

The Role of Network Structural Properties in Supply Chain Sustainability: A Systematic Literature Review and Agenda for Future Research

Abstract

Purpose – The purpose of our paper is to systematically review and assess the current status of research on supply chain sustainability from a network structural perspective and provide an organising framework for future scholarship in this area.

Design/methodology/approach – Adopting an evidence-based approach, this study conducts a systematic review of 73 articles from 18 peer-reviewed journals published between 2000 and 2020.

Findings – Adopting a social network analysis approach, our review identifies specific node-level (i.e. degree centrality, closeness centrality, betweenness centrality) and network-level (i.e. network density, network sub-groups, network diversity) structural properties that play a role in supply chain sustainability. Our results reveal that structural properties determine the extent of perception of sustainability risks, the diffusion of sustainability targets, introduction of sustainable innovations, development of sustainability capabilities, adoption of sustainability initiatives, as well as the monitoring of sustainability performance throughout the supply chain.

Originality/value – Distinguishing between supply network and sustainable supply network types, our study extends the existing understandings of the role of network connectivity patterns in supply chain sustainability through synthesising and evaluating the extant literature. Our study further clarifies the role of these network structural properties in supply chain sustainability by describing their impact on a set of sustainable supply chain management practices through which firms achieve sustainability goals across their supply chains.

Keywords Social network analysis, Supply chain sustainability, Systematic literature review, Sustainable supply chain management

1. Introduction

The incorporation of sustainability into the management of supply chains involves “the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account” (Seuring and Müller, 2008, p. 1700). Given the increasing number of actors involved in the design, production and delivery of products and services, firms increasingly need to interact with various supply chain members to achieve their sustainability goals (Miemczyk *et al.*, 2016; Ni and Sun, 2018; Petljak *et al.*, 2018). The extant literature has identified various practices that firms adopt to achieve sustainability across their supply chains. Specifically, these studies have examined firms’ behaviours towards supply chain sustainability (Dou *et al.*, 2018) as well as the processes they implement to communicate and enforce sustainability targets (Tachizawa and Wong, 2014), develop sustainability capabilities (Arora *et al.*, 2020; Paulraj *et al.*, 2017), introduce sustainable innovations (Beske and Seuring, 2014) and monitor sustainability performance (Tachizawa and Wong, 2014) throughout their supply chain.

Although research has largely focused on firms’ direct relationships with their first-tier suppliers, in recent years a growing number of studies have highlighted the criticality of the broader supply network, including lower-tier suppliers, in driving sustainability (Frostenson and Prenkert, 2015; Sauer and Seuring, 2018; Tachizawa and Wong, 2014). Indeed, in investigating sustainability, these studies have shifted their focus from single buyer-supplier dyads to the broader network of relationships in which supply chain members are embedded. As complex adaptive systems (Choi *et al.*, 2001), supply networks emerge without the control of a single entity, resulting in complex, unique and often invisible connectivity patterns (i.e. the network structure) that surround the participating firms (Kim *et al.*, 2011). Extant studies have demonstrated that these structural properties influence how the embedded firms achieve

their sustainability goals. First, adopting a social network analysis approach, an emerging body of work has identified and investigated various network structural properties, such as centrality and density, which influence the sustainability behaviour and performance of the embedded supply chain members (e.g. Beckman *et al.*, 2009; Saunders *et al.*, 2019; Tate *et al.*, 2013; Vurro *et al.*, 2009). Second, the role of connectivity patterns in supply chain sustainability can be discerned from studies investigating the management, orchestration and governance of multi-tier supply chains in relation to sustainability (e.g. Sauer and Seuring, 2018; Tachizawa and Wong, 2014). Although network structural properties are not explicitly conceptualised in these studies, the investigation of how supply chain members from multiple tiers are connected to address supply chain sustainability issues has provided a foundation upon which to identify prevalent network structural properties from this second body of literature.

While the notion of network structure is a common underpinning theme in these two research strands, the present literature lacks a synthesis of major findings and a consistent analytical lens to systematically operationalise the current developments in this area. In this study, we adopt social network analysis as a theoretical lens and an analytical approach (Borgatti and Foster, 2003) to examine the various characteristics of relationship patterns that arise among interacting supply chain entities and their role in driving sustainability. Thus, the purpose of our paper is to systematically review and assess the current status of research on supply chain sustainability from a network structural perspective and provide an organising framework for future scholarship in this area. With this aim, we address the following review questions:

RQ1. What network structural properties are examined in relation to supply chain sustainability?

RQ2. How do network structural properties affect supply chain sustainability?

This study contributes to the existing literature in several respects. First, we undertake a transparent and replicable systematic literature review that attempts to synthesise dominant scholarly discourses on supply chain sustainability from a network structural perspective and provide an evaluation of the scientific status of the field. Adopting a social network analysis approach, we identify multiple network structural properties that influence supply chain sustainability. Specifically, adopting a structural view, our review complements the existing systematic literature reviews that examine the role of *governance mechanisms* in supporting supply network sustainability goals (e.g. Gimenez and Tachizawa, 2012; Tachizawa and Wong, 2014). Second, in our review, we distinguish between the structural properties of *supply networks* and those of *sustainable supply networks* (i.e. networks formed to enhance the sustainability of the underlying supply network), clarifying the relationship between them and explaining their role in supply chain sustainability. Third, our study clarifies the role of network structural properties in supply chain sustainability by articulating a set of key practices through which firms achieve sustainability goals across their supply chains. Specifically, our study contributes to recent research by providing a synthesis of the *theories* (Johnsen *et al.*, 2017) and *performance metrics* (Schaltegger and Burritt, 2014) that explain achieving supply chain sustainability in network contexts. Finally, our study offers multiple avenues for advancing research in this field.

