, journal, method, underlying theory, product category, and region.

To more clearly summarize the characteristics of the literature published over the years, the process can be roughly divided into four stages according to the concentration of the documents, as presented in Figure 2. Cheng and Simmons (1994) introduced traceability into food research for the first time, and afterwards, Moe (1998) officially defined the traceability and proposed traceable operational logic. Until 2000, scholars came up with traceability ideas but have not formed a complete theoretical system. In the second period (2001-2008), food traceability has gradually attracted attention from the public and associations alike, which was closely associated with its official writing into EU regulations in 2000. Scholars began to discuss the adoption and preferences of food traceability from different perspectives, not just conceptually analyzing definitions and functions. For example, in 2002, the first paper focusing on consumers' traceable preference emerged, while the study on firms' TS preference was published two years later. From 2009 to 2016, traceability received considerable attention compared with the past because food TSs had been applied in most developed countries and written into government documents in part of developing countries. Also, scholars started to consider the optimization problems from different settings under traceability, like how to reduce the scale of product recall and enhance the traceability level, and how to design economic incentives to encourage firms to implement TSs. Since 2017, the literature on pre-TS adoption (e.g. consumers' traceability preferences) has decreased, but research on traceability motivations and performance has emerged. As firms are the practitioners of traceability ideas, their active participation in TSs is strongly associated with traceability performances. However, small enterprises, especially those existing in emerging countries, are not as keen to track, mainly because of the inability to balance costs and benefits. In this case, many authors have therefore begun to build optimal models of traceability from mathematics to analyze the feasibility and break-even point of adopting TSs or empirically establish structural models to examine the effect of traceability on business operation. However, a consensus has not been reached on the benefits of traceability from these models, and such issues need further discussion.

138 publications that involved food (supply chain) traceability were identified. As shown in Table 1, the journal with the most publications is 'Food Control', followed by the 'British Food Journal' and 'Food Policy'. Those top three belong to food journals, which implied that the most concern in the past was mainly on the food science field. More recently, journals in the management field also pay attention to this topic. Some of them have published some articles focusing on the issue of the impact of traceability on operations management or how to make production decisions based on traceability. At present, the challenge of food traceability is not only on how to develop and build high-performance TSs but also on operational research,

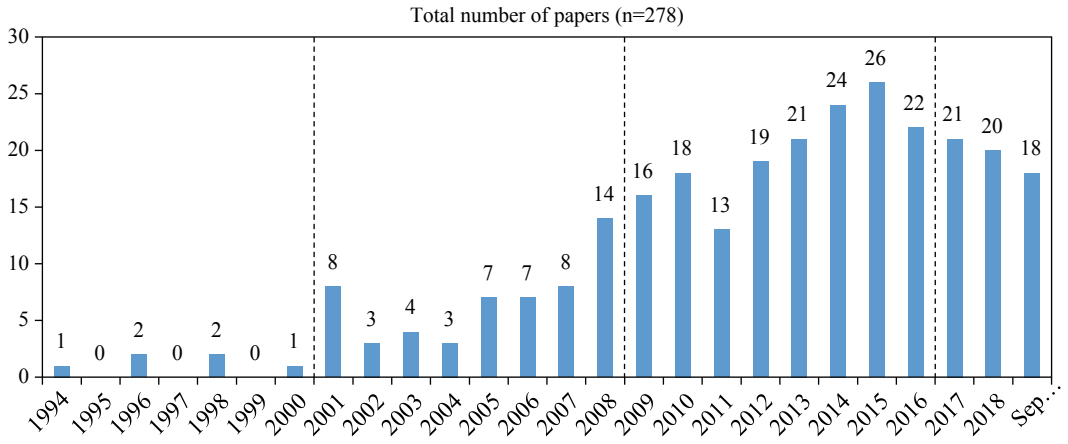

Figure 2. Distribution of literature published over the years.

Table 1. Distribution of reviewed papers by journals.[1]

Journal	Papers
Food Control	23
British Food Journal	23
Food Policy	10
Agribusiness	9
International Journal of Production Economics	8
Revue Scientifique et Technique	7
International Food & Agribusiness Management Review	7
Sustainability	6
Supply Chain Management: an International Journal	5
Quality-Access to Success	5

[1] n=278 and this table only presents the journal that published more than three papers collected.

such as how to effectively manage the coordination of SCT. Therefore, to solve such issues, more scholars from the SCM field were required to get involved.

For the methods used in the collected literature, surveys (covering field research and public secondary data) and also conceptual analysis were the two most popular approaches, comprising two-thirds of the total papers (Figure 3). A total of 33 papers have used mathematical modeling methods, and among which, the game theory model was the most common one, in addition to the linear programming and batch dispersion model. Moreover, the fourth most common approach was case studies (9.35%), followed by literature review.

Table 2 shows the distribution of underlying theories used in those reviewed papers. Notably, most of the literature did not explicitly indicate which theory supporting their research. We classified those that did into four disciplines, namely, Psychology, Economics, Management, and Information System. The most commonly used theories were random utility theory, transactional cost economics, resource-based view, technology acceptance model, the theory of planned behavior, and consumer perspective.

A total of 135 articles clearly pointed out the specific food category in their research object, whereas the rest only used the relatively broad concept/term of 'food' (Figure 4). Among them, the most studied were meat and meat products, followed by seafood, vegetables, dairy products, and fruits. Considering the probability and severity of food risks, meat traceability has become a priority for governments in developed countries (Viaene and Verbeke, 1998). Similarly, aquatic products may suffer from biological problems, such as hormones, antibiotics, and other harmful substances, whereas vegetables and fruits are vulnerable to a

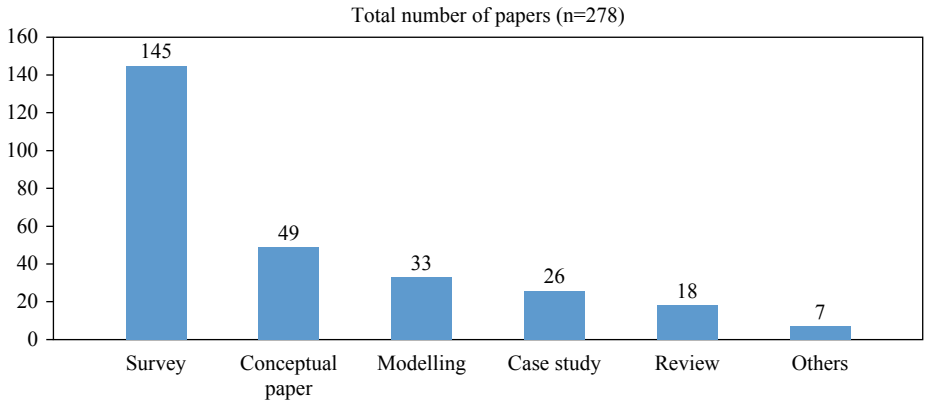

Figure 3. Research methodologies applied.

Table 2. Distribution of underlying theories.[1]

Theory		Papers
Not specified		200
Psychology	Random utility theory	15
	The theory of planned behavior	7
	The theory of reasoned action	5
Economics	Transaction cost economics	9
	Agency theory	5
	Institutional theory	2
	Information asymmetry theory	2
Management	Resource-based view	8
	Consumer perspective	7
	SCM theory	3
	Organizational theory	2
	Stakeholder theory	2
Information system theory	Technology acceptance model	8
	Network theory	2
	Information processing theory	2

[1] Some papers combined more than one theory, and this table only presents the theory applied more than once.

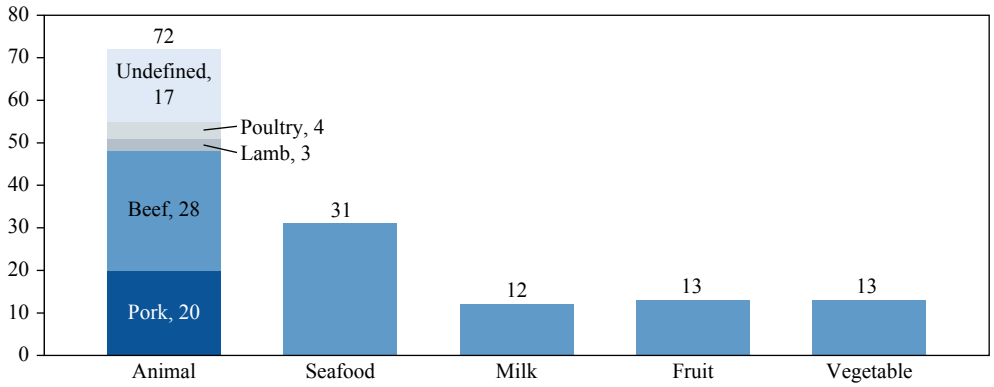

Figure 4. Classification by product category.

pesticide problem. Moreover, dairy products are natural to be manipulated by milk fraud, specifically in infant milk powder, in which quality control has become a serious concern.

A total of 214 papers (76.98%) identified 45 different areas, and of which, the most studied research area was China followed by the US (Figure 5). China serves as the most popular region owing to the fact that the country is populous with different economic levels in each area. Moreover, consumers from different areas may have varying attitudes and willingness for traceability, bringing excellent research opportunities. Furthermore, food risk is still the main problem that concerns Chinese consumers in purchasing products. How to promote traceability ideas and technologies in China, especially for farmers in those upstream states, deserves an extensive discussion.

