

Traceability in multi-tier supply chains: insights from five case studies

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Abstract

Purpose – The study aims to explore the complexities of multi-tier sustainable supply chain management (MT-SSCM) by investigating the factors that influence traceability and how these factors affect firms' efforts towards MT-SSCM.

Design/methodology/approach – Using a multiple case study approach, this study provides empirical evidence from 25 firms across 5 multi-tier supply chains in various industries. The study involved 5 focal firms, 10 first-tier suppliers and 10 lower-tier suppliers as the primary data sources, obtaining data through 44 semi-structured interviews.

Findings – Using inductive data analysis, this study revealed four key factors that affect traceability for sustainability: supply chain complexity, regulatory and industry environments, information sharing and traceability resources. The findings highlight the role of traceability in driving firms' efforts towards MT-SSCM.

Practical implications – This study offers valuable insights for firms and their purchasing and supply chain management on achieving supply chain traceability for sustainability. By understanding and leveraging these enablers, firms can develop appropriate strategies to achieve traceability for sustainable multi-tier supply chain management.

Originality/value – This study responds to the call for more research on the intersection of traceability and multi-tier supply chain management. Furthermore, it studies firms at multiple levels of the supply chain, including lower-tier suppliers.

Keywords Traceability, Multi-tier sustainable supply chain management, Sustainable purchasing and supply chain management, Lower-tier supplier management

Paper type Case study

1. Introduction

Supply chain traceability has become a critical component in addressing growing consumer demands for transparency, regulatory requirements and sustainability objectives (Jia *et al.*, 2025; Sodhi and Tang, 2019). Firms are increasingly expected to provide detailed insights into the origins of their products, the ethical sourcing of materials and the environmental impact of their supply chain activities. However, despite these expectations, implementing effective traceability mechanisms remains challenging, particularly in multi-tier supply chains characterised by complex networks of suppliers and intermediaries (Cui *et al.*, 2024; Gualandris *et al.*, 2021; Martinen *et al.*, 2024). The current approaches to traceability often fall short in addressing these complexities, leading to gaps in firms' visibility, accountability and compliance.

In 2021, the European Union trade policy required firms to assess sustainability at multiple tiers in their supply chains instead of only accounting for the firm's own operations and purchasing (European Commission, 2021), further strengthening stakeholders' pressure. This trend continued with the European Parliament's

proposal for a product passport reporting on environmental impacts (European Parliament, 2023) and the Corporate Sustainability Reporting Directive (CSRD), which demands firms to report Scope 3 emissions from their supply chains (EUR-Lex, 2022). These examples clearly indicate that legislation and policies, along with traceability demands from end consumers, are growing.

Traceability can be defined as “the capability of a company for ascertaining provenance” (Sodhi and Tang, 2019, p. 2946) and as the level of a firm's knowledge about the locations of their suppliers, from the original source to the end customer and the processes followed by their products (Cousins *et al.*, 2019) – the definition we adopted for this study. To enhance traceability, firms must encompass multiple supply chain tiers by engaging with their suppliers more closely to ensure adherence to environmental and social standards, thus

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Supply Chain Management: An International Journal
30/7 (2025) 77–99
Emerald Publishing Limited [ISSN 1359-8546]
[DOI 10.1108/SCM-07-2024-0428]

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Received 3 July 2024
Revised 17 October 2024
11 February 2025
23 May 2025
5 June 2025
Accepted 6 June 2025

expanding the scope of supply chain sustainability (Bateman and Bonanni, 2019; Grimm *et al.*, 2014). However, incorporating sustainability initiatives across these tiers remains difficult (Villena and Gioia, 2018), as weak or non-existent contracts with lower-tier suppliers hinder the implementation of such initiatives, causing firms to rely on first-tier suppliers for managing these tiers (Grimm *et al.*, 2014). The challenge lies in identifying and engaging lower-tier suppliers, as they lack visibility in terms of their identity, operations and capabilities (Choi *et al.*, 2001; Villena and Gioia, 2018; Wilhelm *et al.*, 2016a). Focal firms may depend on first-tier suppliers for information on subsequent tiers; however, obtaining details about lower-tier suppliers remains particularly challenging (Hartmann and Moeller, 2014), especially when direct suppliers are unwilling to share information about their suppliers (Grimm *et al.*, 2014; Wilhelm *et al.*, 2016a). In addition, lower-tier suppliers may be located in emerging markets that are often geographically and institutionally distant from the focal firm (Alwaysheh and Klassen, 2010), further obstructing the latter's efforts to trace and engage with them. Thus, a firm's ability to identify lower-tier suppliers and trace the origin of their raw materials can be considered critical for effective management of multi-tier supply chains.

In the context of multi-tier sustainable supply chain management (MT-SSCM), prior studies have investigated the factors critical for successful sub-supplier management (Grimm *et al.*, 2014) and the contingency factors affecting firms' approaches to managing lower-tier suppliers (Wilhelm *et al.*, 2016b). Most studies have focused on the determinants of lower-tier supplier management, while traceability in multi-tier supply chains remains overlooked. When firms are unable to trace their supply chains, a crucial enabler for SSCM is missing (Garcia-Torres *et al.*, 2019), leading to difficulties in managing lower-tier suppliers (Marttinen *et al.*, 2024). Hence, understanding how traceability can be achieved by investigating its enabling factors is key to multi-tier management and sustainability. However, the understanding of the role of traceability in shaping firms' management approaches in MT-SSCM remains limited, because recent studies on traceability have focused on product quality, consumer safety, risk management and technological solutions (Hoang *et al.*, 2023; Razak *et al.*, 2023; Zhou *et al.*, 2024). Therefore, this study aims to investigate the following research question:

RQ. What factors influence traceability for sustainability in multi-tier supply chains, and how do these factors affect MT-SSCM approaches?

This study contributes to the intersection of traceability and multi-tier supply chain management (e.g. Tachizawa and Wong, 2014; Villena and Gioia, 2018; Wilhelm *et al.*, 2016b) by examining how firms across industries and supply chain levels navigate traceability challenges (Grimm *et al.*, 2014). Using a multiple case study approach on five multi-tier supply chains, the study showed that factors at the levels of organisation, relationship and multi-tier supply chain influence firms' traceability efforts. The study identified the following factors as key factors: supply chain complexity, regulatory and industry environments, traceability resources and information sharing. The findings indicate that complex supply chains and

resource constraints hinder traceability, often leading to firms' relying on indirect or third-party management approaches in their multi-tier supply chains, even when facing stakeholder pressure. In addition, the study highlights the critical role of information sharing in facilitating traceability and enhancing tracking capabilities. Finally, the results show how these factors drive firms' adoption of different multi-tier management approaches. Hence, this study contributes to the literature by demonstrating how traceability enables effective management of multi-tier supply chains.

2. Theoretical background

2.1 Multi-tier sustainable supply chain management

Ensuring a sustainable supply is strongly linked to suppliers' actions and performance. Sancha *et al.* (2016) state that a firm's sustainability level cannot surpass that of its suppliers, and Villena and Gioia (2018, p. 83) continue that "a supply network cannot be sustainable if lower-tier suppliers are not addressing their social and environmental issues". Thus, suppliers in the lower tiers need to embrace sustainability because the most significant environmental and social risks are associated with them (Kähkönen *et al.*, 2023; Villena and Gioia, 2018). These suppliers, however, are the least regulated, monitored and equipped (Villena and Gioia, 2018), causing significant social failures in global supply chains (Wilhelm *et al.*, 2016a).

In multi-tier supply chain management, the focus is not only on direct suppliers but also on lower-tier suppliers. Managing more suppliers than first-tier suppliers is difficult for managers because of the newness and complexity of issues regarding environmental and social sustainability (Grimm *et al.*, 2016). In addition, effectively influencing firms' practices beyond the direct buyer-supplier relationship is challenging (Seuring *et al.*, 2008). A firm's regional and contractual distance from lower-tier suppliers increases information asymmetry between the focal firm, first-tier and lower-tier suppliers (Sarkis *et al.*, 2011).

Such difficulties may either make focal firms passive towards managing multiple tiers of suppliers (Wilhelm *et al.*, 2016a) or increase their reliance on their first-tier suppliers to manage sub-suppliers (Grimm *et al.*, 2014). Lee and Klassen (2008) state that, although direct pressure on lower-tier suppliers is not common, motivating first-tier suppliers to acknowledge sustainability-related factors in their supply chain management helps focal firms indirectly manage their lower tiers. Tachizawa and Wong (2014) found that firms can take four different management approaches for managing sustainability in multi-tier supply chains: direct, indirect, work with third parties and don't bother. A direct approach indicates that the focal firm manages its lower-tier suppliers directly, whereas the indirect approach indicates that a first-tier supplier oversees lower-tier suppliers' sustainability practices. Collaborating with external entities, such as non-governmental organisations (NGOs), to enhance sustainability is called working with third parties. Finally, don't bother approach refers to situations in which a firm does not engage in managing its lower-tier suppliers. Tachizawa and Wong (2014) found that a firm's choice of management approach for multi-tier supply chains is affected by various contingent factors, namely, the distance between the supply chain members, material criticality, power, dependence and knowledge resources. Grimm *et al.* (2014) identified 14 factors that

play critical roles in lower-tier (sub-supplier) management, including, for example, trust, long-term commitment, willingness to provide sub-supplier information and geographical and cultural distance. Wilhelm *et al.* (2016b) identified several factors, including complexity and transparency of supply chains, the type of sustainability in question, power imbalances and the technical expertise of suppliers, that determine how and when firms extend their sustainability strategies to their sub-suppliers. These studies do not focus, however, on traceability and how traceability could be better achieved in multi-tier supply chains. This might be partly because traceability requirements have grown during recent years, whereas earlier the focus was more on overall sustainability.