This paper proceeds as follows. First, we present the key concepts and definitions concerning supply chain sustainability and supply chain network analysis. We then discuss the systematic literature review methodology in terms of the review process, the sample selection and analysis. Next, we describe the sample articles using descriptive analysis, followed by a thematic analysis articulating the various structural properties and their relationships with sustainability practices. Finally, we conclude with a discussion of areas of future research and an examination of the study's implications for practice.

2. Literature Review

2.1 Supply chain sustainability

The incorporation of sustainability into the management of supply chains is one of the most rapidly growing and dynamic research areas. Supply chain sustainability has been predominantly investigated in the literature through the concept of sustainable supply chain management (SSCM). Alternative conceptualisations of SSCM have been proposed in the literature, among which the SSCM definitions proposed by Seuring and Müller (2008) and Carter and Rogers (2008) have been widely used by scholars (Ahi and Searcy, 2013):

“the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements.” (Seuring and Müller, 2008, p. 1700)

“the strategic, transparent integration and achievement of an organization’s social, environmental, and economic goals in the systemic coordination of key interorganizational business processes for improving the long-term economic performance of the individual company and its supply chains.” (Carter and Rogers, 2008 p. 368)

Although the role of interorganisational processes among supply chain members in achieving economic, environmental and social goals (commonly referred to as the triple bottom line) across the supply chain is emphasised in the suggested definitions above (Carter and Rogers, 2008; Seuring and Müller, 2008), recent work has also recognised the broader strategic role of firms in the design and orchestration of supply chains to achieve sustainability goals. For instance, Pagell and Shevchenko (2014, p. 45) defined SSCM as:

“the designing, organizing, coordinating, and controlling of supply chains to become truly sustainable with the minimum expectation of a truly sustainable supply chain being to maintain economic viability, while doing no harm to social or environmental systems.”

In conceptualising and investigating SSCM, scholars have generally identified a set of internal and external practices that firms adopt to achieve sustainability across their supply chains (Gimenez *et al.*, 2012). In particular, prior studies have suggested that such practices often manifest through behaviours firms exhibit towards sustainability or the various processes that they implement. First, scholars have highlighted the behavioural aspects of SSCM through an examination of firms’ values, attitudes and orientation towards sustainability. In particular, extant studies have investigated firms’ adoption of sustainability initiatives in terms of their willingness to support sustainability initiatives (Dou *et al.*, 2018), the incorporation of initiatives in the company’s mission (Pagell and Wu, 2009) and top management involvement (Beske and Seuring, 2014). Scholars have further drawn on the perceived sustainability risk to account for the firm’s perception of environmental uncertainty or potential harm to social reputation that may arise when sustainability goals are violated across their supply chain (Meinlschmidt *et al.*, 2018).

Furthermore, studies have suggested that firms implement a set of processes such as establishing codes of conducts or environmental and social requirements to diffuse (i.e. communicate and enforce) sustainability targets across the supply chain (Tachizawa and Wong, 2014). Firms engage in collaborative processes to develop sustainability capabilities (Arora *et al.*, 2020; Paulraj *et al.*, 2017) and introduce sustainable innovations (Beske and Seuring, 2014) across their supply chains. Finally, firms use monitoring processes such as audits to assess the sustainability performance of supply chain members (Tachizawa and Wong, 2014).

Although initially the literature was dominated by studies investigating SSCM practices that firms adopt in relation to their direct connections (e.g. first-tier suppliers), a growing body of work has begun to shed light on the role of broader network of relationships in driving supply chain sustainability (e.g. Mejías *et al.*, 2019; Sauer and Seuring, 2018; Tachizawa and Wong, 2014; Touboulic *et al.*, 2018). Specifically, two strands of literature have emerged concerning the structure of these networks and their impact on supply chain sustainability.

First, by adopting a social network analysis approach, scholars have highlighted the criticality of the often-invisible connectivity patterns (i.e. the network structure) that surround supply chain members in achieving their sustainability goals. Specifically, this emerging body of research has identified and investigated various network structural properties such as centrality and density that influence the sustainability behaviour and performance of the embedded supply chain members (Beckman *et al.*, 2009; Saunders *et al.*, 2019; Tate *et al.*, 2013; Vurro *et al.*, 2009).

Second, prior studies investigating the management, orchestration and governance of multi-tier supply chains in relation to sustainability in multi-tier SSCM literature (e.g. Sauer and Seuring, 2018; Tachizawa and Wong, 2014) have laid a foundation upon from which certain connectivity patterns can be discerned. Although explicit structural properties are yet to be recognised by this dominant literature, the findings on how supply chain members from multiple tiers are connected to address supply chain sustainability issues can be used to generate insights on network structural properties. In particular, the various governance mechanisms that firms adopt to manage the sustainability of lower-tier suppliers (Alexander, 2020; Tachizawa and Wong, 2014; Villena and Gioia, 2020) generate specific connectivity patterns in the network. For instance, the direct governance approach, in which a focal firm bypasses the first-tier suppliers and establishes direct contact with lower-tier suppliers in

achieving its sustainability goals (Tachizawa and Wong, 2014; Tuni *et al.*, 2019), would create a highly centralised network position for the focal firm.