According to the classification of global countries in the World Economic Situation and Prospects in 2019 (UN, 2019), 28 of those regions mentioned belong to developed economies, whereas the remaining regions are categorized as developing. Evidently, reviewed literature focusing on developed economies was far more than that focusing on developing ones (Figure 6). However, authors began to shift their focus on traceable practice to developing economies in the early 2010s, specifically after 2017, when the focus on developing

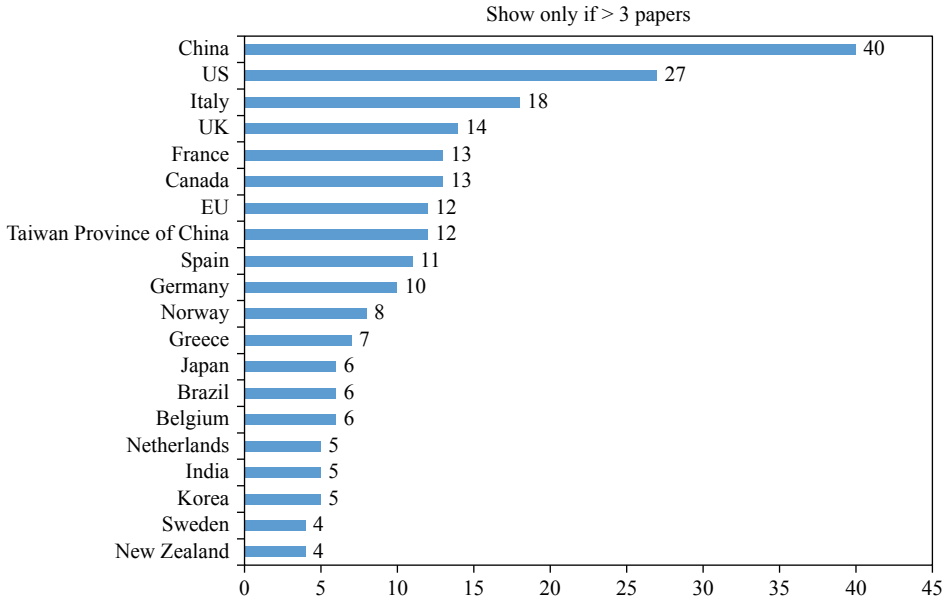

Figure 5. Classification by regions of focus.

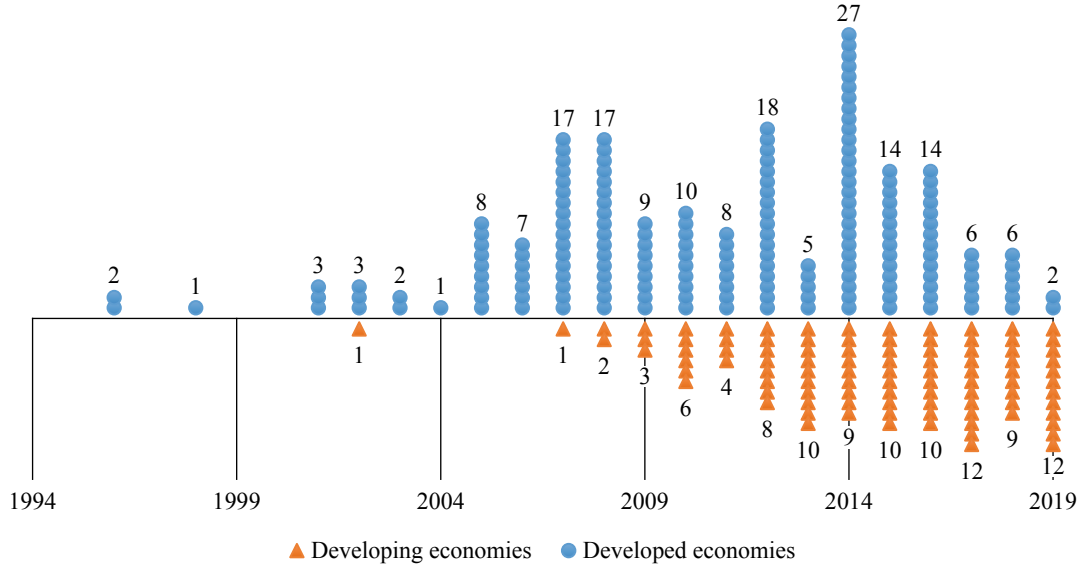

Figure 6. Classification by the economic level of economy of focus.

economies has outstripped the developed ones. For developing countries, food risk incidents have erupted more frequently, but traceability has started later. Some issues related to traceability, such as consumers/producers' perceptions and traceable product decisions, have even not received enough attention. Transferring research results from developed economies directly is impossible because of the differences in economic development and institutional background. This notion also shows that developing economies may become a novel and indispensable focus in future FSCT research.

3. Thematic analysis

After identifying the categories of document codes, this study conducts thematic analysis to present the status quo and explore the research gaps from terminology development and critical themes in FSCT.

3.1 Terminology development

The concept of 'traceability' was first proposed in the ISO 8402 1994 standard as a goal of quality management and quality assurance for the industry (Zhou *et al.*, 2021). Within this official specification, traceability was defined as: '…ability to trace the history, application or location of an entity by means of recorded identifications'. With the outbreak of mad cow disease in Europe in the late 1990s, quality control in the food industry has attracted unprecedented attention. The Codex Alimentarius Commission (CAC) proposed a concept of food traceability in 1997, which clarified the range of tracing and tracking processes. In 2002, the EU proposed a more formal and comprehensive definition of traceability in the EC 178/2002, which made a clear explanation of the traceability object. Based on the expositions provided by the above organizations, ISO revised the definition of traceability in 2000 and 2005 successively, further broadened and enriched the scope of traceability objects, so that traceability across the supply chain is not only limited to the specific processing link but also extends to all relevant actions and processes.

From the perspective of academic research, the definition of 'traceability' generally has two types of viewpoints. Danish scholar T. Moe represented the first one, who attached great importance to 'accountability', and described traceability as an instrument to clarify product safety 'responsibility' in each link of the supply chain (Moe, 1998). Then, American scholar Elise Golan represented the other type, who emphasized the function of traceability in risk identification and regarded it as product information record system to identify potential hazards and critical control points. Three standards including 'precision', 'breadth', and 'depth' have been set to measure the performance of such a system. Among them, precision refers to the smallest unit of identifiable product, breadth refers to the range of data that can be obtained, and depth refers to the distance at which data can be tracked forward or backward. Through the overview of definitions of traceability terminology proposed in the past academic articles, Olsen and Borit (2013) proposed an integrated definition that emphasized using 'access' to describe the activities of 'trace' and 'track' and further expanded the traceability process to 'entire life cycle.' Such definition has been recognized and extended by many authors in their follow-up study (Aung and Chang, 2014; Dabbene *et al.*, 2014; Dandage *et al.*, 2017; Karlsen *et al.*, 2013). For example, rooted in the specific theoretical perspective, food traceability has been redefined from food logistics management (Bosona and Gebresenbet, 2013), supply chain risk management approaches (Ringsberg, 2014), safety and quality (Aung and Chang, 2014), and so on.

To sum up, the definition of 'traceability' can be categorized as the official and academic type. Official definitions made by institutions mainly were enlightened by the views from the theoretical discussion, whereas the meanings of academic definitions are more specific and broader than those of officials. However, given the functions of the TSs, the ultimate purpose of such definitions is, no doubt, identical, which aims to recognize the entire supply chain monitoring from farm to fork. In addition, those definitions change over time in their action, scope, manner, and content. For example, actions of traceability described have become more accurate with the evolution from 'trace', 'track' to 'trace and track' to 'access' in 2013, which may be due to the update of tracing technologies that makes traceable information more available and exchangeable.

FSCT has no unequivocal definition even though the implication of the 'supply chain' was explained by authors particularly in the above concepts of traceability (Verbeke *et al.*, 2002). Does the definition of FSCT equate with that of food traceability? Previous literature often conceptually defined traceability from several aspects: unit, who, where, when, and how (Olsen and Borit, 2013). However, such definitions only described the behavior and process of traceability, rather than getting into the essence, goal, or value of traceability. Thus, a more structural, clear, and profound definition of FSCT to reveal the private information

and economic mechanism may be needed for further exploration of traceability. In this study, we attempt to deliver a definition of FSCT:

> As a risk control and governance solution, FSCT refers to a management practice used to track and trace movement trajectories or footprints of various foods, raw materials as well as ingredients in entire supply chain stages from procurement, processing, and sales, which comes down to systems that can form a reliable and continuous flow of safety information to monitor, to achieve quality assurance beforehand and recallable afterwards.