Firms that take a multi-tier perspective in managing their supply chains are better able to manage, for example, sustainability and risks related to lower tiers (Grimm *et al.*, 2016; Kähkönen *et al.*, 2023; Zehendner *et al.*, 2021). However, Grimm *et al.* (2014) and Wilhelm *et al.* (2016b) found that multi-tier supply chain management with lower tiers is not always possible. Firms must be able to identify their lower-tier suppliers and trace the origin of their raw materials. Hence, firms must be able to gather information about their lower-tier suppliers and develop strategies to achieve traceability.

2.2 Traceability for sustainability

The research on supply chain traceability first started in the late 1990s, which was related to food safety in the food industry (e.g. Viane and Verbeke, 1998; Wilson and Clarke, 1998). However, with the growing requirements for sustainability, the role of supply chain traceability and related research has also changed. In particular, the exploration of traceability in relation to sustainability is a recent development in the research related to supply chain management (Hastig and Sodhi, 2020; Sodhi and Tang, 2019). Contributors include Garcia-Torres *et al.* (2019), who examine the overlap of sustainability and traceability and study how companies execute traceability for sustainability within their global supply chains and their role in fostering SSCM. Garcia-Torres *et al.* (2019, p. 98) suggest that traceability for sustainability “can help minimise sustainability risks and impacts by the mimetic effect of inter-organisational collaboration strategies, alliances and initiatives, distributing and transferring knowledge, learning and resources more evenly along the entire SC”. Kumar *et al.* (2017) studied how traceability contributes to sustainability and identified traceability as a vital component in pursuing sustainability. They found that traceability integrates information and can be seen as a competitive factor because it enables providing detailed information to consumers. However, the studies by Garcia-Torres *et al.* (2019) and Kumar *et al.* (2017) lacked empirical research as the studies are conceptual ones. Furthermore, many recent contributions, such as those by Hastig and Sodhi (2020), Agrawal *et al.* (2021) and Zhou *et al.* (2024), focused on exploring the opportunities of implementing traceability in supply chains through technological solutions. The study by Hastig and Sodhi (2020) is a conceptual and Zhou *et al.* (2024) focused on the focal firms, thus ignoring lower-tier suppliers. Agrawal *et al.* (2021) used a simulation-based demonstration and claimed to use a multi-tier perspective; however, the perspective was more from the perspective of a traditional supply chain. Some studies have also investigated the drivers that enable the adoption of blockchain to achieve sustainable food security (Yadav *et al.*, 2021) and the drivers and

barriers to Industry 4.0 adoption for extending sustainability within the context of multi-tier manufacturing supply chain (Sharma *et al.*, 2021). Despite the growing research on traceability, a lack of empirical research and many unanswered questions remain, for instance, regarding the role of traceability in strategic decision-making (Hoang *et al.*, 2023).

According to Garcia-Torres *et al.* (2022), traceability and transparency can be regarded as key instruments for fostering cooperation and ensuring coordination to achieve sustainability within supply chains. Fernie *et al.* (2010) discovered that the degree of transparency between organisations and their willingness to share information significantly promotes enhancement in firms’ tracking and tracing capabilities within supply chains, highlighting the value of mutual openness and information sharing in enhancing traceability. Garcia-Torres *et al.* (2019) found that transparency can be considered a driver of traceability, as both concepts are often linked. According to Schäfer (2023), traceability, visibility and disclosure are variably linked to transparency, ranging from being synonymous to independent or even integral components or pre-requisites of transparency. When traceability can be defined as a firm’s capability to ensure the origin by identifying suppliers and knowing their location and processes (Cousins *et al.*, 2019; Sodhi and Tang, 2019), transparency can be understood as a firm’s openness to revealing information about its upstream operations and products to the public (Sodhi and Tang, 2019) or information sharing among organisations (Garcia-Torres *et al.*, 2022) to enable traceability by reporting to and communicating with key stakeholders (Morgan *et al.*, 2018). This study adopts the latter perspective, positing that transparency is essential for achieving traceability.

Kumar *et al.* (2017) state that multiple brands have identified traceability as a competitive factor, but recent developments emphasise traceability as a must-have supply chain element. Existing research mainly studies traceability in the context of direct supplier management, but traceability is about identifying also the lower-tier suppliers and tracing the supply chain (Cousins *et al.*, 2019; Sodhi and Tang, 2019), which tightly connects it to a multi-tier perspective. If firms cannot trace their supply chains, managing lower-tier suppliers becomes difficult. Research on the topic is, however, missing. Existing research lacks contributions on traceability from the multi-tier perspective and especially on the connection between traceability and the management approaches of lower-tier suppliers. Thus, discovering key factors that affect traceability in multi-tier supply chains can improve lower-tier supplier management and an understanding of the management approaches that can be taken in MT-SSCM.

3. Methodology

3.1 Research design and case selection

To investigate the emerging subject of traceability for sustainability, this study has adopted an exploratory, inductive approach. The research method chosen is a multiple-case study design, featuring several embedded units of analysis (Eisenhardt, 1989; Yin, 2009). This methodology allows for the exploration of a broad spectrum of perspectives, enriching the overall comprehension of the topic. The study examines five multi-tier supply chains that involve five focal firms, 10 first-tier suppliers and 10 lower-tier suppliers comprising various industries.

Using a multiple case study approach allows for an investigation from different contexts and viewpoints, which can increase the credibility and generalisability of the findings (Yin, 2009).

This research focused on focal firms in Finland and their European suppliers based in Finland, Germany, Belgium and Italy. Since 2021, Finland has been ranked first in the annual global ranking of sustainable development and was among the top 3 many years before that (Sachs *et al.*, 2021); thus, Finland offers an excellent context for studying sustainability-related issues. The official ranking of the Sustainable Brand Index (SBI) in 2018 guided the selection of focal firms. The SBI is an annual independent study that evaluates more than 1000 brands in the Nordics and The Netherlands (Sustainable Brand Index, 2018). The focal firms were selected from the top-ranked 100 Finnish firms, presuming them as sustainability leaders within the Finnish market and thus committed to practicing sustainable supply management and possessing advanced knowledge of the field, as suggested in previous studies (e.g. Pagell and Wu, 2009; Villena and Gioia, 2018). Firms representing different industries were included in the study as called for by Senyo and Osabutey (2023) to increase the empirical research perspectives on sustainability in multi-tier supply chains. Firms' sustainability reports and websites were screened to ensure that they prioritised sustainability in their purchasing and supply management. The first- and lower-tier suppliers were selected through snowball sampling; during the interviews, the focal firms were asked to nominate 1–3 suppliers who held strategic significance for their operations or those with whom they faced challenges in terms of achieving sustainability.

3.2 Data collection

In total, 44 informants participated in semi-structured interviews that lasted from 60 to 90 min. The interviews were primarily conducted face-to-face; however, due to the geographical spread of suppliers, some were conducted virtually. Figure 1 presents the case supply chains and provides firm- and interview-related information. The informants were selected based on their expertise in purchasing, supply chain management and sustainability, and they were, for example, sourcing and supply chain managers,

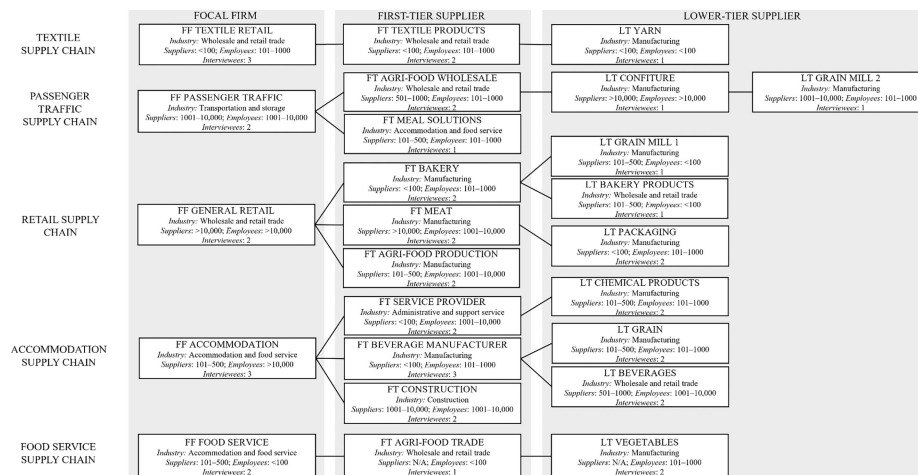
purchasing directors, corporate social responsibility managers and sustainability coordinators. Account managers were interviewed to fill the gap between the buyer company and the supplier firm's purchasing department.

To ensure a comprehensive understanding and validate the collected data, approximately two representatives from each firm were interviewed using a triangulation approach (Eisenhardt and Graebner, 2007). However, in some cases, only one informant was interviewed because of the extensive knowledge of the interviewee and the small company size. The informants were asked questions related to, for instance, the ability to trace products, services and raw materials, their knowledge about the members in their supply chains, the factors that help them in ensuring lower-tier suppliers' sustainability and the challenges they have faced. The study was conducted by following the guidelines of Eisenhardt (1989) and Strauss and Corbin (1998) in terms of the saturation point, indicating sufficiency of interviews as a situation in which new information produces little or no change to the codebook. To guarantee reliability and validity, a number of precautionary measures (Eisenhardt and Graebner, 2007), such as the use of multiple sources of evidence, investigator triangulation, establishment of the chain of evidence and creating a case study protocol and database, were used.

3.3 Data coding and analysis

The data from the five multi-tier supply chains were analysed using NVivo qualitative data analysis software and a systematic inductive approach to concept development, as proposed by Gioia *et al.* (2013). Special attention was paid to capturing informants' perspectives that uncovered new concepts beyond revisiting established ones. The research methodology included a first-order analysis using informant-centric terms and codes and a second-order analysis employing researcher-centric concepts, themes and dimensions to discover the enablers and barriers of traceability for sustainability. Appendix 1 illustrates the transition of raw data to identified emergent factors in detail. Creating such a data structure is a critical aspect of demonstrating rigour in qualitative research (Gioia *et al.*, 2013; Pratt, 2008).