While the notion of network structure is a common underpinning theme connecting these two strands of work, the present literature lacks a common language and an analytical lens through which to consistently characterise these often-invisible supply chain connectivity patterns and their role in supply chain sustainability. In this study, we adopt social network analysis as a theoretical lens and an analytical approach to synthesise the literature at the intersection of supply chain network analysis and supply chain sustainability.

2.2 Supply chain network analysis

Recent years have witnessed a rapid growth of interest and the systematic adoption of social network analysis in visualising and analysing the patterns of connectivity in supply chains (e.g. Bellamy *et al.*, 2014; Borgatti and Li, 2009; Kim *et al.*, 2011; Kim *et al.*, 2015; Wichmann and Kaufmann, 2016). Social network analysis provides an analytical method for examining the various characteristics of these connectivity patterns and for drawing inferences about the network as a whole or about those firms belonging to it (Borgatti and Foster, 2003).

Social network analysis views any system as a set of interrelated nodes (Borgatti and Li, 2009). Indeed, a network consists of a set of nodes along with a set of ties that link them. The ties interconnect through shared end points to form paths that indirectly link nodes that are not directly tied (Borgatti and Foster, 2003). The extension of social network analysis to supply chain management is a fairly natural development in that supply chains represent a fundamental form of network of interconnected firms that are involved in the design, supply, production, distribution and aftersales service of products and services (i.e. supply network) (Harland *et al.*, 2004; Ketchen Jr and Hult, 2007).

Prior studies examining supply networks through the lens of social network analysis have predominantly considered these networks to consist of a focal firm, the set of firms with any kind of tie to the focal firm and all ties among those firms (Borgatti and Li, 2009). Prior investigations have largely conceptualised ties in supply networks in the form of physical flows of materials or contractual relationships between firms (i.e. two firms are connected because of the delivery and receipt of materials or through a supply contract) (Choi and Hong, 2002; Kim *et al.*, 2011; Peck, 2005). For instance, a focal firm may establish a contract with a second-tier supplier and direct the first-tier supplier to receive materials from them. In this instance, materials flow between two firms (first-tier and second tier suppliers) who are not connected via the contract tie (Choi and Krause, 2006; Kim *et al.* 2011). Hence, supply chain members are involved in two frequently overlapping supply networks based on the type of supply tie (i.e. material flow or contractual relationship).

In addition, in addressing the sustainability of the supply chains, firms often establish a new form of tie to communicate, monitor and/or collaborate with other firms in achieving their underlying supply network sustainability goals (i.e. sustainability tie), leading to different connectivity patterns. We label these networks that are formed to enhance the sustainability of the underlying supply network as “sustainable supply networks” (i.e. a network consisting of a focal firm, the set of firms with sustainability ties to the focal firm and all sustainability ties among those firms) (Patala *et al.*, 2014). The emerging sustainable supply network possesses a unique structure, which often differs from that of the underlying supply network. For instance, although a focal firm might not establish a direct supply contract with a second-tier supplier, it may directly monitor or collaborate with a second-tier supplier to achieve its sustainability goals (Tachizawa and Wong, 2014).

In recent years, supply chain scholars have adopted a range of network metrics to characterise the structural properties or patterns of the collective arrangement of supply

network ties (Kim *et al.*, 2011; Wichmann and Kaufmann, 2016). Specifically, in examining the structural properties, two levels of analysis have been prevalent, namely, node-level and whole-network-level (Kim *et al.*, 2011). Node-level properties assess how an individual firm is embedded in a network from its own perspective, whereas network-level properties represent how the overall network connections are organised from the perspective of an observer with a 'bird's eye view' (Kim *et al.*, 2011).

The notion of firms' centrality as one of the most fundamental node-level structural properties in terms of a focal firm's number of direct connections (i.e. degree centrality), the mean distance between the focal firm and all other firms within the network (i.e. closeness centrality) and the extent to which the focal firm connects firms that would be otherwise disconnected (i.e. betweenness centrality) has been investigated by prior studies in the context of supply chains (Borgatti and Li, 2009; Wasserman and Faust, 1994).

Degree centrality reflects the degree of supply/demand load and the extent to which the focal firm is influential in terms of impacting on the operational decisions and strategic behaviour of other firms (Kim *et al.*, 2011). Networks in which only one or a few firms enjoy high degree centrality with many others having a low number of connections are known as centralised networks (Kim *et al.*, 2011). Although a higher operational burden as a result of conflicting schedules is imposed on the firm with a high degree centrality (Kim *et al.*, 2011; Wichmann and Kaufmann, 2016), this firm is more likely than others to gain access to assets or information of a broad range of firms (Borgatti and Li, 2009). Firms with low closeness centrality in supply networks also appear to access resources more rapidly and have freedom from the controlling actions of others in terms of accessing information (Bellamy *et al.*, 2014). Shorter network paths, in terms of the number of steps a focal firm's raw materials must go through to get to the focal firm, are less susceptible to disruptions and cost increases (Borgatti and Li, 2009). Finally, firms occupying high betweenness centrality positions enjoy

great control over the flow of information and resources between the two other nonadjacent supply network actors (Sloane and O'Reilly, 2013; Wichmann and Kaufmann, 2016). In particular, these firms can enjoy the increased sourcing leverage when they lie between two competing suppliers (Choi and Wu, 2009).