3.2 Key themes in reviewed papers

Based on a systematic analysis of 'research objectives, main contents, and findings' of 278 articles, we divided the research themes of FSCT into nine clusters as shown in Figure 7, namely, consumer preference (T1), conceptual understanding (T2), firm preference (T3), practice experience (T4), optimization (T5), the effect on operations (T6), cost-benefit analysis (T7), performance evaluation (T8), and impact on traceability (T9). From the horizontal point of view, more than 31.93% of the collected papers focused on T1, which discussed consumer's preference for different traceable products, labels, and information. Followed by T2, 54 articles explained the concept, scope, principle, the value of traceability, and also certification, standards, or rules to establish a theoretical basis of SCT. Then, 46 papers in T3 discussed the firm's preference including drivers and barriers to TS adoption. Moreover, 27 papers (T4) shared their practice experiences of TS implementation, and 26 articles explored T5, analyzing the various decision problems that may arise in the specific operation, such as recall, information sharing, and the optimal batch size. A total of 13 papers within T6 considered how traceability level utilization or traceability technology adoption affects an organization or supply chain's operations management. Authors were also concerned about the economic outcome after TS implementation by analyzing the cost and benefit in T7. Nine papers also pointed out the necessity of performance evaluation of TS, and a few of them suggested the assessment framework and approach. Furthermore, eight papers tried to examine the antecedents of traceability determination.

To more clearly track changes in their research subjects over time, we classified nine themes into pre- (ex-ante), post-studies (ex-post), or both were involved (cross) based on the TS adoption. Notably, those pre-studies, such as T1, T3, and T9, account for 50.88%, which shows the evidence that pre-research has already been well established, specifically those involving consumer traceability behaviors. T4 and T5 have been explored since 2005 and 2010, respectively, discussing the experience and decision-making issues that may require improvement in TS implementation. However, post-studies, such as performance evaluation (T8) and traceability effect (T6), were rarely considered, which may become a concentration for future FSCT research.

To show the research boundaries and present different perspectives of each cluster more clearly and specifically, we outline the research status of each specific theme.

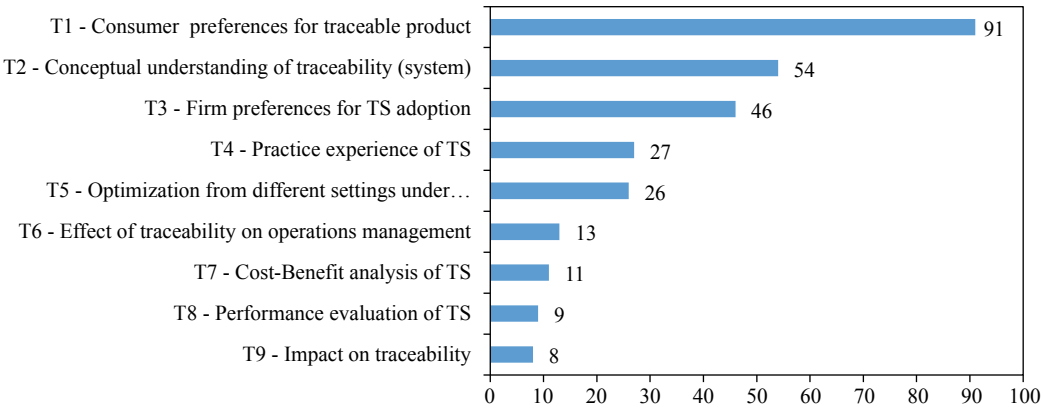

Figure 7. Key themes in reviewed papers.

3.3 Traceability systems: pre- and post-adoption

■ *Perspective of consumers' preference for traceable products*

For some products that are consumed daily, such as meat and seafood, merely rely on its current certification system is far from enough (Alfnes *et al.*, 2018). Attention to the origin and channel information inspires a new focus on 'traceable label'. The first paper explored consumers' preference for traceable products published in 2002, and since then, increasing scholars have analyzed such problems from different perspectives, such as regions, product categories, and methodologies applied. Generally, research on consumers' preferences mainly discusses the perception, attitude, and willingness to pay (WTP) for label information, technology, or food product, respectively.

From the perception and attitude theories, like random utility theory, authors drew attention to the factors that may affect consumers' opinions, and whether such relationships are positive or negative. Except for individual characteristics, price (Van Rijswijk and Frewer, 2008), risk perception (Angulo and Gil, 2007), and trust in traceability information (Choe *et al.*, 2009) were the three factors that scholars are mostly concerned about. Authors further discussed consumers' WTP for traceable products, but such willingness has not yet reached a unanimous conclusion. Angulo and Gil (2007) argued that food traceability could address safety and recall problems. Moreover, they tested the initiative and enthusiasm of consumers to purchase traceable products through empirical evidence.

Consumers who held positive views expressed different preferences for traceable labels from providers, information attributes, and information authenticity. For information providers, consumers lack trust in the information disclosed by enterprises but showed high levels of credence in the information issued by the regulatory agency (Wu *et al.*, 2016) as well as independent third-party certification (Bai *et al.*, 2013). For information attributes, consumers demonstrated differentiated preferences for the compulsory or voluntary label and other specific label cues (Lu *et al.*, 2016). A certain amount of premium would be paid once the traceability level is improved (Wu *et al.*, 2016). Moreover, past literature presented the levels of interoperability of TSs that could satisfy consumers and the kind of identification and query tools that could be applied for enterprises. For example, blockchain traceability technology is deeply trusted by consumers (Sander *et al.*, 2018).

For the theories and methods adopted, in this theme, theories such as random utility theory, the theory of planned behavior, and the consumer perspective were applied to explain consumers' preference for traceable products. Experimental auction, revealed preference, and stated preference (including contingent valuing method, choice experiments) are three main approaches in the topic, while the latter is the most widely used to analyze consumer preference and WTP for traceable foods (Wu *et al.*, 2016).

■ *Conceptual understanding of (food) traceability (system)*

Theoretical understanding of traceability or TS in the supply chain mainly includes introductions to traceability concepts, functions, values, and dimensions, as well as the interpretation of traceability-related standards, laws, and regulations. As a means of food safety monitoring, traceability has been regarded as a unique dynamic capability (Canavari *et al.*, 2010) and organizational competence (Epelbaum and Martinez, 2014) for a business. Traceability has played an indispensable role in operations management and become an instrument to strengthen weak links in production and distribution (Dandage *et al.*, 2017).

As a technical realization of traceability, TS is a tool for conducting tracking and tracing procedures throughout the entire supply chain (Zhou *et al.*, 2021). Its slightly varies depending on the research field, such as operational management, food science, and computer science. Hobbs (2004) stated that the essential functions of TSs are quality assurance beforehand and rapid recall afterwards. Although the details of the universal TS have not yet been determined, some countries have set legislation on comprehensive labeling

and, in some cases, requiring full traceability within the FSC. In practice, TSs have two main types, namely, government mandatory and enterprise voluntary (Lavoie and Forest, 2009). Besides, it can also be divided into distinct types according to different standards, such as service subject (Mol and Oosterveer, 2015), behavior characteristics (Canavari *et al.*, 2010), and the technology used (Vo *et al.*, 2016).

■ *Firms' preference for traceability systems*

Considering that enterprises are the actual operators of the TS, corporate behavior has become one of the research priorities in FSCT. Early work focused on such a topic published in 2004, discussing producers' perception of traceability issues in organic agriculture, and since then, firms' preference for TSs involves the following issues. The first is the preference for participation in TSs, while the second is the preference for adopting TSs. These two issues have gained considerable results in past work, and conclusions on the drivers and barriers that can impact TS adoption have been widely discussed (Manos and Manikas, 2010; Mattevi and Jones, 2016). The third is the preference for different traceability levels, but few works focused on this issue (Stranieri *et al.*, 2017a). By analyzing firm's preference for traceability capabilities, consumers can further understand how companies can engage in traceability initiatives more effectively.

The transaction cost economics is used to analyze the possible behaviors and costs in the distribution and management of traceability activities (Stranieri *et al.*, 2017b). The technology acceptance model revealed the cognition, intentions, and behavior of enterprises using traceability techniques that have been broadly used in this theme (Heyder *et al.*, 2012). In addition to using the same research methods as the previous topic, scholars also use multiple case study to identify and extract the factors impacting the preference of firm's TS adoption (Manos and Manikas, 2010). In practice, the adoption of TSs will lead to the rise of enterprise costs and not produce many economic benefits in the short term in the face of the conflict between the drivers and barriers. Despite this, whether it is voluntary or downstream pressure (Starbird and Amanor-Boadu, 2006), focal companies still have to adopt TSs due to possible government regulation and public requirements. Hence, an appropriate time for TS introduction should be considered in advance.

■ *Practice experience of traceability systems*

Unlike technically designing TSs, this cluster provided some theoretical guidance for TS implementation and management, and summarized the operation experience of TSs in different industrial chains and regions practically.