Figure 1 Case study participants and interview information



Source: Authors' own work

The objective was to uncover key factors influencing a firm's ability to trace the origins of its supplies, thereby gaining insights into the enablers and obstacles impacting traceability and MT-SSCM approaches. First, an in-depth analysis of data at the firm level was conducted, and the identified firm-level factors resulted in four main dimensions. Then, a broader supply chain-level analysis was conducted to detect patterns prevalent across different supply chains, allowing for a comparative understanding of these patterns among various industries.

4. Findings

As a result of firm and supply chain-level analysis, four factors affecting traceability were identified: *supply chain complexity*; *regulatory and industry environments*; *traceability resources*; and *information sharing*. Table 1 displays the factors that may either support or hinder traceability in each firm. Appendix 2 provides detailed information about the case firms' traceability and MT-SSCM efforts. The following sub-sections elaborate on the insights from each of these factors.

4.1 Supply chain complexity

Supply chain complexity was identified as a significant contributing factor to traceability, comprising the following aspects: *number of intermediaries*, *geographical distance and dispersion*, *number of suppliers* and *product or service complexity*. The firms emphasised the effect that the number of intermediaries involved in a supply chain has on the complexity of tracing the origins of products and services. Each layer of intermediaries with its own set of suppliers was observed to increase the number of entities that needed to be traced, contributing to the potential for information distortion or loss. Because of their long and complex supply chains, some firms found it difficult and, in some cases, impossible to trace back the origins of their products and raw materials:

If it's really clear so that there is only one step, then there is at least a theoretical chance to go. But if it chains in a way that there are two or more between us and the farmers, then it already becomes complicated. (LT Confiture)

In particular, buying from importers was emphasised when it came to complicating firms' traceability efforts:

This is where the visibility completely disappears [...] because the batches they sell are enormous. (LT Beverages)

The biggest traceability challenges were related to global supply chains. An informant from FT Textile Products mentioned that working with geographically distant suppliers is challenging because of the complex supply chains consisting of many globally dispersed suppliers and outsourced operations. In contrast, geographically close suppliers were easier to trace:

It [tracing] is easiest with domestic suppliers and producers. The shorter the chain and the closer it is, the more transparency there is. (FT Beverage Manufacturer)

To simplify the supply chain structure, firms reported pursuing direct contracts with manufacturers, which can bring both traceability and cost-related benefits:

We also make contracts directly with manufacturers; therefore, we would not be involved in the chain quite as much. Of course, there are also economic benefits, but this way we know where those products come from. (FF Accommodation)

The firms reported the benefits of vertical integration of the production process; firms found tracing easier if their direct supplier was responsible for many steps in the production process.

For example, the lengths of the supply chains of FF Textile Retail varied, depending on how much of the manufacturing process was handled by their supplier; although their partner from Turkey oversaw most of the production process, their Latvian supplier may only be responsible for printing fabrics. The focal firm found it beneficial for traceability that its supplier, FT Textile Products, managed most of the process:

They buy yarn from a local operator, weave the towels and dye and do the whole process themselves. They have quite a lot in their own hands. (FF Textile Retail)

Vertical integration and supply chain non-complexity were also found to help auditing and lower-tier supplier management because it could increase the coverage of the audited supply chain members:

If the audit covers our first partner that makes [a product] from the thread onwards, then the auditing already covers a very big part of the production. On the other hand, if the supplier handles only the sewing part, the audit only covers this, and there are all those others [suppliers] that have not been audited. In that sense, the more they have in their own hands, the better it is for us. (FF Textile Retail)

Furthermore, the number of suppliers was found to contribute to the level of supply chain complexity. For instance, a large number of suppliers made it difficult to follow and maintain information about their supply chains:

We cannot send questions to 2,000 suppliers every day via email and ask if everything is the same way as before. (FF General Retail)

Based on the data, we identified product and service complexity as an aspect influencing the degree of supply chain complexity, thus contributing to the ability to trace the origin. The informants stressed that the less processed the product or raw material was, the easier it is to recognise the suppliers:

Our supply chain is fairly straightforward compared with clothing or retail industries, for instance [...] When we buy tomatoes, it is easy to see where they come from. (FF Food Service)

It is a different matter, because we don't buy finished products. It would be difficult to trace those, because even one product may consist of several different ingredients. We receive just basic plastic granules. (LT Packaging)

Firms with less complex supply chains were able to trace, acquire information about and visit lower-tier suppliers more easily, supporting a more direct approach to lower-tier supplier management:

Yes, we can [trace] because we buy raw materials, and thus, it is easier to get to the source. We do not buy products, for example, ready-made food with different components here and there, and they prepare the food with spices and so on. We have pretty straightforward [supply chains]. We buy raw materials, such as ham chips, so there is not much in it. More than 90% is meat—and we get to visit the pig farm as well. [...] We can physically see the origin, where they come from, and where they are made. I have also been fishing for tuna myself, so I have spent time with fishermen. (FF Food Service)

In contrast, firms with more complex supply chains, such as LT Confiture, faced traceability-related challenges that affected their approach towards multi-tier supply chain management:

At the moment, it is basically based on the fact that we need to convince the first tier that this issue needs to be passed forward. Of course, spot checks can do it, but we are pretty much in the starting blocks in terms of how we get deep into that chain [...]. It is extremely challenging in the food industry when the chain is long. It becomes a network very quickly [...]. It is impossible on many occasions. (LT Confiture)

4.2 Regulatory and industry environments

Regulatory and industry environments, including *regulatory pressure for traceability*, *industry-wide traceability mechanisms* and

Table 1 Factors affecting firms' traceability efforts in multi-tier supply chains

Supply chain	Participant	Supply chain complexity			Regulatory and industry environments			
		Number of intermediaries	Geographical distance and dispersion	Number of suppliers	Product and service complexity	Regulatory pressure for traceability	Industry-wide traceability mechanisms	Traceability requirements from customers
Textile	FF Textile Retail	•		•	•		•	•
	FT Textile Products	•	•	•				•
Passenger traffic	LT Yam		•	•	•		•	•
	FF Passenger Traffic	•			•	•		
	FT Agri-food	•	•		•	•		•
	Wholesale							
Retail	LT Confiture	•	•	•	•	•	•	
	LT Grain Mill 2	•	•		•	•	•	
	FT Meal Solutions	•	•		•	•		•
	FF General Retail	•	•	•	•	•		
	FT Bakery	•	•	•	•	•	•	•
	LT Grain Mill 1	•	•	•	•	•	•	•
	LT Bakery Products							•
	FT Meat	•	•			•		
	LT Packaging	•			•	•		•
	FT Agri-food		•	•	•			
Accommodation	Production							
	FF Accommodation	•	•		•	•		
	FT Service Provider	•	•					
	LT Chemical Products	•	•	•	•		•	
	FT Beverage	•	•		•			
	Manufacturer							
Food service	LT Grain	•	•					•
	LT Beverages	•	•		•	•	•	•
	FT Construction	•	•			•		
	FF Food Service	•	•		•			
	FT Agri-food Trade	•	•			•		•
	LT Vegetables	•	•			•	•	

Note(s): • = A mention about an effect on firm's ability to trace the provenance of raw materials, products or services
Source(s): Authors' own work

(continued)

Table 1

Supply chain	Participant	Traceability resources			Information sharing		Power dynamics
		Information systems and tools	Staff allocation	Supplier's willingness to disclose information	Supplier's capability to collect and share information		
Textile	FF Textile Retail		•	•			•
Passenger traffic	FT Textile Products			•	•		
	LT Yarn			•	•		
	FF Passenger Traffic						
	FT Agri-food Wholesale	•			•		
	LT Confiture	•		•	•		
Retail	LT Grain Mill 2				•		
	FT Meal Solutions		•		•		
	FF General Retail	•			•		
	FT Bakery				•		
	LT Grain Mill 1						
Accommodation	LT Bakery Products	•		•	•		
	FT Meat						
	LT Packaging	•			•		
	FT Agri-food Production	•	•				•
	FF Accommodation	•		•			
Food service	FT Service Provider			•	•		
	LT Chemical Products	•		•	•		
	FT Beverage Manufacturer			•			•
	LT Grain	•		•	•		
	LT Beverages	•	•	•			•
	FT Construction		•	•			
	FF Food Service		•	•			
	FT Agri-food Trade						•
	LT Vegetables	•			•		
Source(s): Authors' own work							

traceability requirements from customers, were identified as having a significant impact on achieving traceability. The impact of regulatory pressure on traceability was particularly stressed by firms in the food industry; the ability to trace suppliers often depends on its product category, as different product groups have different requirements in terms of the extent of required information. Legislation was highlighted as a key enabler of traceability:

It is guided by legislation that which product groups have what kind of obligations. Through supplier contracts, we require our suppliers to comply with the legislation. They will then have to grant at least the transparency required by the law. (FT Agri-food Wholesale)

Traceability is often realised through traceability testing. For instance, for LT Packaging, a supplier of FT Meat, traceability is a number one priority. They stated that traceability tests must be conducted for direct food contact products:

If there is a recall situation – for example, a dairy or a meat product that needs to be withdrawn from the store – the customer traces their own batch; however, we need to be able to trace and locate them. For example, we just did a traceability exercise as part of the audit, which meant that we traced the origin. We must be able to do that. This is a basic requirement. (LT Packaging)

Products or raw materials that received no regulatory pressure for traceability were more difficult to trace:

If it [traceability] has not been required at a more precise level, then we cannot really demand it, either. This is because the supply chain is not built in a way that facilitates communication with operators differently in terms of the origin of a product. (FT Agri-food Wholesale)

When we are tracing the origin of a product, it depends on the fact that—we cannot really force anyone by saying, “Now you must send that information to us”. Perhaps we can in the future, but at least for the moment, we cannot say that. (LT Beverages)

Importantly, regulatory requirements for traceability create a common ground in that firms do not have to trade off. According to LT Grain Mill 2, legislation for traceability has provided a solid foundation for environmental and social sustainability in terms of purchasing and supply management. They also stated that, beyond legislation, additional industry requirements for sustainability and traceability create a common ground, allowing them to compete on an equal footing with their competitors in terms of pricing. Regulatory and industry environments can also have an impact on supply chain configuration:

Due to the increased requirements in our market, we usually try to be as close as possible to the origin because we have to provide a lot of customer information about the origin of raw materials. (FT Meal Solutions)

The results indicated that industry-wide traceability mechanisms, such as product passports, third-party certifications and blockchain technology, can enable firms to achieve traceability. Such mechanisms were reported to increase the levels of reliability in terms of tracing products across supply chains, accessing origin information and possessing the potential to provide information to stakeholders and consumers. Members of the textile retail supply chain, including FF Textile Retail, described how industry-specific certifications helped them trace the country of origin for cotton.