Extant studies have also adopted a number of network-level properties to characterise the overall structure of supply networks. First, network density (the proportion of all possible connections present relative to the total number possible) has been examined to investigate the overall connectedness or cohesion of the supply networks (Bellamy *et al.*, 2014; Kim *et al.*, 2011). On the one hand, network density facilitates knowledge transfer and thus collaboration among supply network members. A dense supply network, in which every member connects with everyone else, is a highly cohesive network that enforces shared and firmly held norms among members. On the other hand, in dense supply networks where members are likely to interact frequently, much of the information circulating becomes redundant. Therefore, extant studies have documented mixed results, with some studies showing a positive (Delbufalo, 2015), negative (Cheng and Shiu, 2020), inverted U-Shaped (Swierczek, 2018) or no relationship (Bellamy *et al.*, 2014) between supply network density and the innovation or operational performance of the embedded firms. Often embedded within a supply network are groups of firms that interact with each other to such an extent that they could be considered separate entities (Kim *et al.*, 2011). These cohesive subgroups of firms (also known as network clusters) are connected through bridge actors (i.e. a firm the removal of which would break up a network into disconnected sub-groups), such as suppliers spanning multiple industries or third parties serving different supply networks. Although much of the information circulating in network sub-groups is often redundant, bridge actors play an important role in their networks by providing access to heterogeneous and nonredundant information (e.g. Li and Choi, 2009; Peng *et al.*, 2010). In addition, these firms

are presented with brokerage opportunities, as they participate in and are in control of information diffusion (Wagner *et al.*, 2018). Finally, recent studies have begun to acknowledge the diversity of supply chain members' attributes as a network-level property. Network diversity is the presence of varying firms' attributes in the network in terms of geographic location, institutional logic, technology, size, role etc. The concept has been reflected in the notion of network complexity, characterised as the numbers of tiers in a supply chain (role diversity) or the dispersion of network members across different countries and locations (geographical diversity) (Choi and Hong, 2002; Kim *et al.*, 2011). Specifically, the extant literature has documented the positive impact of network diversity in terms of product (Cheng and Shiu, 2020) and technology (Gao *et al.*, 2015) on firms' innovation performance.

Our study aims to provide a systematic synthesis of both node-level and network-level structural properties in the context of supply chain sustainability. Specifically, we seek to clarify how the structural properties of supply networks and sustainable supply networks in which firms are embedded influence the achievement of their sustainability goals across their supply chains.

3. Methodology

To best address the review questions, we adopt a systematic review approach. By using a transparent, reproducible and iterative review process, we seek to provide an organised synthesis of the literature (Tranfield *et al.*, 2003). This involves a comprehensive search and analysis framework that allows researchers to collect relevant data from diverse knowledge bases and synthesise them to provide insights into the field. In particular, we follow Denyer and Tranfield's (2009) key steps for systematic reviews, explained below.

3.1 Locating studies

We executed our literature search across the Scopus, EBSCO, and ABI/INFORM databases by applying multiple combinations of alternative keywords that reflected the three core phenomena of interest (i.e. sustainability, supply chain, and network). An initial scoping study identified the relevant keywords. In particular, the review of seminal work on network analysis in supply chain management research (e.g. Borgatti and Li, 2009; Kim *et al.*, 2011; Wichmann and Kaufmann, 2016), as well as recent systematic literature reviews of supply chain sustainability (e.g. Ashby *et al.*, 2012; Johnsen *et al.*, 2017; Schaltegger and Burritt, 2014; Tachizawa and Wong, 2014), resulted in a preliminary list of terms. The review enabled us to identify alternative terms used in the theorisation and operationalisation of network related as well as supply chain sustainability concepts. Updates of the preliminary list of terms occurred through an iterative process that included identifying additional terms throughout the search and evaluation process. Grouping keywords and applying search conventions, such as truncation characters and Boolean connections (AND, OR), resulted in the subsequent construction of the search strings (see Table I). We searched for the three search strings simultaneously among study titles, abstracts and keywords in the three databases (Scopus, EBSCO, and ABI/INFORM) during the winter of 2020.

Insert Table I about here

3.2 Study selection and evaluation

We limited our search to those articles from the highly regarded and world-leading journals included by the Financial Times on their top 50 journal list, the 2019 Australian Business Deans Council (ABDC) journal quality list rated A* or A, or that the 2018 Chartered Association of Business Schools (CABS) ranking guide rated 3 or higher. We further limited our search to studies published in English. This generated an initial sample of 3,693 articles,

which included 1,466 articles from the Scopus database, 1,223 articles from the EBSCO database and 1,002 articles from the ABI/INFORM database. The elimination of duplicates (1,053 articles) resulted in the retention of 2,640 articles.

We then applied a set of selection criteria to assess the relevance of each article to our study's review questions. First, to ensure that the selected articles adopted a network structural perspective (i.e. the article examines the structural properties of the broader network), we included those articles that investigate more than two firms with apparent patterns of connectivity. In particular, we excluded from our sample those articles merely focusing on dyadic relationships. Second, we only included those network investigations that were conducted in the context of supply chains. Finally, we only included studies that investigated the structural properties of networks in relation to sustainability.

We applied these relevance criteria in two stages of *abstract* and *full paper* review. After screening the abstracts, we rejected 2,218 articles because they lacked either focus on the sustainability dimensions or a network lens in their examination of supply chain sustainability. In the full paper review of the remaining 422 articles, we applied the same criteria, which led to the selection of 73 articles from 18 journals in the final sample. Figure 1 shows the selection process.