On the one hand, prior work has made theoretical contributions regarding the application of TSs, including guidance (Zhang and Bhatt, 2014), design method (Dai *et al.*, 2015a), structure (Verbeke *et al.*, 2002). On the other hand, authors described various practical operation and management experiences of TS from different regions, product categories, and others. From the application areas, Dandage *et al.* (2017) introduced the typical experiences and models of TSs in the US, UK, India, China, Japan, and other countries. For a specific product, poultry meat (Viaene and Verbeke, 1998) and pork (Verbeke *et al.*, 2002) have been the focus to describe their practical experience associated with identification, labeling, and traceable process. In terms of specific traceable actions, to reduce the harm caused to consumers by products with safety risks, Lavoie and Forest (2009) proposed several control points that should be emphasized during the recall process. In the practice of traceability management, resource-based value is often used to explain that product traceability is a unique knowledge resource of an enterprise. The information processing theory explains how traceability information streams are identified, collected, and processed (Wowak *et al.*, 2016). To better extract and summarize the typical practical experience of TS, case analysis including exploratory case study and descriptive case study is widely used by scholars. Related work includes (Lavoie and Forest, 2009; Verbeke *et al.*, 2002; Viaene and Verbeke, 1998).

■ *Optimization from different settings under traceability*

Considerable studies from various angles examined the issue of corporate decision-making in a traceable context, which mainly involved three parts, that is, the feasibility issue to invest in TSs; the production issues on traceable procurement, product recall, information sharing, channel coordination, and liability incentive; and the optimization issues on traceability improvement.

Whether to invest in TSs has caused distress to enterprises, especially those small and medium ones. Authors earlier focused on the feasibility of firms to adopt TSs (Saak, 2016; Starbird and Amanor-Boadu, 2006). However, although most authors hold positive opinions, they still have no consensus on whether the benefits of implementing TS exceed costs. Saak (2016) stated that enterprises should adopt TSs as they can serve a regulatory role in the conflict of cost and reputation. Wang *et al.* (2010) confirmed the feasibility of TSs and proposed a scheme to minimize the potential loss in the FSC.

Furthermore, the production and operations decision issues, such as quality and food safety (Pouliot and Sumner, 2008; Wang and Li, 2012), recall (Dai *et al.*, 2015b), the incentive (Resende-Filho and Hurley, 2012), and liability cost (Pouliot and Sumner, 2008), have been discussed after firms adopted TSs. They almost considered the choices of traceability effort (or level) to achieve production and operation objectives together. To address such decision-making problems, mathematical modeling such as equilibrium models and game theory models have been widely used.

Some authors discussed optimal traceability issues and put maximum traceability as one of the objective functions. Specifically, the optimal batch size in manufacturing and distribution and batch dispersion model was mainly used for studying how to improve the traceability level together with the objectives like the minimum impact of a food recall (Wang *et al.*, 2010), and the minimum total cost (Wang *et al.*, 2009).

■ *Factors that impact traceability*

The factors that may affect the traceability of enterprises and the number of levels of traceability that will prompt enterprises to choose have been a matter of great concern in recent years. For characterization of the traceability level, the different ways in which the literature described traceability were considered, such as the level of traceability complexity (high, medium, low) (Banterle and Stranieri, 2008a), and dimensions of traceability (depth, breadth, and precision) (Souza-Monteiro and Caswell, 2010). This theme can be extended from the impact on traceability level and technology. For the impact on traceability level, scholars discussed various possible factors that affect the focal company's selection of traceability level or capability, such as buyer-supplier relationships (Rábade and Alfaro, 2006), changes in transaction characteristics, costs and governance (Banterle and Stranieri, 2008a). For the impact on traceability technology, Manos and Manikas (2010) identified that traceability could be improved through technology updates. Basole and Nowak (2018) used the transaction cost and institutional theory to examine those effect of the supply network on tracking technology selection and assimilation.

Various theories such as transaction cost theory (Banterle and Stranieri, 2008a), institutional theory (Basole and Nowak, 2018), diffusion of innovation theory (Basole and Nowak, 2018), and agency theory (Souza-Monteiro and Caswell, 2010) have been employed to underpin and support authors' research founding. Empirical approaches including case study (Rábade and Alfaro, 2006) and PLS-SEM (Basole and Nowak, 2018) have been applied in this theme to explore the potential factors affecting traceability.

■ *Cost-benefit analysis of traceability systems*

In practice, the adoption of TSs may lead to an increase in costs and not produce economic spillovers in the short term (Banterle and Stranieri, 2008a). Consequently, a pre-analysis of cost-benefit analysis and an appropriate time for TS introduction are necessary (Starbird and Amanor-Boadu, 2006). The cost-benefit

evaluation can be divided into the assessment after the TS is set up and operated (i.e. happened) and before the potential TS is implemented (i.e. perceived). On the one hand, as for the occurred cases, the additional benefits, and comprehensive income of traceability information (Saltini and Akkerman, 2012), extra costs of TSs for agro-product enterprises (Chen *et al.*, 2019) have been discussed. The cost-benefit model was built to evaluate the occurred economic usefulness of TSs (Fritz and Schiefer, 2009).

On the other hand, according to perceive observation, Gunawan *et al.* (2019) analyzed perceived and marginal costs of TS implementation respectively. Aiello *et al.* (2015) focused on and explained the perceived internal and external benefits. Furthermore, a comprehensive perceived cost-benefit evaluation framework has been proposed to compare the economics of traceability and value to the FSC (Chryssochoidis *et al.*, 2009). The analysis of perceived costs and benefits of the implementation of the TS allows companies to more rationally consider whether they have abilities to introduce a TS, or the timing of the adoption of such a system.

Scholars usually applied survey and case study methods to determine the objective of cost-benefit analysis, and then, they used more detailed methods for comparisons, such as cross-case comparison (Gunawan *et al.*, 2019), single case study (Chryssochoidis *et al.*, 2009), and break-even pricing (Chen *et al.*, 2019), and so on. However, literature in this theme hardly mentions the theoretical basis supporting their research conclusions.

■ *Performance evaluation of traceability systems*

Performance evaluation is conducted to verify whether the TS can trace and track products effectively, which can help practitioners further adjust the management strategy for traceability. Four dimensions including 'breadth', 'depth', 'precision', and 'speed' have been widely used to distinguish TSs performance (Gunawan *et al.*, 2019; Stranieri *et al.*, 2017a). Moreover, 'granularity', which was measured by batch size and scale was employed to characterize the precision of the product traceability (Karlsen *et al.*, 2012). And also, traceability records and traceability time have been used to evaluate the system's capability to obtain and process traceable information (Dzwolak, 2016). Regarding method adopted, approaches such as simulated recall methods (Donnelly *et al.*, 2012; Forås *et al.*, 2015) and factorial and cluster analyses (Banterle and Stranieri, 2008b) have been employed to assess system performance.

■ *Impact on operations management*

This topic appeared at the end of the second stage (2001-2008) of FSCT research, and the authors began to discuss the impact of implementing TS on enterprises' operational efficiency and internal network relationship. The adoption of traceability technology not only solves the problem of food quality control but also brings many spillovers to focal companies and the whole supply chain. Past documents showed that TSs lead to changes in transaction modes (Vo *et al.*, 2016) and economic incentives (Stranieri *et al.*, 2016). Moreover, the application of tracing technology strengthens resource integration of supply chain companies (Engelseth, 2009). Mol and Oosterveer (2015) stated that traceability can optimize the original ecological structure of the supply chain and encourage members to pay more attention to corporate social responsibility and sustainable development goals (Garcia-Torres *et al.*, 2019), not just economic benefits. In addition, Epelbaum and Martinez (2014) and Engelseth *et al.* (2014) believed that traceability could contribute to technological innovation and diffusion for operations management.

Collected literature on this topic shows that the theory of transaction cost economics (Banterle and Stranieri, 2008a; Galliano and Orozco, 2013; Vo *et al.*, 2016) and resource-based view (Engelseth, 2009; Epelbaum and Martinez, 2014) is the theoretical perspectives most adopted by scholars. Meanwhile, the survey is the most popular method in this field, that work includes (Banterle and Stranieri, 2008a,b; Epelbaum and Martinez, 2014; Galliano and Orozco, 2013; Stranieri *et al.*, 2016; Vo *et al.*, 2016).

4. Discussion

4.1 Trends in food supply chain traceability research

Based on the descriptive and thematic analysis of FSCT research over the past three decades, we can draw several conclusions. First, the focus of themes has moved to research on the post-adoption of TSs. Additional attention has been paid to how focal companies structure and leverage their traceability resources, including coordinate and manage traceability activities across the supply chain (Charlier and Valceschini, 2008). Second, concerning the research area, the focus has shifted to developing economies because most developed economies have well-established theoretical and practical experience in food traceability. For developing economies, food safety incidents are more frequent, but traceability-related research has started later. Directly duplicating research conclusions from developed economies might not be applicable (or even paradoxical) owing to the differences in the economic and institutional background. Rather, placing the traceability in the developing economy context may bring additional research opportunities. Third, as to the unit of analysis, the focus has moved from the organizational to the supply chain level. In addition, work regarding FSCT has started to appear in SCM and logistics journals and not just in food science journals (Garcia-Torres *et al.*, 2019; Saak, 2016; Wang *et al.*, 2009). One big challenge for focal companies is to address and coordinate traceability issues with their multi-tier supply chain partners, which requires researchers from the field of supply chain and operation management to get involved.