You can surely trace the production of yarn, regardless of the partner. They always have that information available. However, managing the information is up to the yarn manufacturer. If the manufacturer is certified, information will be obtained. Otherwise, they may say, “well, usually it is from these countries,” and then they mix the cotton from different countries, because they do not

keep them separately. Therefore, you can never be absolutely sure. (FF Textile Retail).

Thus, lower-tier suppliers' use of certifications was seen as enabling traceability for the focal firm. In addition, enforcing certain certification requirements on suppliers was found to trigger a beneficial chain reaction, enhancing traceability and sustainability within multi-tier supply chains. The representatives from both FT Bakery and FT Beverage Manufacturing expressed parallel views regarding the implications of enforcing certification requirements on suppliers. Suppliers reacting to these requirements were observed to either adopt certifications or construct their own systems for overseeing their upstream partners, thereby increasing traceability. LT Grain Mill 1 provided an example of how product passports for traceability are used in the food industry:

It [grain] comes directly from the farmer, so we can trace it. There is a grain passport in which you can see who has grown it, in what harvest year and what plant protection products have been used. All information is there, including the farmer's signature. When we know which silo it came and from which silo it was driven to the mill, we can trace it very far. (LT Grain Mill 1)

Related to industry-wide traceability mechanisms, several firms were interested in blockchain technology because it can provide easy access to information across supply chain tiers. However, there were concerns about the practicalities. The informant from LT Confiture highlighted the challenges faced in hazelnut supply chains in which upstream actors could not be properly traced and identified owing to the complex nature of the industry, comprising vast networks of crackers and farms. Although LT Confiture was interested in blockchain technology, it lacked practical knowledge about how tracing the origin in such supply chains would actually work, especially considering the potential lack of suppliers' necessary capabilities:

We are very interested in blockchain and what it could bring, but my imagination cannot show yet how the technology—yes, it makes tracing possible, but how it would work in practice and enhance transparency [...] How do they [farmers and other upstream actors] track and add information to the system, so that we can trace it. (LT Confiture)

Thus, suppliers would also need to possess the capabilities to effectively support traceability and transparency initiatives. To address these challenges, the informant from LT Confiture emphasised the importance of making investments in traceability that are mutually beneficial for suppliers; they highlighted the need to engage and motivate suppliers, ensuring that they comprehend the advantages associated with investing in traceability initiatives.

The participants highlighted the significance of increasing customer demand for traceability. Traceability efforts are linked to the pressures firms receive from customers and consumers and the visibility of products to customers. This demand, coupled with the growing consumer consciousness, can accelerate firms' efforts to implement mechanisms for traceability. However, firms acknowledged the unfortunate reality that having full traceability in today's complex supply chains is not always achievable:

I had a situation with a customer company that wanted detailed information about palm oil and their brokers, and it was just a matter of finding out the information. There was a wall that both we—as the brand holder of a private label product and well-known industrial brand houses—had to say that “from now on, we will not be able to report”. This is an example of how there are customer companies where sustainability is really at the forefront of their operations, and they wish they could get increasingly accurate

reporting and information—more than anyone in this supply chain is currently capable of. (FT Agri-food Wholesale)

4.3 Information sharing

Inter-organisational information sharing is a critical aspect of traceability. Key elements that were found to contribute to this were the *supplier's willingness to disclose information* to their buyers, the *supplier's capability to collect and share information and power dynamics*. Regarding the *supplier's willingness to disclose information*, contrasting results were noted across different firms. Some firms found that their suppliers shared essential information quite willingly, while others reported challenges in acquiring the required information from their suppliers. Firms such as LT Bakery Products and FF Accommodation reported that their suppliers were sometimes unwilling to disclose information about their suppliers or sources:

Perhaps the most challenging thing is when we acquire furniture or equipment imported from anywhere around the world, and the importers are not necessarily willing to openly disclose their sources. The issue is the competitive factor here because the importers do not want to reveal information about their good suppliers to their competitors. (FF Accommodation)

Conversely, interviewees from FF Textile Retail and FF Food Service observed a recent shift in that suppliers are now more willing to share information. Compared to a decade ago, when many suppliers guarded their raw material sources as trade secrets, this recent change significantly facilitates traceability:

If we want to know the [lower-tier supplier's] name, locations of their factories, characteristics of their factories and the kind of people that work in those factories, then nobody would mind sharing this information unless there is something to hide. (FF Textile Retail)

They continued that they publicly disclosed the origins of their raw materials because they perceived no need for secrecy in doing so from their standpoint.

Furthermore, the data revealed instances in which suppliers failed to notify the buying firm about changes in lower-tier suppliers and countries, despite the contractual requirement to do so. In response to the information disclosure issue, a lower-tier supplier from the accommodation supply chain reported that they did not want to share detailed information with their customers sometimes:

It is our task to trace, and we may not even want to tell all our sources simply because the suppliers of raw materials and the countries of raw materials' origin may change. (LT Chemical Products)

They also added that regardless of any changes in the supplier base or non-disclosure of information related to the supplier or origin of raw materials, they would ensure that sustainability issues remain under their control. This example demonstrates that full traceability to the downstream supply chain requires an uninterrupted information flow through all supply chain members.

Hence, the supplier's capability to collect and share information emerged as an important element for enabling traceability across multi-tier supply chains. For instance, the traceability capabilities of the lower-tier supplier LT Grain enabled FT Beverage Manufacturer to trace its supply chains:

For example, [LT Grain] has batch tracking [...]. They can see for themselves where the barley in question came from. We can trace it very far, if necessary. (FT Beverage Manufacturer)

When suppliers are equipped with the necessary tools and knowledge to collect relevant information, they can effectively share it with other stakeholders within the supply chain. This underscores the importance of motivating suppliers to improve their traceability capabilities, as they may lack such capabilities:

Linking everything from the farmer or food packaging supplier to the end product is not easy; however, we encourage suppliers to do so quickly and accurately, as an automated way and opportunity to do so is available. (LT Vegetables)

In terms of accessing supply chain information, the firms mentioned how power dynamics among supply chain partners may affect information sharing. For example, a powerful firm can easily gather information from suppliers:

They [suppliers] may even make an exception in their own process if that requires revealing more [information]. (FT Agri-food Production)

It was also mentioned that this led to enhanced traceability and the capability to engage in discussions with lower-tier suppliers. In contrast, the data showed that it can be difficult to acquire information from suppliers if a supplier has more power than the buyer:

In the end, obtaining the required information is difficult because we are quite small in the end. On a global scale, a big brand may react like, "Oh, [LT Beverages], we do not care. We can export these products elsewhere". We can set requirements; "do this" and "fill out this Excel", but in the long run, we may shoot our own foot. However, [...] if we all [industry peers] ask for these things together, then the large volumes will inspire better receptivity. (LT Beverages)

Based on the data, accessing even general information about lower-tier suppliers, often limited to the country of origin or the supplier's name, was challenging and had implications for firms' MT-SSCM. For instance, insufficient information sharing caused firms' failures in managing their lower-tier suppliers directly:

Second-tier suppliers? No, we do not know them. In such a world, they [direct suppliers] do not even like to tell us [...]. We do not have any contact with them [lower-tier suppliers]. There has been some discussion about it, but we have run into a wall. Our suppliers are quite unwilling to reveal the names of their suppliers. (LT Bakery Products)

In addition, possessing minimal information about lower-tier suppliers can force companies into a position in which they must rely solely on their suppliers' assurances:

Of course, they could use who knows what sub-suppliers without us knowing because we do not have constant control over the issue 24 / 7. Perhaps you just have to trust your partner, though you can never be fully sure. (FF Textile Retail)

4.4 Traceability resources

Firm's resources for traceability work, comprising *information systems and tools* and *staff allocation*, were identified as an important element to achieve traceability. Information systems and tools were recognised as critical for tracing and storing information. The development and application of such systems seemed to vary across different industries, with the food industry having the lead:

An information system that is constantly updated is needed. We must start somewhere, and that is the kind of system we have been developing, and that is why we can trace raw material sources. (FF General Retail)

Some companies, such as LT Beverages and LT Chemical Products, emphasised the need for better information systems and tools for tracking and tracing goods and services effectively, because their existing traceability systems were insufficient in

catering to the complexities of their supply chains and supporting MT-SSCM.