Insert Figure 1 about here

3.3 Data extraction and synthesis

Using a data extraction template organised by *descriptive* and *thematic* categories (see Table II), we prepared a summary of the information in each article. The descriptive category consists of the year of publication, the lead author's affiliated institution location, the journal's title, study type, methodology, industry and sustainability dimensions. The thematic category revolves around each article's *key findings*. These mainly include the supported hypotheses or the stated propositions explaining the network structural properties and their

role in supply chain sustainability. In addition, we extracted the definitions and operationalisations of the key constructs used by the hypotheses and propositions. Where a hypothesis or a proposition was not advanced, we prepared for further investigation a summary of the key findings in line with the study review questions.

Insert Table II about here

The thematic analysis followed a two-step coding process (Glaser, 1978). First, we began with a line-by-line review of the extracted data, to identify multiple network structural properties and their antecedents, as well as the key mechanisms through which firms achieve sustainability goals in network contexts, along with contextual factors. We assigned a descriptive label (code) to the segments of data in which the concept was present, to cluster the data units into common themes. We then conducted the process of generating higher-order codes (Strauss and Corbin, 1990), to conceptualise how the initial codes related to one another. Table III summarises the results of the thematic analysis, which we introduce and further elaborate on in the following sections.

Two of the authors independently performed the coding process. We then verified the extent to which these authors had both allocated the same text segments to the initial codes. This created a basis for the further development of the codes into a robust set of categories.

4. Descriptive findings

Our sample consists of 73 articles from 18 peer-reviewed journals published between 2000 and 2020. Figure 2 demonstrates the number of relevant papers published each year. The trendline of the total articles' quantity demonstrates a mounting interest in scholarly research in this specific area, with the majority (70 per cent) published after 2014. Scholars from a wide range of countries generated the research outputs. Specifically, lead authors were from 17 countries (see Figure 3), with most originating in Europe and North America (90 per cent).

Insert Figure 2 about here

Insert Figure 3 about here

The articles in the sample are drawn from 18 different journals (see Figure 4). Seven of them account for 78 per cent of the included articles. In a further refinement, we found that *Supply Chain Management: An International Journal* had the highest numbers of articles, followed by *Journal of Business Ethics* and *International Journal of Production Economics*.

Insert Figure 4 about here

Adopting Wacker's (1998) typology of research, our sample consists of 53 empirical and 20 analytical studies. Figure 5 illustrates the methodologies that these studies had adopted, with the majority (49 per cent) adopting a case study approach, followed by conceptual studies (26 per cent) and statistical sampling research (14 per cent).

Insert Figure 5 about here

Figure 6 demonstrates the distribution of articles according to the industries in which the empirical investigations were conducted. Manufacturing, agriculture and food, and textile and apparel account for 80 per cent of the study contexts. Whilst the energy sector comprises a range of the industries that pollute most, only three articles examine sustainability in this context.

Insert Figure 6 about here

Finally, while all studies in all sample have implicitly assumed the incorporation of the three dimensions of social, environmental and economic in their studies of supply chain sustainability, here we provide a descriptive analysis of sustainability dimensions that have been explicitly conceptualised or operationalised. Figure 7 illustrates the distribution of articles in our sample according to the sustainability dimensions examined. As illustrated, most articles (60 per cent) examined the environmental, social and economic dimensions

together, with the next largest groups evaluating the environmental dimension of sustainability (14 per cent), environmental and economic dimensions together (12 per cent) and the social dimension of sustainability (7 per cent).

Insert Figure 7 about here

5. The role of network structural properties in supply chain sustainability

Drawing on the research sample, we identified a set of node-level and network-level structural properties that affect the ways in which sustainability goals are achieved in supply networks. Our thematic analysis revealed the notion of firms' centrality in terms of *degree centrality*, *closeness centrality* and *betweenness centrality* as one of the most fundamental node-level structural properties. In addition, our review identified network-level properties, including *network density*, *network sub-groups* and *network diversity*, that play a role in driving supply chain sustainability. Our systematic review further identified the SSCM practices that are affected by these node-level and network-level structural properties. Specifically, the results revealed that structural properties determine the extent of (1) *perception of sustainability risks*, (2) *diffusion of sustainability targets*, (3) *introduction of sustainable innovations*, (4) *development of sustainability capabilities*, (5) *adoption of sustainability initiatives* and (6) *monitoring of sustainability performance* throughout the supply chain.

Table III summarises the thematic findings, in terms of the identified structural properties and the associated SSCM practices. The table also includes the implications of the identified structural properties that were investigated by the reviewed articles to explain their links with different SSCM practices as well as the contextual factors affecting these relationships. Finally, the table presents the antecedents of structural properties as identified from the reviewed articles. The following sections detail the thematic analysis of the literature.

Insert Table III about here

5.1 Degree centrality

Firms taking high degree central positions in their supply networks often tend to take a central position in the sustainable supply network to utilise their power and respond to pressure from various stakeholders (Tachizawa and Wong, 2014; Xiao *et al.*, 2012). These firms often establish direct contacts with a high number of first-tier and lower-tier suppliers to monitor, govern and collaborate with them and hence achieve sustainability goals (Bush *et al.*, 2015; Sauer and Seuring, 2019; Tachizawa and Wong, 2014). Specifically, firms occupying high degree centrality positions in sustainable supply networks can exert influence over their connections' adoption of sustainability initiatives (Beckman *et al.*, 2009; Ciliberti *et al.*, 2009; Kauppi and Hannibal, 2017). These firms enforce their own interpretation of sustainability and its translation into practice (Vurro *et al.*, 2009). They often adopt a transformational leadership style with which they inspire, incentivise, intellectually stimulate, pay individualised consideration and create a shared schema, to encourage the implementation of sustainability initiatives at different stages of initiation, execution and maintenance (Alvarez *et al.*, 2010; Jia *et al.*, 2019; MacCarthy and Jayarathne, 2012; Meqdadi *et al.*, 2017; 2019; Touboullic *et al.*, 2018). As a result, suppliers serving these central firms with a strong sustainability agenda are more likely to adopt these sustainability initiatives (Villena and Gioia, 2018). Specifically, these suppliers are motivated (or, in severe cases, forced) to meet the introduced sustainability targets, to avoid being relegated to the status of a lower-tier supplier (Tura *et al.*, 2019).