Few theories were used to explain the essential characteristics and impact mechanism of FSCT. Most previous literature rarely mentioned the theory employed to underpin their research. Moreover, many fundamental or unresolved questions have still not received enough attention (Karlsen *et al.*, 2013). Some parts of the articles repeatedly addressed the problems of higher homogeneity, such as consumers' WTP for traceable food product. Although they may apply different perspectives, most articles were still addressing a problem that seems to have been largely verified. Therefore, at this stage, the issues that should be paid attention to in the future and the problems that are worth exploring and require further understanding should be considered to push FSCT to theoretical and practical application. Essentially, the first step is to reorganize and reclassify peer-reviewed papers over the FSCT field and clarify theoretical characteristics, sum up existing research themes, and identify research gaps on this basis.

4.2 Relation between the themes

As the research topics on FSCT can be generally divided into pre- and post-study based on the timeline of TS adoption, we have checked whether the research problem of the target literature occurred before or after the adoption of TS, or both were involved (cross). Then, the relation among nine clusters were obtained, as depicted in Figure 8. Among them, T2, T4, T5, and T7 belong to involved (cross), T1, T3, and T9 belong to pre-adoption, and T6 and T8 belong to post-adoption.

First, T2 is the theoretical basis of FSCT. All clusters (including articles) involve traceability-related concepts and knowledge as an introduction. In turn, the theoretical contributions of other clusters also enrich the research boundaries of T2 to a certain extent. T1 and T3 are management behavioral issues focusing on preferences. In essence, whether TS should be established or not partially comes from consumers' preference and the tendency for product traceability, including firms' perception and willingness to implement traceability. Therefore, these two types of problems are typical ex-ante studies. Providing assumptions about consumers' traceability preferences for the decision-making problems of the optimization model (T5) is possible by exploring consumers' traceability behavior. Moreover, preconditions for research on related topics, such as T4 and T7, can be provided by discussing firms' different traceability preferences. The problem of corporate preference can also be related to T5, that is, the former is to empirically explore firms' preferences, and the latter is to simulate a firm's TS-implementation decision from a mathematical perspective. T9 and T6 mainly adopt the methods of survey and regression analysis. The former discussed the antecedents of traceability, such as influencing factors that impact the use of traceability technology. On the contrary, the latter discussed

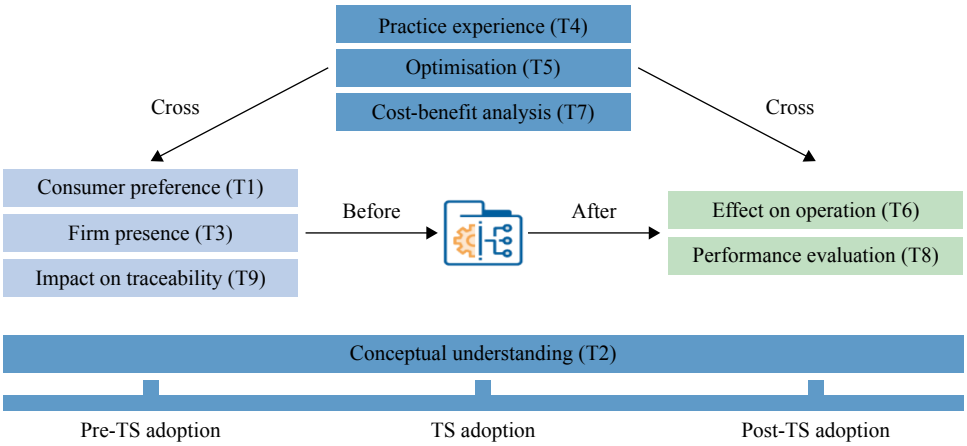

Figure 8. Relation among nine clusters.

the consequences of traceability, that is, the impact of traceability technology or capabilities on the operation of enterprises and the supply chain. When traceability technology becomes more popular and gradually accepted, scholars are increasingly concerned about how to effectively manage traceability technology to promote its positive impact on enterprises. The concerns of T4, T5, and T7 exist before and after TS adoption. Compared with technical discussions on how to establish a TS, T4 mainly discusses how to better manage the system. Moreover, T7 focuses more on how to optimize or improve traceability. Based on the above topics, T8 is a typical pre-adoption study, which mainly investigates the performance of TSs. Establishing a set of evaluation systems is generally necessary to assess the sustainable output that the enterprise can produce after implementing the system for quite some time. The current discussion on this topic is not yet complete, and how to establish a more comprehensive sustainable performance evaluation system is a key issue.

4.3 Framework for future research direction based on the review of each topic

After elaborating on the status quo of each topic, we review and suggest possible research opportunities for each cluster in the future direction, refer to (Chen *et al.*, 2021; Yang *et al.*, 2018; Zeng *et al.*, 2017), as shown in Figure 9. Overall, compared with minor supplements on well-established pre-adoption research of TSs, issues related to post-adoption may be the focus of further research.

- *Review on the perspective of consumers' preference for traceable products*

As a pre-TS adoption study, research on consumers' traceability preferences has been well established, and this topic has many achievements, particularly on WTP for traceable products and information. One can further explore the preference and choice for traceability technology. Consumers have concerns about which traceability technology companies may apply. Considering the widespread application of blockchain technology, which technologies that consumers expect supply chain companies to adopt or which kind of traceability query tools that consumers prefer are worth investigating (Sander *et al.*, 2018). Moreover, considering that consumers attach great importance to the credibility of traceability information, which traceability dominant model (Charlier and Valceschini, 2008) that consumers prefer or trust in the future should be empirically examined. Furthermore, future research could extend from consumers to multiple stakeholders and compare which stakeholders are more inclined to choose foods with traceability labels.

- *Review on the conceptual understanding of (food) traceability (system)*

Although many conceptual articles related to food traceability exist, theoretical research still needs to be updated and supplemented. First, for the definition of related terminologies, previous descriptions of 'traceability' attached great importance to the exposition of tracing behavior and process. However,

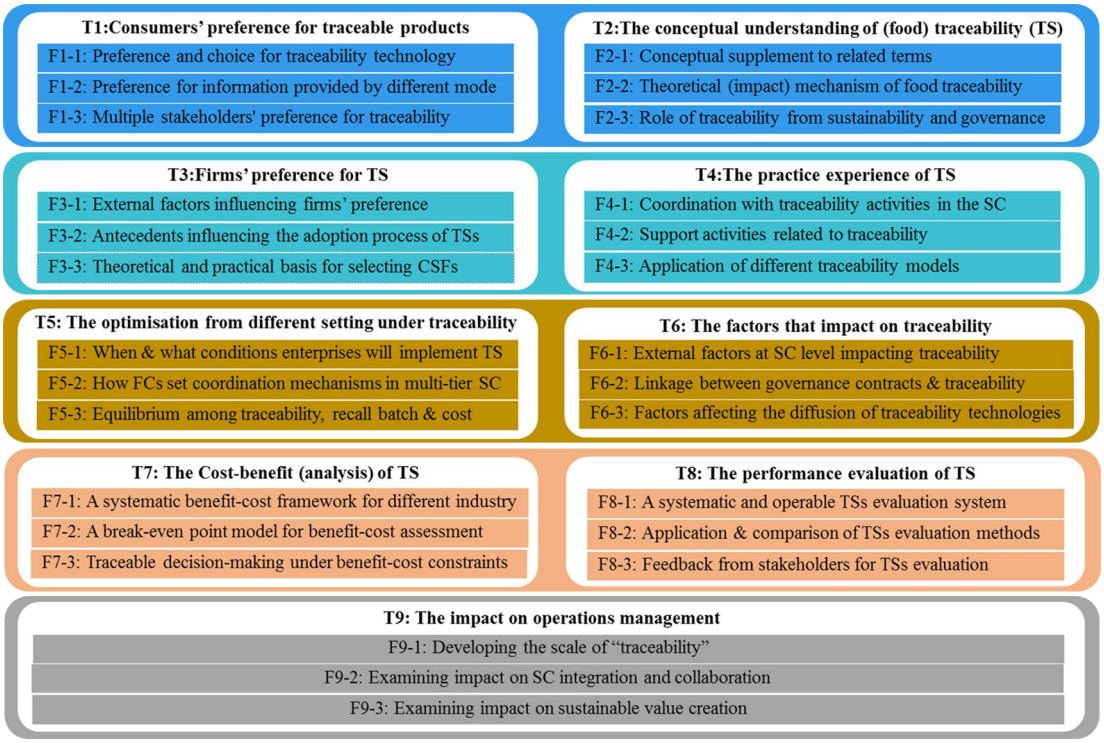

Figure 9. Framework for future research direction.

substantive characteristics, such as the inherent value of tracing and tracking as well as the external scope of the supply network structure to which traceability worked are also lacking. Future work could consider defining 'traceability' from more perspectives to enrich the extension of traceability theory, for example, from the supply chain structure (Verbeke *et al.*, 2002), resource base view (Engelseth *et al.*, 2014), and diffusion of innovation (Basole and Nowak, 2018). Second, only a few studies focused on the inherent theoretical mechanism of food traceability. Future research could start from informatics (e.g. information processing theory) (Wowak *et al.*, 2016), economics (e.g. transaction cost economics) (Stranieri *et al.*, 2017b), and management (e.g. stakeholder theory) (Sander *et al.*, 2018) perspectives to provide the mechanism of food traceability and further explore the theoretical value of SCT research. In addition, although prior works explained many traceability functions, they seldom discussed the role of traceability in complex supply networks from a sustainable governance structure perspective. The reason is that the latter explained the ultimate goal and essential means of FSCT (Garcia-Torres *et al.*, 2019).