Traceability systems and tools were considered to form the key for collecting information across supply chain tiers and facilitating MT-SSCM; however, some challenges were observed in terms of their practical implementation. Firms observed that significant amounts of time and resources were required to maintain and update systems. Furthermore, the potential for inaccuracies arising because suppliers frequently changed their raw material sources could not be ignored. However, implementing traceability systems can undeniably enhance sustainability by increasing transparency and improving supplier management. Importantly, a lack of information systems and traceability tools in a firm was found to be linked to its passiveness towards MT-SSCM. Highlighting industry-related differences, an informant from LT Chemical Products explained the reasons for not prioritising lower-tier supplier management:

That [lower-tier suppliers] has not yet been our focus. Thus, we do not have the opportunity to maintain our information in any system. I know that such systems are available, for example, in the food industry, so that, in the event when a recall is required, you can quickly look back at the chain. (LT Chemical Products)

The informants emphasised the significance of human resources' allocation in the staff to effectively support and facilitate traceability for sustainability. These resources enabled tracing and monitoring of suppliers and products throughout the supply chain. In particular, the lack of staff for tracing and ensuring sustainability was noted in their global supply chains, as highlighted in the case of FT Agri-food Production, whose strategy was to focus on relationship management and indirect management through direct suppliers:

To ensure that they [suppliers] start promoting these issues, we further increased the influence on the main activities [in lower tiers] by concentrating on and realising our thoughts through to the next tier. (FT Agri-food Production)

5. Discussion

The aim of this paper was to examine how traceability can be achieved in multi-tier supply chains by identifying enabling factors and their effects on firms' MT-SSCM. The results indicate that the case firms faced many challenges while they increasingly sought to enhance traceability in their multi-tier supply chains, further affecting their approaches and motivation towards MT-SSCM. Tachizawa and Wong (2014) categorised MT-SSCM approaches into the following four types: direct, indirect, work with third parties and don't bother. Based on the findings, we propose the following four key factors for traceability that affect these MT-SSCM approaches: supply chain complexity, regulatory and industry environments, information sharing and traceability resources. We further propose that these factors represent factors at three different levels: the multi-tier supply chain level, the relationship level and the organisational level. Supply chain complexity and the regulatory and industry environments are observable at the multi-tier supply chain level, while information sharing is a relationship-level factor and traceability resources are at the organisational level. Figure 2 shows the framework for traceability and MT-SSCM and illustrates how the identified key factors affect management approaches in multi-tier supply chains.

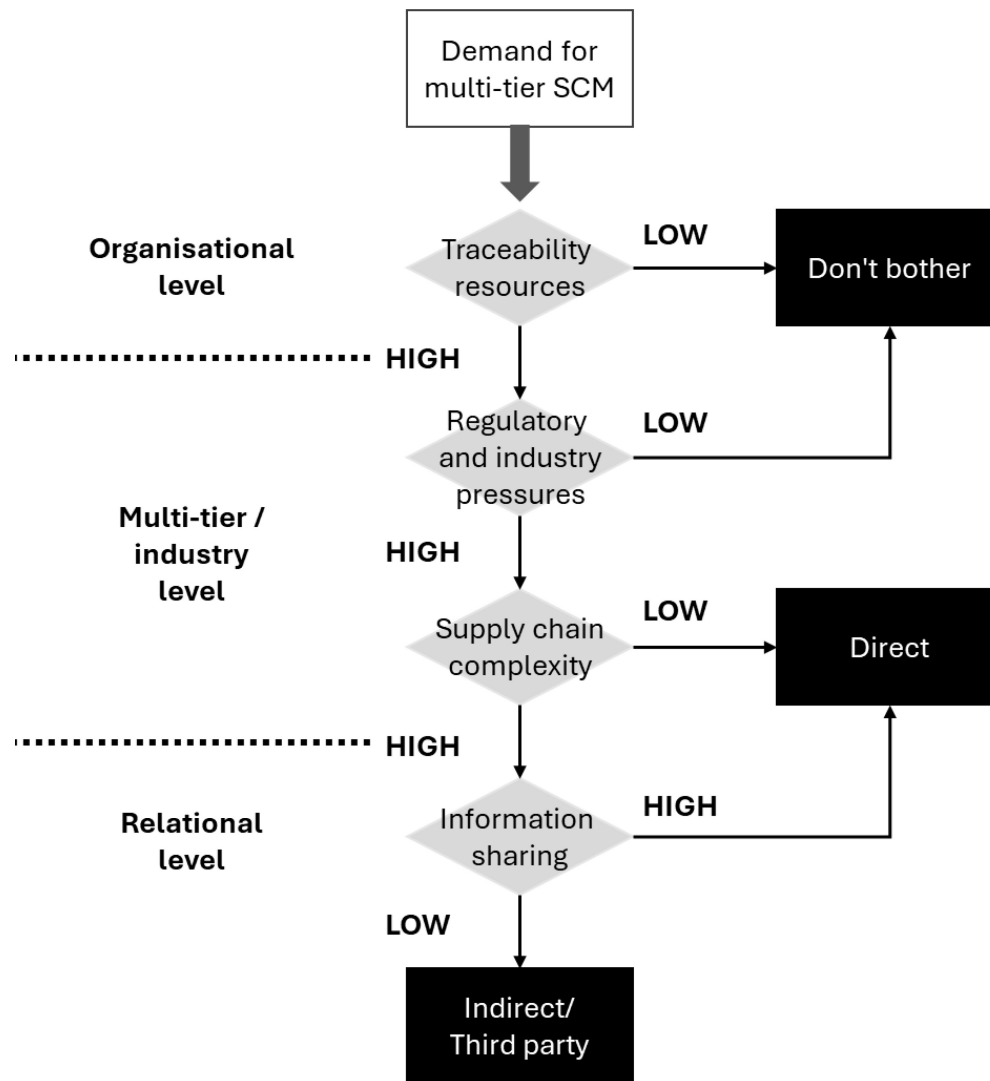
The case studies show that similar to the findings of Sodhi and Tang (2019), regulations act as catalysts for achieving

traceability. Supportive regulatory and industry frameworks provide firms with a common ground for their operations, mandating sustainability and traceability standards that ensure transparency and accountability. Hence, regulatory and industry environments can enforce information sharing and the adoption of information systems and traceability technologies, enabling more effective MT-SSCM. This study highlights the value of industry-wide traceability mechanisms, such as sustainability certifications, that cover the entire multi-tier supply chains and enhance traceability by providing insights into the upstream supply chain. For example, in the food industry, where traceability usually plays an important role (Razak *et al.*, 2024) and where regulatory requirements demand it, traceability systems that enable effective tracing were widely adopted. The results also show that food industry companies are managing lower-tier suppliers directly more often than companies operating in other industries.

We also found that the complexity of a firm's supply chain (in terms of the number of intermediaries, geographical distance and dispersion, number of suppliers and product or service complexity) is a multi-tier supply chain level factor that can influence the management approach that firms take towards the lower-tier suppliers. Firms with more complex, multi-layered supply chains are inclined towards an indirect approach in that they do not prioritise interactions with lower-tier suppliers (see Figure 2). Conversely, firms with less complex or more linear supply chains seem more inclined to establish direct contact with their lower-tier suppliers because, as Gualandris *et al.* (2021) mentioned, a simpler structure facilitates easier identification and closer relationships. The complex configuration of supply chains, where different levels of disclosure of product origin to different participants are impractical in terms of traceability, makes it challenging to have varying levels of disclosure to different supply chain participants. The results indicate that amid significant regulatory pressures and a relatively simple supply chain structure, firms are more inclined to directly manage their lower-tier suppliers to ensure compliance and traceability. Hence, we propose the following:

- P1. A direct approach to managing lower-tier suppliers and ensuring traceability across multi-tier supply chains is adopted when industry-specific regulations and requirements are stringent and supply chain complexity is low.

At the relationship level, it was found that suppliers' reluctance to share information causes information asymmetry and undermines buyers' MT-SSCM efforts. The cases show that if suppliers are not willing or able to share information on their lower-tier suppliers, the buyers face difficulties in getting information about the lower tiers. This emphasises the importance of collaborative efforts and open communication across organisations to enable traceability and thus ensure effective MT-SSCM. Trust building fosters information sharing and traceability, while information gaps caused by uncertainty, especially in complex supply chains, can erode trust. Kumar *et al.* (2017) suggested that by enabling the communication of product-related information, traceability can foster trust building across firms. Furthermore, this study indicated the influence of power dynamics on information sharing. Previous studies have

Figure 2 Framework on traceability and MT-SSCM

Source: Authors' own work

suggested that a power imbalance can influence achieving of sustainability objectives (Corsi and Filippini, 2023; Touboul et al., 2014). We demonstrate that firms in a stronger power position are better positioned to access supply chain information, enabling traceability and direct lower-tier supplier management. Conversely, a weaker power position may restrict information sharing and compel firms to adopt an indirect MT-SSCM approach, limiting the management of lower-tier suppliers. In situations of constrained information sharing – due to a lack of trust, resources or effective strategic possibilities – firms may resort to managing lower-tier suppliers through an indirect approach or by engaging third parties, reflecting a strategic adjustment to cope with barriers to information flow, even under direct management intent:

- P2. An indirect or third-party approach to managing lower-tier suppliers and ensuring traceability across multi-tier supply

chains are used when suppliers are not willing or able to share information and supply chain complexity is high.

The case studies reveal that when firms lack sufficient resources to implement practices that enable traceability mechanisms, even substantial pressures from stakeholders – such as regulatory bodies or customers – fail to inspire meaningful actions. In such situations, organisational resource constraints overshadow external demands, leading firms to deprioritise traceability initiatives. This was particularly emphasised by firms with extensive supplier bases and diverse product categories, while those with more manageable supply bases found it easier to control, suggesting that the perceived costs and complexities associated with establishing robust traceability mechanisms outweigh the potential risks of non-compliance or reputational damage. Consequently, despite stakeholders' expectations, firms may either resort to superficial compliance or avoid complying altogether, depending on challenges such as

insufficient staff, information systems and adequate traceability tools (Kim and Davis, 2016; Villena and Gioia, 2018; Wilhelm *et al.*, 2016a). The results show that the lack of traceability resources, such as information systems and tools, was linked to the passiveness towards MT-SSCM and the pursuit of traceability. Highly developed tools and information systems, however, would support better lower-tier management, but the case companies were lacking these kinds of resources. Thus, the role of organisational resources in facilitating traceability is significant and highly affects the approach that the firms can take towards lower-tier management:

- P3. A don't bother approach to managing lower-tier suppliers and ensuring traceability across multi-tier supply chains is most likely taken when firms have limited resources.