Firms occupying central positions can also facilitate the communication of sustainability-related information as a result of their direct interactions with a high number of suppliers. Indeed, drawing on their influence, firms in highly central network positions can easily set and diffuse sustainability targets and demand compliance from many suppliers (Brockhaus *et*

al., 2013; Castka and Balzarova, 2008; Lim and Phillips, 2008; Villena and Gioia, 2020; Vurro *et al.*, 2009) and, thus, reduce the compliance-information asymmetry in supply networks (Sarkis *et al.*, 2011; Touboulic *et al.*, 2018). Specifically, high degree centrality is effective when the focal firm adopts a compliance-based approach (Tachizawa and Wong, 2015) that does not require intensive cooperation with suppliers in achieving sustainability targets (Lund-Thomsen and Lindgreen, 2014). Where achieving sustainability goals requires a high allocation of resources (i.e. sustainability capability development and monitoring processes), firms with high degree centrality tend to be less efficient. Consistently, Vachon and Klassen (2006) illustrated that the extent of sustainability collaboration between a focal firm and its suppliers is higher when the degree centrality is low. Similarly, Kim and Davis (2016) showed that firms with a high degree centrality are less efficient in tracking sustainability-related data. Under uncertain conditions (e.g. material criticality or dependence on suppliers, Tachizawa and Wong, 2014), firms may still increase their degree centrality by directly working with a high number of suppliers to show short-term sustainability achievements (Sauer and Seuring, 2018). This may also be present where a slow pace of change in sustainable initiatives in the industry allows the focal firm to establish jointly developed initiatives with a high number of suppliers over time, or in those instances where the focal firm has enough resources to work with a high number of suppliers (Tachizawa and Wong, 2014). However, these firms may choose to reduce their degree centrality in the long run by working with third parties or relying on lower-tier suppliers (Sauer and Seuring, 2018).

5.2 Closeness centrality

Firms occupying high closeness centrality positions in their supply networks tend to receive information through several intermediary actors in the network (Meehan and Bryde, 2015).

The lack of visibility into indirect suppliers leads to a higher perceived sustainability risk

(Meinlschmidt *et al.*, 2018). For instance, Wilhelm *et al.* (2016b) illustrated that non-compliance regarding sustainable practices is less traceable in networks where the average length of the path connecting firms is large. Similarly, distant suppliers often tend to show passivity in adopting sustainability practices because they are not exposed to the focal firm's incentive or penalty mechanisms (Gong *et al.*, 2018; Villena and Gioia, 2018).

Hence, a focal firm that cannot easily reach (or be reached by) all others in their supply network tends to directly connect with lower-tier suppliers (bypassing the first-tier suppliers) in its sustainable supply network (Alexander, 2020; Tachizawa and Wong, 2014; Wilhelm *et al.*, 2016b). Extant studies demonstrated that the probability of a firm directly engaging with a supplier to address sustainability increases when the supplier is distant from the firm (Awaysheh and Klassen, 2010; Roberts, 2003). Specifically, focal firms occupying these positions in sustainable supply networks are often held accountable for the actions of their suppliers (Hartmann and Moeller, 2014), and they tend to significantly invest in capability development and monitoring programmes of these lower-tier suppliers (Mejías *et al.*, 2019). While they adopt a compliance strategy with middle-tier suppliers, these firms often use a direct and collaborative approach with more distant suppliers (Jia *et al.*, 2019).

5.3 Betweenness centrality

The betweenness centrality positions are often taken by first-tier suppliers or third-party firms such as NGOs, auditors or trade associations in sustainable supply networks. These structural positions form where the focal firm adopts an indirect approach to achieving sustainability goals. In these settings, the focal firm requires first-tier suppliers or third parties to assist lower-tier suppliers in developing sustainability capabilities and/or monitor their performance (Tachizawa and Wong, 2014; Tuni *et al.*, 2019). Initially, the focal firms closely work with these intermediaries to take them on board, cascading the sustainability targets and initiatives to lower-tier suppliers (Nair *et al.*, 2016; Villena and Gioia, 2020; Wilhelm *et al.*, 2016a).

This specifically reduces the operational burden of managing a high number of suppliers in industries where sustainability initiatives are rapidly changing and requiring continuous new sustainability capability development (Tachizawa and Wong, 2014). At the same time, first-tier suppliers taking a high betweenness centrality position control over the information flow (Mena *et al.*, 2013) and can shield their true self from the focal firm (i.e. showing inauthenticity, Beckman *et al.*, 2009).