■ *Review on firms' preference for traceability systems*

With the rising interest in corporate behavior studies, future research could be extended in the following three aspects. First, in the discussion of factors influencing the traceability level, prior literature focused on firms' internal factors, such as the background of chief executive officers (Mattevi and Jones, 2016). Conversely, external factors were rarely identified, and their impact on TS adoption was less discussed. Examples include whether the changes in the institutional environment will influence focal companies to leverage the traceability capability and whether social pressure will force those companies to provide more traceability information. Second, the application of TS goes through different stages from initiation to implementation. Hence, which antecedents may affect the TS adoption process should be explored so that those focal companies can better understand how to operate such systems (Matta *et al.*, 2009). Third, for critical success factors, future work could explore whether common typical factors exist in different product chains and regions to guide practitioners to promote traceability. Furthermore, the theoretical and practical basis for selecting those factors and the impact of factors on TS implementation require further comparative analysis.

■ *Review on the practice experience of traceability systems*

TS adoption has several practical achievements, but how to manage and coordinate SCT is rarely discussed, particularly in a multi-level supply chain. However, without the coordination of focal companies, supply chain members may not be able to form compatibility and docking in TSs, thereby increasing the risk of errors or omissions in transaction costs and quality information between actors (Zhang and Bhatt, 2014). Moreover, extremely lower-tier members of the entire supply chain do not have the ability or willingness to participate in the unified TS (Garcia-Torres *et al.*, 2019), making achieving tracing and tracking of the source and end of the product difficult. Therefore, exploring the modes used by the TS leader to orchestrate, coordinate, and organize traceability activities in the multi-level supply chain will affect the traceability, transparency, and sustainability of the product. Future work could use multiple case studies to explore how focal companies coordinate upstream and downstream traceability activities to develop full-chain traceability. Then, for TS implementation, prior literature has summed up the technical experience but ignored the importance of some non-technical factors supported to traceability initiatives, such as employee training and traceable institutional arrangements (Charlebois *et al.*, 2014). Furthermore, less literature focused on different traceability modes that enabled TS operation. Comparing the application practices of traceability modes from different products, regions, and even institutional backgrounds can provide suggestions for governments and practitioners to determine the appropriate traceability mode for the product.

■ *Review on the optimization from different settings under traceability*

Examining the optimization problems after TS adoption in the FSC from a mathematical model can effectively help practitioners decide how to implement and manage TSs. First, whether to implement TS is still a question worth exploring, specifically for small companies without the ability or willingness to involve traceability (Garcia-Torres *et al.*, 2019). When and what conditions those enterprises will adopt TS should be examined. Second, the management of TSs requires coordination and incentive among supply chain members, and those members can improve their internal traceability through the contract design (Golan *et al.*, 2004). Future work could address how focal companies establish coordination mechanisms and design effective contracts to ensure consistent traceability goals for supply chain members, particularly in multi-level supply chains. Third, fewer articles focused on the decision-making of the traceability level, which is still an issue that most linked to actual operation (Wang *et al.*, 2009). Decision-making issues, such as optimal production of traceable products, responsible procurement, pricing strategies, the granularity of traceable units, and recall problems, need further analysis.

■ *Review on the factors that impact traceability*

Early research focused more on the factors that affect TS performance at the organizational level (Banterle and Stranieri, 2008a; Souza-Monteiro and Caswell, 2010). However, this topic is seldom discussed at the supply chain level, where factors will explicitly impact the TS implementation in the FSC. External factors, such as supply chain relationship (Rábade and Alfaro, 2006) and supply network integration (Engelseth, 2009), may exert influence on the determination of the traceability level of the product chain. Future work could also study the linkage between the implementation level of TSs and the different kinds of supply chain contracts, such as economic incentives (Souza-Monteiro and Caswell, 2010) for traceability standards. On the other hand, this review defines the extension and intension of FSCM, which also evokes that the antecedents of food traceability need to consider the collective impact of technology, supply chain structure, and food safety. From the perspective of technology management, few studies regarded the antecedents or impact mechanisms of the adoption or management of traceability technologies (Basole and Nowak, 2018). Future work could discuss the influencing factors and hierarchical structure of supply chain companies' adoption of different traceability technologies diffusion and assimilation, such as what factors might prompt companies to diffuse the blockchain traceability technology.

■ *Review on the cost-benefit analysis of traceability systems*

Prior work related to this topic mainly focused on the description or measurement of the cost-benefit of TS implementation (Chryssochoidis *et al.*, 2009). Most of the published papers only considered the cost and benefit of an individual link or a specific cost or revenue (Chen *et al.*, 2019). A systematic cost-benefit framework needs to be designed in the future after wide-ranging investigations to present the overall revenue-cost structure of TS implementation more comprehensively. In addition, integrating the cost-benefit framework with decision theory can be a follow-up study (Aiello *et al.*, 2015). On the one hand, future work could fully consider how to introduce a break-even point model as an extension of supply chain decisions after assessing the system's cost-benefit framework. On the other hand, decision-making methods could be adopted to analyze changes in the traceability behavior and capabilities of enterprises by considering the revenue objective and cost constrain conditions of the entire supply chain.

■ *Review on the performance evaluation of traceability systems*

The existing measures and methods are not fully applicable to the evaluation and acceptance of various TSs. On the one hand, a common indicator system particularly used for different product chains is scarce, which may increase the difficulty of performance evaluation by government regulators and are not conducive to the comparison of TSs in distinct industries (Forås *et al.*, 2015). Future research could develop systematic, standard, and operable evaluation index systems that are more applicable to general product TSs on the basis of theoretical and practical investigations. On the other hand, regarding the evaluation methods, prior work often only uses a particular approach for evaluating whose robustness and effectiveness need a further verification (Donnelly *et al.*, 2012). Moreover, the application of various systematic evaluation methods can be further compared to examine which method is more effective in presenting the performance differences of TSs. In addition, participants in TSs are not only internal stakeholders but also external stakeholders such as regulators, public media, consumers (Sander *et al.*, 2018). Therefore, further consideration must be given to incorporating feedback from more stakeholders in the TS performance evaluation.

■ *Review on the impact on operations management*

Although many scholars have mentioned the impact of traceability on supply chain operation management, they have not conducted in-depth exploration on the relationship between the two. The reason that hinders authors from an in-depth analysis of those effects is, first, the theoretical characterization of traceability technology. At present, some scholars used the concept of the 'traceability level' and chose four dimensions including 'breadth', 'depth', 'precision', and 'speed' to describe such a capability. Specific traceability technologies, such as identification and communication, were also used to describe 'traceability' (Epelbaum and Martinez, 2014). Future research needs to further develop the scale of 'traceability' through an extensive sample survey or case study as such construct has not yet reached a consensus. The second reason is the lack of awareness of the technological impact. Many scholars still hold the understanding of traceability as a tool to monitor food processing (Regattieri *et al.*, 2007) but fail to observe the attributes of 'publicity' and 'whole-process' that the traceability technology has. Responding to food safety assurance, the impact of traceability on FSC companies is more profound in terms of society and sustainable development (Garcia-Torres *et al.*, 2019). For a technology that requires the participation and cooperation among entire supply chain members, whether the implementation of TSs will affect the integration and whether such an implementation will produce sustainable value creation are worth further verification (Banterle and Stranieri, 2008a).

In addition to future research directions of the above nine clusters, we also suggest that SCT research should not be limited to the food industry, and traceability associated with transparency and visualization could be popularized to all sectors that consumers are concerned about, such as the apparel and pharmaceutical industry. Moreover, a causal relationship is observed between traceability and sustainability, as traceability management is the prerequisite to achieve sustainable development (Epelbaum and Martinez, 2014; Garcia-Torres *et al.*, 2019; Mol and Oosterveer, 2015). Future work can explore the impact mechanism of FSCT

from the SSC perspective, to make up for the deficiency of SCT theory. Finally, attention should also be paid to the fact that current traceability applications and technological evolution may generate new research opportunities. For example, blockchain-enabled traceability technology may bring substantial changes in traditional supply chain quality management.

5. Conclusions

A systematic literature review of FSCM related was carried out in this study. We have reviewed 278 articles published from 1994 to September 2019, and clearly stated the four stages of FSCM issues evolution, and identified three major published journals (published over ten papers). Survey and conceptual analysis are the two most widely used methods, and meat and meat product were found to be the main food category in traceability application. Nine key themes were extracted and integrated into thematic analysis after an in-depth discussion about the terminology development of traceability, which can be classified into pre- and post-studies of TS adoption. We finally concluded with three significant trends that the focus of themes has moved to research on the post-adoption of TSs, the area has shifted to developing economies, and the analysis unit has transferred to supply chain level. On this basis, a framework for future research direction is presented after the systematic review of each key theme.