5.1 Theoretical contributions

This study contributes to the research on MT-SSCM (Tachizawa and Wong, 2014; Villena and Gioia, 2018; Wilhelm *et al.*, 2016b) and traceability for sustainability (Garcia-Torres *et al.*, 2019; Garcia-Torres *et al.*, 2022) by focusing on the intersection of these. We contribute by showing that supply chain complexity, regulatory and industry environments, information sharing and traceability resources are the key factors for traceability in multi-tier supply chains and that these factors appear at three different levels: the multi-tier supply chain, the relationship and the organisational level. Traceability resources are organisational-level factors, and each company has its own resources for ensuring traceability. Information sharing occurs at the relationship level because it takes place within dyadic buyer-supplier relationships between two parties. Supply chain complexity and the regulatory and industry environments are factors that are present at the multi-tier supply chain and industry level.

The findings emphasise the role of multi-tier level factors of regulatory requirements and industry environments in driving traceability initiatives. Previous studies (e.g. Garcia-Torres *et al.*, 2022) have acknowledged the contrast between a lack of regulation as a barrier to traceability and the existence of regulation as a source of pressure to disclose information (Sodhi and Tang, 2019). However, this study indicates that in the absence of sufficient resources for traceability, even stakeholder pressure can be ineffective. The results further show that a non-complex supply chain configuration supports firms in their traceability efforts. The results highlight that transparency fades across multiple tiers, aligning with the study by Roth *et al.* (2008) and revealing uncertainties related to MT-SSCM, particularly in long and complex supply chains in which firms may lack control. Gualandris *et al.* (2021) stated that supply chain structures support or hinder collective outcomes, such as transparency. Seuring *et al.* (2008) found that the global scope of supply relationships increases firms' challenges in influencing practices beyond the direct buyer-supplier relationship. In particular, tracing and reaching lower-tier suppliers located in geographically and institutionally distant countries remains difficult for firms, as suggested by Awaysheh and Klassen (2010). Consistent with prior research (Sarkis *et al.*, 2011; Simpson *et al.*, 2007), a firm's

geographical and contractual distance from lower-tier suppliers seems to amplify information asymmetry and cause a lack of information. This distance can create barriers to communication, limiting a comprehensive overview of suppliers' operations and practices and thus posing challenges to managing sustainability within a multi-tier supply chain.

Moreover, our research aligns with that of Fernie *et al.* (2010) and highlights that enhanced inter-organisational transparency and a willingness to share information facilitate the development of firms' tracking and tracing capabilities within supply chains. The findings reveal that uncertainty in MT-SSCM is because of firms' limited information and control. Firms are often unaware of the details about their supply chain and lower-tier suppliers because of the complexity of supply chains, insufficient regulatory pressure and a lack of information sharing and traceability resources, underscoring the importance of direct suppliers' actions and emphasising that firms must prioritise collaboration with their direct suppliers. This study demonstrates that a firm's ability to trace the origin of raw materials, products and services can influence its motivation and approach towards MT-SSCM. Thus, we further contribute by showing that firms' approaches to managing multi-tier supply chains depend on different factors at the multi-tier supply chain, relationship and organisational level. Therefore, the research contributes to both the MT-SSCM and the research on managing multi-tier supply chains (e.g. Mena *et al.*, 2013).

Previous research has recognised traceability as a key mechanism for coordination and collaboration in (sustainable) supply chains, highlighting its significant enabling role in SSCM (Garcia-Torres *et al.*, 2019; Garcia-Torres *et al.*, 2022). This study contributes to the literature on traceability (Garcia-Torres *et al.*, 2019; Garcia-Torres *et al.*, 2022) and MT-SSCM (Tachizawa and Wong, 2014; Villena and Gioia, 2018; Wilhelm *et al.*, 2016b) through its findings that extend the previous view by highlighting the significant role of traceability as a facilitator of MT-SSCM and showing that if firms are unable to trace their supply chains, managing lower-tier suppliers becomes an unattainable task. This study drew from previous research on the factors affecting MT-SSCM (Grimm *et al.*, 2014; Tachizawa and Wong, 2014; Wilhelm *et al.*, 2016b) by underlining the role of traceability in driving and enhancing MT-SSCM.

5.2 Implications for practice

This study offers valuable insights for purchasing and supply chain professionals, highlighting strategies to enhance traceability, manage lower-tier suppliers and improve supplier relationships. Managers should recognise the factors that can enhance or limit a firm's ability to achieve traceability in multi-tier supply chains. These factors can appear at the levels of organisation, relationship and multi-tier supply chain and thus, it is critical that managers take a multi-tier perspective when defining strategies, for example, to ensure traceability. A firm's access to comprehensive information about its supply chains and supplier practices enables it to achieve sustainability across multiple supply chain tiers. This may require firms' efforts towards supply chain reconfiguration by focusing on selecting trustworthy suppliers with good traceability and sustainability capabilities and pursuing collaboration with suppliers committed to

transparency and traceability. Firms should be mindful of the complexities within their supply chains that can impede MT-SSCM efforts.

The framework presented in Figure 2 offers a blueprint that managers can use when defining strategies for managing lower-tier suppliers. For example, it shows that a direct approach should be taken when industry-specific regulations and requirements are stringent. Those with less complex supply chains have a greater opportunity to manage and engage with lower-tier suppliers directly to enhance sustainability. Conversely, when the supply chain complexity is high, investing in collaboration and engagement with direct suppliers to manage lower-tier suppliers remains crucial. By fostering close relationships with suppliers, firms can encourage them to be more transparent about their practices and provide the necessary information to ensure traceability. By building strong relationships, firms can create a culture of transparency that is essential for traceability and MT-SSCM. Finally, the results emphasise that every firm in the supply chain plays a critical role in achieving traceability, thus requiring a multi-tier perspective. Traceability and transparency are needed for creating a truly sustainable supply chain and to respond to the tightening legislation, policies and demands.

6. Conclusion

This study contributes to the MT-SSCM literature by identifying factors influencing traceability for sustainability in the context of multi-tier supply chains and developing a deeper understanding of how traceability facilitates MT-SSCM through tracing the origins of raw material suppliers. By providing empirical evidence from 25 companies within three supply chain tiers and five supply chains, this study has answered the call for more research on multi-tier supply chain design in light of the presence of lower-tier suppliers.

However, it is vital to recognise the study's limitations that may impact the interpretation of the findings. The scope of the study is limited to the European context, especially Northern Europe, which raises questions about its generalisability to other regions or global scenarios. Given this limitation, future studies can broadly explore the relationship between traceability and MT-SSCM in different geographical regions to provide a more comprehensive understanding of traceability in global supply chains.

This study highlighted the pressing need for additional research dedicated to overcoming traceability-related obstacles. Given traceability's important role in shaping firms' MT-SSCM efforts, future studies should examine strategies for improving traceability and the circumstances that facilitate the adoption of particular MT-SSCM strategies. In addition, exploring the role of direct suppliers in extending traceability and sustainability to lower-tier suppliers is vital. Currently, many buyer firms focus their sustainability efforts only on their direct suppliers, largely ignoring the lower tiers. Hence, further research can provide valuable insights into and best practices for achieving sustainability goals in complex and multi-tiered supply chains.

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Appendix

Table A1 Data structure

Illustrative quotes	First-order codes	Factors affecting traceability
"If we were to buy from an importer here, we would have no visibility into where those products actually come from." (FF General Retail) "The chains are quite long. Whether it is a raw material or some components in a machine—there are very many stages in those supply chains." (LT Chemical Products) "We'll get quite far on the brewery side [. . .]. As usual, if we talk about raw materials, of course, we have one step backwards. That much is abundantly clear. With regards to our operating model, we always try and want to do direct trade with industry and manufacturing partners. So, as much as possible, we try to avoid having many middlemen." (FT Beverage Manufacturer) "Those longer international chains—I think if we challenge [a sugar supplier] to tell the country of origin of the sugar, as far as possible, one more step to the upstream, then I don't know how easy it will be for them." (FT Beverage Manufacturer) "When we work in China, it is more difficult, because there is a lot of outsourcing and a lot of different suppliers [. . .] they mostly work with an exporting company, and this exporting company is working with also—so one is doing spinning and one is doing weaving and another the dyeing." (FT Textile Products) "For us, there are very few raw materials that come from the other side of the world, for which we wouldn't know who the supplier is." (FT Bakery) "As far as our own production is concerned, we pretty much source raw materials directly from the source. Then we know that there is a domestic meat wholesaler or fish wholesaler in the background, and we know exactly where the product comes from." (FF Passenger Traffic) "I think if you work with one source or supplier for different raw materials, it is easier to trace back." (LT Yarn) "If you consider that there are 2,000 items here, and there are 400 raw materials and there are packaging materials – I think we have thousands of items to buy. If you add all these things up, it's impossible to know the suppliers—of course, there aren't that many active suppliers. But in critical cases, it is possible for us to know." (LT Chemical Products) "Materials that have various components—these are difficult to trace." (FF Food Service) "The more refined the product, the more challenging it [traceability] is." (FT Beverage Manufacturer) "Spare parts are a number one thing. We need to know exactly which nob is attached to which machine and where it was sourced from [. . .] the technical side is very regulated." (FF Passenger Traffic) "There are certain categories where legislation requires [traceability]. For example, contact materials that are in contact with the product—there has to be a certain degree of traceability." (FT Meat) "We have to do it. Because when we make our final product, which is an edible product, we have to trace everything from raw material to packaging—and we do it." (LT Vegetables)	Number of intermediaries Geographical distance and dispersion Number of suppliers Product and service complexity Regulatory pressure for traceability	Supply chain complexity (supporting literature, e.g. Kumar et al., 2017; Gualandris et al., 2021; Akin Ateş et al., 2022) Regulatory and industry environments (supporting literature, e.g. Sodhi and Tang, 2029; Garcia-Torres et al., 2022)

(continued)