The delegation of authority regarding lower-tier suppliers' sustainability management, and hence, the emergence of betweenness centrality positions appear where the focal firm perceives a low risk of lower-tier suppliers showing passivity in addressing sustainability (Gong *et al.*, 2018). These structural positions are particularly evident where noncompliance regarding sustainability is more traceable (e.g. environmental sustainability practices as opposed to social sustainability practices) leading to a higher sustainability commitment from lower-tier suppliers (Wilhelm *et al.*, 2016b). Additionally, research suggests that focal firms tend to delegate the authority regarding lower-tier suppliers' sustainability management in cases where they lack enough resources to directly work with lower-tier suppliers (Tachizawa and Wong, 2014). First-tier suppliers also occupy high betweenness centrality positions when they demonstrate strong sustainability management capabilities (Wilhelm *et al.*, 2016b). However, where power asymmetries increase towards the lower tiers, the nominated first-tier suppliers may be unable to commit to the relegated sustainability responsibilities (Wilhelm *et al.*, 2016b).

Generally, firms occupying high betweenness centrality in sustainable supply networks play two key roles: 1) to set up sustainability initiatives and support lower-tier suppliers in developing sustainability capabilities and 2) to monitor lower-tier suppliers' sustainability performance and report back to the focal firm. These actors often require adopting an informal, collaborative and transformational approach to managing the lower-tier suppliers'

sustainability (Jia *et al.*, 2019; Tachizawa and Wong, 2015). Yet, they may adopt a compliance and transactional approach in the later stages of sustainability initiative adoption, where the key focus should be on monitoring and sustaining these initiatives, rather than capability development (Jia *et al.*, 2019). Similarly, a compliance and transactional approach appears where lower-tier suppliers take a high betweenness centrality position (Nath *et al.*, 2019).

5.4 Network density

In dense supply networks, network members are often held accountable for the actions of each other's actions, due to the high degree of interdependencies (Chen, 2018) leading to a high level of sustainability-related interactions among embedded members. Additionally, the shared objectives and economic interests present in dense networks (also known as community logic) would support the creation of a dense sustainable supply network (Wu and Pullman, 2015). Dense sustainable supply networks may also form as a response to sustainability-related supply uncertainty (Zander *et al.*, 2016).

The normative pressure and distributed power associated with dense sustainable supply networks often encourage the embedded suppliers to engage in collective behaviour towards sustainability (Fontana and Egels-Zandén, 2019; Nath *et al.*, 2019; Wu and Pullman, 2015). Specifically, the normative and mimetic pressures resulting from institutional homogeneity would encourage the embedded suppliers to invest in radical changes to support the adoption of sustainability initiatives (Sayed *et al.*, 2017). Conversely, suppliers residing in sparse networks (i.e. networks with low density) where such norms are absent are not motivated to develop or adopt sustainability initiatives since other network members ignore actions by even a committed supplier (Roberts, 2003; Vurro *et al.*, 2009). While normative pressures resulting from network interconnectivity have less effect on supply network members in positions of power (e.g. those with a strong economic position) (Fontana and Egels-Zandén,

2019; Wu and Pullman, 2015), they often limit these powerful actors' ability to influence others in the network (Touboulic *et al.*, 2014).

Suppliers communicating their sustainability-related information to a high number of interconnected stakeholders (i.e. dense sustainability networks) find that being inauthentic is risky (Beckman *et al.*, 2009). Additionally, the greater network density leads to repeatedly encountering and discussing information, promoting a shared understanding among members. Hence, it becomes easier in dense networks to collaborate on developing sustainability capabilities (Koh *et al.*, 2012; Miemczyk *et al.*, 2012; Villena and Gioia, 2020; Vurro *et al.*, 2009). Informal, collaborative and relational mechanisms to facilitate such collaborations progressively replace formal governance mechanisms (Geng *et al.*, 2019; Tachizawa and Wong, 2015; Vurro *et al.*, 2009). Suppliers diagnose each other to identify strengths and weaknesses (Herczeg *et al.*, 2018) and exchange complementary capabilities (e.g. digitalisation for data analytics, developing fleet management systems and big data collection and analytics, Melander and Pazirandeh, 2019) through jointly developed platforms (e.g. digital collaborative platforms) to develop sustainability capabilities (Melander and Pazirandeh, 2019; Plambeck *et al.*, 2012).

Over time, dense networks generate institution-like structures that set the roles and responsibilities of suppliers in the network (Helfen *et al.*, 2018; Nair *et al.*, 2016). As discussed, these community-like networks adopt similar values and promote strong relationships among their members. These mechanisms create a network of homogenous like-minded suppliers, resulting in a higher rate of sustainability initiative adoption (Fontana and Egels-Zandén, 2019; Lu *et al.*, 2018). While dense networks are particularly instrumental in rolling out sustainability initiatives (Johnston and Linton, 2000; Tate *et al.*, 2013; Van Bommel, 2011), they are often limited in channelling new ideas and innovative solutions to the network (due to the homogeneity of network members).

5.5 Network sub-groups and bridge actors

Extant studies have shown that the number of bridge actors in sustainable supply networks is positively associated with the access to new sustainable solution ideas leading to radical sustainable innovations (Roscoe *et al.*, 2016; Tate *et al.*, 2013). Furthermore, bridge actors are well positioned to diffuse the sustainability targets to the most remote or inaccessible network clusters (Saunders *et al.*, 2019). In fact, whilst bridge actors assist the focal firms during the initiation stage of sustainability initiatives, by providing access to novel ideas, they contribute to the execution of these initiatives through supporting remote suppliers in the network with sustainability-related information (Saunders *et al.*, 2019). Suppliers serving multiple industries or sectors occupy a bridge actor position. These bridge suppliers transfer knowledge and innovative ideas from one network to another (Oosterveer, 2015; Nair *et al.*, 2016) and have a stronger record of adopting sustainability initiatives themselves (Villena and Gioia, 2018).