This study also delivers some significant contributions. In general, for theoretical contributions, this study may be the first systematic review of the FSCT research over the past 30 years to classify prior work into pre- and post-studies of TS adoption, to better understand and identify research trends. Through the in-depth discussion of nine research topics, readers can understand the research history and overview of FSCT more clearly and systematically. In addition, a structural and holistic definition of FSCT is proposed in this study, which not only described the behavior and process of traceability but also expressed its essence and value, thereby making up for the vagueness of the FSCT concept. Moreover, the framework for future research direction from each cluster covers available gaps and opportunities, which enriches the implication of food traceability and further extends FSCT research from food science and engineering fields. From a management perspective, this literature review may help managers recognize the significance of FSCT and particularly motivate companies to engage or deepen their understanding of traceability, thereby assisting supply chain managers from the food sector to optimize resource allocation and integrate traceability into their corporate strategies.

This study also has limitations. On the one hand, WoS and Scopus were chosen as the primary search databases, but they did not fully cover all highly cited peer-reviewed journals. Although we have tried to relax the search terms to minimize the lack of literature due to the incomplete selection of keywords, avoiding this situation ultimately seems to be complicated. On the other hand, we attempt to reduce subjectivity and personal prejudice in the selection and classification of documents by double-checking. However, the research results are still influenced to some extent by the experienced judgment and educational background of the reviewers. Despite these limitations, the results of our analysis provide significant implications for academic research and management practices.

References

Aiello, G., M. Enea and C. Muriana. 2015. The expected value of the traceability information. *European Journal of Operational Research* 244(1): 176-186. https://doi.org/10.1016/j.ejor.2015.01.028

Alfnes, F., X. Chen and K. Rickertsen. 2018. Labeling farmed seafood: a review. *Aquaculture Economics & Management* 22(1): 1-26. https://doi.org/10.1080/13657305.2017.1356398

Angulo, A.M. and J.M. Gil. 2007. Risk perception and consumer willingness to pay for certified beef in Spain. *Food Quality & Preference* 18(8): 1106-1117. https://doi.org/10.1016/j.foodqual.2007.05.008

Aung, M.M. and Y.S. Chang. 2014. Traceability in a food supply chain: safety and quality perspectives. *Food Control* 39(1): 172-184. https://doi.org/10.1016/j.foodcont.2013.11.007

Bai, J.F., C.P. Zhang and J. Jiang. 2013. The role of certificate issuer on consumers' willingness-to-pay for milk traceability in China. *Agricultural Economics* 44(4-5): 537-544. https://doi.org/10.1111/agec.12037

Banterle, A. and S. Stranieri. 2008a. The consequences of voluntary traceability system for supply chain relationships. An application of transaction cost economics. *Food Policy* 33(6): 560-569. https://doi.org/10.1016/j.foodpol.2008.06.002

Banterle, A. and S. Stranieri. 2008b. Information, labelling, and vertical coordination: an analysis of the Italian meat supply networks. *Agribusiness* 24(3): 320-331. https://doi.org/10.1002/agr.20169

Basole, R.C. and M. Nowak. 2018. Assimilation of tracking technology in the supply chain. *Transportation Research Part E: Logistics & Transportation Review* 114: 350-370. https://doi.org/10.1016/j.tre.2016.08.003

Borit, M. and J. Santos. 2015. Getting traceability right, from fish to advanced bio-technological products: a review of legislation. *Journal of Cleaner Production* 104: 13-22. https://doi.org/10.1016/j.jclepro.2015.05.003

Bosona, T. and G. Gebresenbet. 2013. Food traceability as an integral part of logistics management in food and agricultural supply chain. *Food Control* 33(1): 32-48. https://doi.org/10.1016/j.foodcont.2013.02.004

Canavari, M., R. Centonze, M. Hingley and R. Spadoni. 2010. Traceability as part of competitive strategy in the fruit supply chain. *British Food Journal* 112(2): 171-186. https://doi.org/10.1108/00070701011018851

Charlebois, S., B. Sterling, S. Haratifar and S.K. Naing. 2014. Comparison of global food traceability regulations and requirements. *Comprehensive Reviews in Food Science & Food Safety* 13(5): 1104-1123. https://doi.org/10.1111/1541-4337.12101

Charlier, C. and E. Valceschini. 2008. Coordination for traceability in the food chain. A critical appraisal of European regulation. *European Journal of Law & Economics* 25(1): 1-15. https://doi.org/10.1007/s10657-007-9038-2

Chen, H.H., Z.H. Tian and F. Xu. 2019. What are cost changes for produce implementing traceability systems in China? Evidence from enterprise A. *Applied Economics* 51(7): 687-697. https://doi.org/10.1080/00036846.2018.1510470

Chen, L., F. Jia, T. Li and T. Zhang. 2021. Supply chain leadership and firm performance: a meta-analysis. *International Journal of Production Economics* 235: 108082. https://doi.org/10.1016/j.ijpe.2021.108082

Cheng, M.J. and J.E.L. Simmons. 1994. Traceability in manufacturing systems. *International Journal of Operations & Production Management* 14(10): 4-16. https://doi.org/10.1108/01443579410067199

Choe, Y.C., J. Park, M. Chung and J. Moon. 2009. Effect of the food traceability system for building trust: price premium and buying behavior. *Information Systems Frontiers* 11(2): 167-179. https://doi.org/10.1007/s10796-008-9134-z

Chryssochoidis, G., A. Karagiannaki, K. Pramatari and O. Kehagia. 2009. A cost-benefit evaluation framework of an electronic-based traceability system. *British Food Journal* 111(6): 565-582. https://doi.org/10.1108/00070700910966023

Dabbene, F., P. Gay and C. Tortia. 2014. Traceability issues in food supply chain management: a review. *Biosystems Engineering* 120: 65-80. https://doi.org/10.1016/j.biosystemseng.2013.09.006

Dai, H.Y., L. Ge and W.H. Zhou. 2015a. A design method for supply chain traceability systems with aligned interests. *International Journal of Production Economics* 170: 14-24. https://doi.org/10.1016/j.ijpe.2015.08.010

Dai, H.Y., M.M. Tseng and P.H. Zipkin. 2015b. Design of traceability systems for product recall. *International Journal of Production Research* 53(2): 511-531. https://doi.org/10.1080/00207543.2014.955922

Dandage, K., R. Badia-Melis and L. Ruiz-García. 2017. Indian perspective in food traceability: a review. *Food Control* 71: 217-227. https://doi.org/10.1016/j.foodcont.2016.07.005

Donnelly, K.A.M., K.M. Karlsen and B. Dreyer. 2012. A simulated recall study in five major food sectors. *British Food Journal* 114(7): 1016-1031. https://doi.org/10.1108/00070701211241590

Dzwolak, W. 2016. Practical aspects of traceability in small food businesses with implemented food safety management systems. *Journal of Food Safety* 36(2): 203-213. https://doi.org/10.1111/jfs.12232

Engelseth, P. 2009. Food product traceability and supply network integration. *Journal of Business & Industrial Marketing* 24(5): 421-430. https://doi.org/10.1108/08858620910966291

Engelseth, P., W. Wongthatsanekorn and C. Charoensiriwath. 2014. Food product traceability and customer value. *Global Business Review* 15: 87S-105S. https://doi.org/10.1177/0972150914550549

Epelbaum, F.M.B. and M.G. Martinez. 2014. The technological evolution of food traceability systems and their impact on firm sustainable performance: A RBV approach. *International Journal of Production Economics* 150: 215-224. https://doi.org/10.1016/j.ijpe.2014.01.007

Forås, E., M. Thakur, K. Solem and R. Svarva. 2015. State of traceability in the Norwegian food sectors. *Food Control* 57: 65-69. https://doi.org/10.1016/j.foodcont.2015.03.027

Fritz, M. and G. Schiefer. 2009. Tracking, tracing, and business process interests in food commodities: a multi-level decision complexity. *International Journal of Production Economics* 117(2): 317-329. https://doi.org/10.1016/j.ijpe.2008.10.015

Galliano, D. and L. Orozco. 2013. New technologies and firm organization: the case of electronic traceability systems in French agribusiness. *Industry & Innovation* 20(1): 22-47. https://doi.org/10.1080/13662716.2013.761379

Garcia-Torres, S., L. Albareda, M. Rey-Garcia and S. Seuring. 2019. Traceability for sustainability – literature review and conceptual framework. *Supply Chain Management: an International Journal* 24(1): 85-106. https://doi.org/10.1108/SCM-04-2018-0152

Golan, E.H., B. Kissoff, F. Kuchler, L. Calvin, K. Nelson and G. Price. 2004. *Traceability in the U.S. food supply: economic theory and industry studies*. Agricultural Economic Report No. (AER-830). Economic Research Service, USDA, Washington, DC, USA.