Table A1

Illustrative quotes	First-order codes	Factors affecting traceability
"We can trace via the GOTS certification with transaction certificates where it [raw material] came from and that it is from an organic origin. So I really think labels and certifications such as GRS and GOTS are the best ways today to trace the origin." (LT Yarn) "There is a grain passport for grain, which shows us information about the farm from which the grain was loaded. In case of, for example, a smaller aggregate warehouse, it is also possible to trace the alternative farms that have delivered to that silo." (LT Grain Mill 1) "We also work with [a brand firm] and [a brand firm] and they want to know this [...] they show their ability to trace on the packing." (FT Textile Products) "Particularly [FT Bakery] has now come to the point where they would like to see the chain from field to table. In other words, they—and many others too—would like to know who has grown the raw material." (LT Grain Mill 1) "If a producer doesn't want to inform us where they [raw materials] come from, it becomes challenging for us to dig that information [...] For the most part, the information is happily communicated to us, because everyone knows that this is about sustainability [...] I don't think we have had a lot of problems with it." (LT Beverages) "Overall, this [tracing] has changed. It is so much easier these days, just by asking. Everything is told and shared." (FF Food Service) "We do have a requirement that they should inform us, but they might not [...] They don't necessarily think that if their raw material or raw material source changes, they should report it." (LT Chemical Products) "It depends on the supplier. There are some really digital and modern suppliers who trace every batch they deliver down to the raw material they process." (LT Vegetables) "... the providers or suppliers of those products are on a certain level; they are working on a very high safety, hygiene level and great facilities, so it's quite easy to trace that back." (FT Meal Solutions) "You can clearly see that our main partners, with whom we have been working for a long time, tell us everything and we get information. However, if there is a slightly bigger partner to whom we are a slightly smaller customer, then perhaps they are not going to invest too much in this information sharing." (FF Textile Retail) "There is a lot of talk about a new system, which would make it easier to collect supply chain and sustainability-related information. It is on the table, and we want to collect that information about all our products." (LT Beverages) "They all [retailers and suppliers] have their questionnaires that they send here to our quality department. Then a few people in the department collect and type that information forward—it's a real challenge. I wish there were some database somewhere where we and suppliers could insert and retrieve the information from." (FT Agri-food Production) "It's more of a resource issue for us. We invest in our main raw materials, and we really want to know information about these." (FF Food Service) "Some people think [...] that we need to shorten supply chains and go straight to the source. However, there are no resources to visit every place where we buy. There is no competence. We simply cannot. Our management doesn't give us a double team, and even that wouldn't be enough." (FT Agri-food Production)	Industry-wide traceability mechanisms (including certifications, product passports, and blockchain technology) Traceability requirements from customers Supplier's willingness to disclose information Supplier's capability to collect and share information Power dynamics Information systems and tools Staff allocation	Information sharing (supporting literature, e.g. Ferne et al., 2010; Tuladhar et al., 2024) Traceability resources (supporting literature, e.g. Razak et al., 2023; Razak et al., 2024; Tuladhar et al., 2024)
Source(s): Authors' own work		

Appendix 2

Table A2 Findings on firms' traceability and MT-SSCM approaches

Case company	Examples on traceability	Factors influencing traceability	MT-SSCM approach
	+ <i>easy to trace</i> – <i>difficult to trace</i>	+ <i>enables traceability</i> – <i>hinders traceability</i>	
Textile SC			
FF Textile Retail	• Strong emphasis on supply chain traceability + Cotton (<i>traceable to yarn producer's source or cotton field, if certified</i>)	+ No intermediaries + A small number of suppliers + Suppliers willing to disclose supply chain information + Implementation of certifications + Traceability requirements from customer firms and consumers + Staff for traceability efforts – Weak power positions hinder the collection of supply chain information	• Requires suppliers to commit to publicly disclose lower-tier suppliers during the supplier selection phase • Requires information from direct suppliers about lower-tier suppliers • Requires direct suppliers to notify of changes in lower-tier suppliers • Visits lower-tier suppliers' premises occasionally • Relies mostly on an indirect MT-SSCM approach due to traceability challenges, which make it difficult to directly manage lower-tier suppliers • Guides and influences suppliers in their material selections and use of certifications to enhance traceability • Power position related to a direct supplier affects the ability to collect supply chain information and manage lower-tier suppliers • Non-complex, vertically integrated supply chain structures facilitate traceability and lower-tier supplier management
FT Textile Products	• Strong emphasis on supply chain traceability + Cotton	+ No intermediaries + Short distance to raw material sources + Implementation of certifications + Traceability requirements from customers + Suppliers willing to disclose supply chain information – Long, complex and geographically distant supply chains (<i>e.g. highly fragmented production</i>) – A large number of suppliers – Suppliers lack the capability to collect and share supply chain information	• Requires information from direct suppliers about lower-tier suppliers • Requires direct suppliers to notify of changes in lower-tier suppliers • Visits lower-tier suppliers' premises occasionally • Guides and influences suppliers in their material selections and use of certifications to enhance traceability
LT Yarn	+ Cotton (<i>traceable to the country of origin or cotton field, if certified</i>) – Polyester	+ A small number of suppliers + Limited variety of product categories, limited sources for raw materials + Implementation of certifications + Traceability requirements from customers + Suppliers willing to disclose supply chain information + Suppliers have the capability to collect and share supply chain information (<i>e.g. European fibre suppliers</i>) – Long, complex and geographically distant supply chains – Suppliers not willing to disclose supply chain information – Suppliers lack the capability to collect and share supply chain information	• Focuses on building good relationships with direct suppliers to indirectly manage lower-tier suppliers • Lower-tier supplier management not always relevant due to proximity to raw material sources

(continued)

(continued)

Table A2

Case company	Examples on traceability		Factors influencing traceability		MT-SSCM approach
	+ <i>easy to trace</i>	– <i>difficult to trace</i>	+ <i>enables traceability</i>	– <i>hinders traceability</i>	
Passenger Traffic SC					
FF Passenger Traffic	- Depends on the product category - Food products - Machinery		- No intermediaries - Short distance to raw material sources - Minimally processed products and raw materials - Regulatory pressure for traceability - Highly processed products and raw materials		- Relies mostly on an indirect MT-SSCM approach - Focuses on building good relationships with direct suppliers to indirectly manage lower-tier suppliers - Engages direct suppliers to ensure that lower-tier suppliers comply with their own policies - Engages with lower-tier suppliers in some critical categories where traceability allows it - Requires information from direct suppliers about lower-tier suppliers - Requires direct suppliers to notify of changes in lower-tier suppliers - Approves lower-tier suppliers if a lower-tier supplier is significantly involved in production - Avoids intermediaries and purchases directly from the source when possible to enhance traceability
FT Agri-food Wholesale	- Depends on the product category - Private label raw materials (<i>traceable to the source</i>) - Food products		- Regulatory pressure for traceability - Traceability requirements from customer firms - Availability of information systems and tools - Intermediaries present - Highly processed products and raw materials - No regulatory pressure for traceability - Suppliers lack the capability to collect and share supply chain information		Focuses on understanding and mapping their supply chains, with specific targets for supply chain mapping of certain raw materials
LT Confiture	- Packaging and industrial products - Agri-food products (<i>e.g. hazelnut</i>)		- No intermediaries - Short distance to raw material sources - Availability of industry-wide traceability mechanisms - Availability of information systems and tools - Long, complex and geographically distant supply chains - A large number of suppliers - Highly processed products and raw materials - No regulatory pressure for traceability - Lack of information systems and tools (<i>e.g. in hazelnut supply chains</i>) - Suppliers not willing to disclose supply chain information - Suppliers lack the capability to collect and share supply chain information		- Relies on an indirect MT-SSCM approach due to resource restrictions and difficulties in identifying lower-tier suppliers - Focuses on building good relationships with direct suppliers to indirectly manage lower-tier suppliers, engaging and motivating direct suppliers to be transparent - Requires information from direct suppliers about lower-tier suppliers - Requires direct suppliers to notify of changes in lower-tier suppliers - Works with third parties to aid in traceability due to complex supply chains - Motivates and supports direct suppliers to improve supply chain information collection and sharing
LT Grain Mill 2	- Depends on the raw material - Grain (<i>traceable to the source</i>)		- No intermediaries - Short distance to raw material sources - Minimally processed products and raw materials - Regulatory pressure for traceability - Availability of industry-wide traceability mechanisms (<i>e.g. grain passport</i>) - Suppliers have the capability to collect and share supply chain information		- Ensures, already during the supplier selection phase, that suppliers are willing to disclose information - Lower-tier supplier management not always relevant due to proximity to raw material sources - Facilitates supplier visits for their customers if needed

(continued)

Table A2

Case company	Examples on traceability	Factors influencing traceability	MT-SSCM approach
	+ <i>easy to trace</i> – <i>difficult to trace</i>	+ <i>enables traceability</i> – <i>hinders traceability</i>	
FT Meal Solutions	- Depends on the product category - Strategic raw materials and high-volume products	- No intermediaries - Short distance to raw material sources - Minimally processed products and raw materials - Regulatory pressure for traceability - Traceability requirements from customer firms - Suppliers have the capability to collect and share supply chain information - Intermediaries present - Long, complex and geographically distant supply chains - Insufficient staff for traceability efforts - Suppliers lack the capability to collect and share supply chain information	- Relies mostly on an indirect MT-SSCM approach due to resource restrictions - Ensures, already during the supplier selection phase, that suppliers are willing to disclose information - Focuses on building good relationships with direct suppliers to indirectly manage lower-tier suppliers - Requires information from direct suppliers about lower-tier suppliers - Avoids intermediaries and purchases directly from the source when possible to enhance traceability - Efforts are made to stay as close to the origin as possible due to traceability requirements from customer firms
Retail SC			
FF General Retail	- Strong emphasis on supply chain traceability 75%–80% of products can be traced very far - Private label raw materials (<i>traceable to the source</i>) - Components	- No intermediaries - Short distance to the raw material sources - Minimally processed products and raw materials - Regulatory pressure for traceability - Availability of information systems and tools - A large number of suppliers - A large number of supply categories and products - Lack of information systems and tools - Suppliers lack the capability to collect and share supply chain information	- Relies mostly on an indirect MT-SSCM approach due to resource restrictions - Approves lower-tier suppliers through audits if a lower-tier supplier is significantly involved in production
FT Bakery	- Volume products - Grain - Spices, seeds, additives - Small volumes bought from wholesalers and non-strategic suppliers	- A small number of suppliers - Implementation of certifications - Regulatory pressure for traceability - Traceability requirements from customer firms - Suppliers have the capability to collect and share supply chain information - Intermediaries present - Long, complex and geographically distant supply chains - Highly processed products and raw materials	- Relies mostly on an indirect MT-SSCM approach - Approves lower-tier suppliers through audits if intermediaries are involved - Guides and influences suppliers' use of certifications to improve traceability - Conducts traceability tests - Examines production facilities and raw material sources for risk evaluation
LT Grain Mill 1	Grain (<i>traceable to the farm</i>)	- No intermediaries - Short distance to raw material sources - A small number of suppliers - Minimally processed products and raw materials - Regulatory pressure for traceability - Availability of industry-wide traceability mechanisms (<i>e.g. grain passport</i>) - Traceability requirements from customer firms	- Focuses on building good relationships with direct suppliers to indirectly manage lower-tier suppliers - Avoids intermediaries and purchases directly from the source when possible to enhance traceability - Lower-tier supplier management not always relevant due to proximity to raw material sources
LT Bakery Products	- Country of origin usually traceable - Components	- Traceability requirements from customer firms - Lack of information systems and tools - Suppliers not willing to disclose supply chain information - Suppliers lack the capability to collect and share supply chain information	- Relies on indirect and don't bother MT-SSCM approaches, as suppliers are not always willing to disclose their lower-tier suppliers - Requires information from direct suppliers about lower-tier suppliers

(continued)

Table A2

Case company	Examples on traceability	Factors influencing traceability	MT-SSCM approach
	+ <i>easy to trace</i> – <i>difficult to trace</i>	+ <i>enables traceability</i> – <i>hinders traceability</i>	
FT Meat	• Depends on product category + Products and raw materials required by regulation (<i>e.g. animal and contact materials</i>) – Components	+ No intermediaries + Short distance to raw material sources + Regulatory pressure for traceability	• Direct lower-tier supplier management possible due to the proximity to the raw material source
LT Packaging	• Strong emphasis on supply chain traceability + Plastic granulate (<i>traceable to the source</i>) – Spare parts, maintenance	+ No intermediaries + Minimally processed products and raw materials + Regulatory pressure for traceability + Traceability requirements from customer firms (<i>e.g. traceability tests</i>) + Availability of information systems and tools + Suppliers have the capability to collect and share supply chain information	• Lower-tier supplier management not always relevant due to proximity to raw material sources • Conducts traceability tests
FT Agri-food Production	• Strong emphasis on supply chain traceability • Has normally information about the processor and possible origin countries • Traceability tests allow traceability to the source + Packaging – Spices	+ Minimally processed products and raw materials + Traceability requirements from customer firms (<i>e.g. traceability tests</i>) + Suppliers willing to disclose supply chain information + Strong power position enables supply chain information collection – Long, complex and geographically distant supply chains – A large number of suppliers – Highly processed products and raw materials – Lack of information systems and tools – Insufficient staff for traceability efforts – Suppliers not willing to disclose supply chain information	• Relies mostly on an indirect MT-SSCM approach due to complex supply chains and resource restrictions • Focuses on building good relationships with direct suppliers to indirectly manage lower-tier suppliers • Requires information from direct suppliers about lower-tier suppliers • Power position related to a direct supplier affects the ability to collect supply chain information and manage lower-tier suppliers • Conducts traceability tests
Accommodation SC FF Accommodation	• Depends on the product or service + Often short and traceable service supply chains + Domestic fish and meat supply chains	+ No intermediaries + Short distance to raw material sources + Regulatory pressure for traceability + Implementation of certifications – Long, complex and geographically distant supply chains – Highly processed products and raw materials – Lack of information systems and tools – Suppliers not willing to disclose supply chain information	• Relies mostly on an indirect MT-SSCM approach • Focuses on building good relationships with direct suppliers to indirectly manage lower-tier suppliers, especially in complex supply chains • Avoids intermediaries and purchases directly from the source when possible to enhance traceability • Visits lower-tier suppliers' premises occasionally
FT Service Provider	– Parts – Machinery	+ Short distance to raw material sources + Minimally processed products and raw materials + Suppliers willing to disclose supply chain information + Suppliers have the capability to collect and share supply chain information – Intermediaries present – Highly processed products and raw materials	• Relies on an indirect MT-SSCM approach • Focuses on building good relationships with direct suppliers to indirectly manage lower-tier suppliers

(continued)

Table A2

Case company	Examples on traceability	Factors influencing traceability	MT-SSCM approach
	+ <i>easy to trace</i> – <i>difficult to trace</i>	+ <i>enables traceability</i> – <i>hinders traceability</i>	
LT Chemical Products	- Increasing emphasis on supply chain traceability + Certified products + Simple raw materials (<i>e.g. domestic ethanol</i>)	+ Short distance to raw material sources + Minimally processed products and raw materials + Implementation of certifications – Intermediaries present – Long, complex and geographically distant supply chains – A large number of suppliers – Highly processed products and raw materials – A large number of supply categories and products – Lack of information systems and tools – Suppliers not willing to disclose supply chain information – Suppliers lack the capability to collect and share supply chain information – A weak power position hinders supply chain information collection	- Relies on an indirect MT-SSCM approach due to difficulties in managing multi-tier supply chain information - Supply chain complexity makes it impossible to know all lower-tier suppliers and manage them effectively
FT Beverage Manufacturer	- Depends on product category + Agri-food products (<i>traceable to the source</i>) – Sugar, chemical products, complex products	+ No intermediaries + Short distance to raw material sources + Minimally processed products and raw materials + Availability of industry-wide traceability mechanisms + Suppliers willing to disclose supply chain information + Suppliers have the capability to collect and share supply chain information – Intermediaries present – Long, complex and geographically distant supply chains – Highly processed products and raw materials	- Collaborates with LT Beverages and LT Grain to enhance traceability and lower-tier supplier management - Visiting lower-tier suppliers is possible because direct suppliers are willing to share information
LT Grain	+ Grain (<i>traceable to the field</i>) + Domestic products	+ No intermediaries + Short distance to raw material sources + Traceability requirements from customer firms (<i>e.g. traceability tests</i>) + Availability of information systems and tools + Suppliers willing to disclose supply chain information + Suppliers have the capability to collect and share supply chain information – Suppliers not willing to disclose supply chain information	- Lower-tier supplier management not always relevant due to proximity to raw material sources - Avoids intermediaries and purchases directly from the source when possible to enhance traceability - Transparency projects with FT Beverage Manufacturer allow consumers to track raw materials - Conducts traceability tests
LT Beverages	- Strong emphasis on supply chain traceability - Depends on product category + Agri-food raw materials	+ Limited variety of product categories + Minimally processed products and raw materials + Implementation of certifications + A strong power position enables supply chain information collection – Intermediaries present – Long, complex and geographically distant supply chains – No regulatory pressure for traceability – Lack of information systems and tools – Insufficient staff for traceability efforts – Suppliers not willing to disclose supply chain information – Weak power positions hinder the collection of supply chain information	- Requires information from direct suppliers about lower-tier suppliers - Works with third parties to enhance traceability and lower-tier supplier management - Power position related to a direct supplier affects the ability to collect supply chain information and manage lower-tier suppliers - Has discarded a supplier due to their unwillingness to disclose supply chain information

(continued)

Table A2

Case company	Examples on traceability	Factors influencing traceability	MT-SSCM approach
	+ <i>easy to trace</i> – <i>difficult to trace</i>	+ <i>enables traceability</i> – <i>hinders traceability</i>	
FT Construction	• Able to trace materials to factories and wholesalers + Technological equipment (<i>e.g. air supply units, solar panels</i>)	+ Regulatory pressure for traceability + Traceability requirements from customer firms – Intermediaries present – Long, complex and geographically distant supply chains – Suppliers not willing to disclose supply chain information	• Avoids intermediaries and purchases directly from the source when possible to enhance traceability
Food Service SC			
FF Food Service	• Strong emphasis on supply chain traceability + Food products + Volume products – Small volumes (<i>e.g. vinyl gloves, trash bags</i>) – Materials with many components	+ Short distance to raw material sources + Minimally processed products and raw materials + Staff for traceability efforts + Suppliers willing to disclose supply chain information – Intermediaries present – Long, complex and geographically distant supply chains – Highly processed products and raw materials	• Traceability and direct lower-tier supplier management possible due to non-complex supply chains • Visits lower-tier suppliers' premises regularly • Willing to invest in traceability resources to be able to manage lower-tier suppliers
FT Agri-food Trade	+ Agri-food products (<i>traceable to a bulk supplier or farm</i>)	+ No intermediaries + Short distance to raw material sources + Regulatory pressure for traceability + Traceability requirements from customer firms + A strong power position enables supply chain information collection	• Requires information from direct suppliers about lower-tier suppliers • Regulatory pressure for traceability eases traceability and lower-tier supplier management • Conducts traceability tests
LT Vegetables	• Strong emphasis on supply chain traceability • Familiar with farmers + Products and raw materials required by regulation	+ No intermediaries + Short distance to raw material sources + Regulatory pressure for traceability + Availability of industry-wide traceability mechanisms + Availability of information systems and tools + Suppliers have the capability to collect and share supply chain information – Suppliers lack the capability to collect and share supply chain information	• Motivates and supports direct suppliers to improve supply chain information collection and sharing • Lower-tier supplier management not always relevant due to proximity to raw material sources

Source(s): Authors' own work

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