Gunawan, I., I. Vanany and E. Widodo. 2019. Cost-benefit model in improving traceability system: case study in Indonesian bulk-liquid industry. *Supply Chain Forum: an International Journal* 20(2): 145-157. https://doi.org/10.1080/16258312.2019.1570671

Heyder, M., L. Theuvsen and T. Hollmann-Hespos. 2012. Investments in tracking and tracing systems in the food industry: a PLS analysis. *Food Policy* 37(1): 102-113. https://doi.org/10.1016/j.foodpol.2011.11.006

Hobbs, J.E. 2004. Information asymmetry and the role of traceability systems. *Agribusiness* 20(4): 397-415. https://doi.org/10.1002/agr.20020

Karlsen, K.M., B. Dreyer, P. Olsen and E.O. Elvevoll. 2012. Granularity and its role in implementation of seafood traceability. *Journal of Food Engineering* 112(1-2): 78-85. https://doi.org/10.1016/j.jfoodeng.2012.03.025

Karlsen, K.M., B. Dreyer, P. Olsen and E.O. Elvevoll. 2013. Literature review: does a common theoretical framework to implement food traceability exist? *Food Control* 32(2): 409-417. https://doi.org/10.1016/j.foodcont.2012.12.011

Lavoie, G. and J.F. Forest. 2009. Implementation of a traceability system from constraints to opportunities for the industry: a case study of Quebec, Canada. *International Food & Agribusiness Management Review* 12(2): 71-84. https://doi.org/10.1093/heapol/czn044

Lu, J., L.H. Wu, S.X. Wang and L.L. Xu. 2016. Consumer preference and demand for traceable food attributes. *British Food Journal* 118(9): 2140-2156. https://doi.org/10.1108/bfj-12-2015-0461

Manos, B. and I. Manikas. 2010. Traceability in the Greek fresh produce sector: drivers and constraints. *British Food Journal* 112(6): 640-652. https://doi.org/10.1108/00070701011052727

Matta, V., D. Koonce and A. Jeyaraj. 2009. Initiation, experimentation, implementation of innovations: the case for radio frequency identification systems. *International Journal of Information Management* 29(2): 164-174. https://doi.org/10.1016/j.ijinfomgt.2011.10.002

Mattevi, M. and J.A. Jones. 2016. Food supply chain: are UK SMEs aware of concept, drivers, benefits and barriers, and frameworks of traceability? *British Food Journal* 118(5): 1107-1128. https://doi.org/10.1108/BFJ-07-2015-0261

Mayring, P. 2003. *Qualitative content analysis*, 8th edition. Beltz Verlag, Weinheim, Germany.

Moe, T. 1998. Perspectives on traceability in food manufacture. *Trends in Food Science & Technology* 9(5): 211-214. https://doi.org/10.1016/S0924-2244(98)00037-5

Mol, A.P.J. and P. Oosterveer. 2015. Certification of markets, markets of certificates: tracing sustainability in global agro-food value chains. *Sustainability* 7(9): 12258-12278. https://doi.org/10.3390/su70912258

Olsen, P. and M. Borit. 2013. How to define traceability. *Trends in Food Science & Technology* 29(2): 142-150. https://doi.org/10.1016/j.tifs.2012.10.003

Pouliot, S. and D.A. Sumner. 2008. Traceability, liability, and incentives for food safety and quality. *American Journal of Agricultural Economics* 90(1): 15-27. https://doi.org/10.1111/j.1467-8276.2007.01061.x

Rábade, L.A. and J.A. Alfaro. 2006. Buyer-supplier relationship's influence on traceability implementation in the vegetable industry. *Journal of Purchasing & Supply Management* 12(1): 39-50. https://doi.org/10.1016/j.pursup.2006.02.003

Regattieri, A., M. Gamberi and R. Manzini. 2007. Traceability of food products: general framework and experimental evidence. *Journal of Food Engineering* 81(2): 347-356. https://doi.org/10.1016/j.jfoodeng.2006.10.032

Resende-Filho, M.A. and T.M. Hurley. 2012. Information asymmetry and traceability incentives for food safety. *International Journal of Production Economics* 139(2): 596-603. https://doi.org/10.1016/j.ijpe.2012.05.034

Ringsberg, H. 2014. Perspectives on food traceability: a systematic literature review. *Supply Chain Management: an International Journal* 19: 558-576. https://doi.org/10.1108/SCM-01-2014-0026

Saak, A.E. 2016. Traceability and reputation in supply chains. *International Journal of Production Economics* 177: 149-162. https://doi.org/10.1016/j.ijpe.2016.04.008

Saltini, R. and R. Akkerman. 2012. Testing improvements in the chocolate traceability system: impact on product recalls and production efficiency. *Food Control* 23(1): 221-226. https://doi.org/10.1016/j.foodcont.2011.07.015

Sander, F., J. Semeijn and D. Mahr. 2018. The acceptance of blockchain technology in meat traceability and transparency. *British Food Journal* 120(9): 2066-2079. https://doi.org/10.1108/BFJ-07-2017-0365

Sen, M.K.C. 2014. Food traceability and consumer awareness in Turkey: a review article. *Journal of Animal and Veterinary Advances* 13: 350-354. https://doi.org/10.36478/javaa.2014.350.354

Souza-Monteiro, D.M. and J.A. Caswell. 2010. The economics of voluntary traceability in multi-ingredient food chains. *Agribusiness* 26(1): 122-142. https://doi.org/10.1002/agr.20233

Starbird, S.A. and V. Amanor-Boadu. 2006. Do inspection and traceability provide incentives for food safety? *Journal of Agricultural & Resource Economics* 31(1): 14-26. https://doi.org/10.2307/40987303

Stranieri, S., A. Cavaliere and A. Banterle. 2016. Voluntary traceability standards and the role of economic incentives. *British Food Journal* 118(5): 1025-1040. https://doi.org/10.1108/BFJ-04-2015-0151

Stranieri, S., A. Cavaliere and A. Banterle. 2017a. Do motivations affect different voluntary traceability schemes? An empirical analysis among food manufacturers. *Food Control* 80: 187-196. https://doi.org/10.1016/j.foodcont.2017.04.047

Stranieri, S., L. Orsi and A. Banterle. 2017b. Traceability and risks: an extended transaction cost perspective. *Supply Chain Management: an International Journal* 22(2): 145-159. https://doi.org/10.1108/SCM-07-2016-0268

United Nations (UN). 2019. World economic situation and prospects in 2019. UN, New York, NY, USA. Available at: https://www.un.org/development/desa/publications/publication/world-economic-situation-and-prospects-2019

Van Rijswijk, W. and L.J. Frewer. 2008. Consumer perceptions of food quality and safety and their relation to traceability. *British Food Journal* 110(10): 1034-1046. https://doi.org/10.1108/00070700810906642

Verbeke, W., O.T. Doyer and D.P. Visser. 2002. Supply chain management and traceability in pork chains: the Belgian and South African case. *Agrekon* 41(1): 97-107. https://doi.org/10.1080/03031853.2002.9523588

Viaene, J. and W. Verbeke. 1998. Traceability as a key instrument towards supply chain and quality management in the Belgian poultry meat chain. *Supply Chain Management: an International Journal* 3(3): 139-141. https://doi.org/10.1108/13598549810230868

Vo, V.D., N. Mainetti and P. Fenies. 2016. Traceability and transaction governance: a transaction cost analysis in seafood supply chain. *Supply Chain Forum: an International Journal* 17(3): 125-135. https://doi.org/10.1080/16258312.2016.1188588

Wang, X. and D. Li. 2012. A dynamic product quality evaluation based pricing model for perishable food supply chains. *Omega-International Journal of Management Science* 40(6): 906-917. https://doi.org/10.1016/j.omega.2012.02.001

Wang, X., D. Li and C. O'Brien. 2009. Optimisation of traceability and operations planning: an integrated model for perishable food production. *International Journal of Production Research* 47(11): 2865-2886. https://doi.org/10.1080/00207540701725075

Wang, X., D. Li, C. O'Brien and Y. Li. 2010. A production planning model to reduce risk and improve operations management. *International Journal of Production Economics* 124(2): 463-474. https://doi.org/10.1016/j.ijpe.2009.12.009

Wowak, K.D., C.W. Craighead and D.J. Ketchen Jr. 2016. Tracing bad products in supply chains: the roles of temporality, supply chain permeation, and product information ambiguity. *Journal of Business Logistics* 37(2): 132-151. https://doi.org/10.1111/jbl.12125

Wu, L.H., H.S. Wang, D. Zhu, W.Y. Hu and S.X. Wang. 2016. Chinese consumers' willingness to pay for pork traceability information-the case of Wuxi. *Agricultural Economics* 47(1): 71-79. https://doi.org/10.1111/agec.12210

Yang, Y., F. Jia and Z. Xu. 2018. Towards an integrated conceptual model of supply chain learning: an extended resource-based view. *Supply Chain Management: an International Journal* 24(2): 189-214. https://doi.org/10.1108/SCM-11-2017-0359

Zeng, Y., F. Jia, L. Wan and H. Guo. 2017. E-commerce in agri-food sector: a systematic literature review. *International Food and Agribusiness Management Review* 20(4): 439-460. https://doi.org/10.22434/IFAMR2016.0156

Zhang, J.R. and T. Bhatt. 2014. A guidance document on the best practices in food traceability. *Comprehensive Reviews in Food Science & Food Safety* 13(5): 1074-1103. https://doi.org/10.1111/1541-4337.12103

Zhou, X., M. Pullman and Z. Xu. 2021. The impact of food supply chain traceability on sustainability performance. *Operations Management Research*. https://doi.org/10.1007/s12063-021-00189-w