Third parties, such as NGOs, auditors, media or trade associations, with a strong sustainability agenda, also appear to take on a bridge role (Bush *et al.*, 2015; Johnson *et al.*, 2018; Liu *et al.*, 2018; Villena and Gioia, 2020). These actors particularly influence the remote suppliers to adopt sustainability initiatives (Castka and Balzarova, 2008; Gong *et al.*, 2018; Saunders *et al.*, 2019; Tachizawa and Wong, 2014). Third parties often achieve this by creating a shared sustainability vision locally and providing complementary resources to these remote suppliers (Jia *et al.*, 2019; Melander and Pazirandeh, 2019; Mena *et al.*, 2014; Nath *et al.*, 2019; Touboulic *et al.*, 2018). Focal firms under strong stakeholder pressure and lacking knowledge resources or power are more likely to work with third party bridge actors in rolling out sustainability initiatives (Rodríguez *et al.*, 2016; Tachizawa and Wong, 2014).

Third party bridge actors can also be tasked with monitoring sustainability performance in supply networks (Plambeck *et al.*, 2012). Specifically, these actors with a monitoring duty

(e.g. certificate agencies) arise in networks with low perceived risk of sustainability initiative development and adoption (Gong *et al.*, 2018; Kauppi and Hannibal, 2017; Sauer and Seuring, 2018). However, Mueller *et al.* (2009) and later Hannibal and Kauppi (2019) observed that the monitoring activities of these bridge actors have not been consistently and comprehensively applied across multiple tiers of supply networks.

5.6 Network diversity

Sustainable supply networks consisting of firms with varying attributes, in terms of different institutional logics, geographical locations, capabilities, economic objectives and roles (i.e. network diversity) are prevalent in practice. Addressing complex sustainability issues in supply networks holistically is generally achieved where a diverse set of stakeholders bring complementary resources to the table (Airike *et al.*, 2016; Bush *et al.*, 2015; Crespín-Mazet and Dontenwill, 2012; Patala *et al.*, 2014; Svensson *et al.*, 2018). For instance, focal firms work with suppliers, competitors, regulatory bodies, technology providers, environmental experts and community advocates (Herczeg *et al.*, 2018; Johnston and Linton, 2000) with different institutional logics (Nair *et al.*, 2016) throughout the development stages of sustainability initiatives (Alvarez *et al.*, 2010). Communication platforms, established to connect network members with different roles and complementary resources, often facilitate these settings (Herczeg *et al.*, 2018).

As one of the most dominant forms of diversity in sustainable supply networks, the extent of institutional diversity affects the ways network members approach and engage with sustainability initiatives. For instance, suppliers that are embedded in networks with high institutional diversity, where 1) multiple interpretations of sustainability initiatives (Sayed *et al.*, 2017) and increased information asymmetry exist, 2) high coordination efforts are required (Tachizawa and Wong, 2014) and 3) shared values and evenly distributed risks and benefits are absent (Brockhaus *et al.*, 2013; Herczeg *et al.*, 2018; Wu and Pullman, 2015), are

only prepared to make incremental changes towards adopting sustainability initiatives. Specifically, suppliers with a high institutional distance from the focal firm tend to adhere to their local institution and interpretation of sustainability initiatives, requiring only incremental adjustments (Sauer and Seuring, 2018). This may lead particularly to tensions at the early stages of developing sustainability initiatives, where the focal firms often enforce significant changes (Touboulis *et al.*, 2018). The focal firm could resolve these network tensions through strong stakeholder communications and active involvement in capability development and monitoring (Tura *et al.*, 2019).

Institutional diversity may lead to the creation of specific network structural properties. For instance, focal firms tend to delegate sustainability management activities to the first-tier suppliers (leading to suppliers taking high betweenness centrality positions) where the network institutional diversity is low. Furthermore, focal firms facing high institutional diversity in their networks tend to engage with third party bridge actors to resolve potential tensions and resource imbalances (Wilhelm *et al.*, 2016b).

Furthermore, geographical proximity (or lack of geographical diversity) leads to highly interconnected local sub-groups (Dou *et al.*, 2018; Zander *et al.*, 2016). Normative pressure and collective behaviour of the overall network to adopt sustainable initiatives often have less influence on suppliers embedded in these local sub-groups (Fontana and Egels-Zandén, 2019). Yet, these suppliers show stronger commitments towards sustainability than their neighbouring local suppliers that are not connected to global networks (Golini and Gualandris, 2018).

6. Directions for future research

Drawing on our thematic analysis, we identify a number of avenues for future research.

Our review provides a systematic synthesis of both node-level and network-level structural properties in the context of supply chain sustainability. Although our review revealed that the

structural properties of both *supply networks* (networks in which supply chain members engage to perform supply-related activities) and *sustainable supply networks* (those formed to enhance the sustainability of the underlying supply network) influence how the embedded firms achieve sustainability goals across their supply chains, the majority of our sample focuses on the structural properties of sustainable supply networks. In particular, the reviewed literature suggests that the structural properties of these sustainable supply networks both positively and negatively affect the embedded members' sustainable supply chain practices (see Table IV). While extant literature has begun to acknowledge the role of sustainable supply network structural properties in supply chain sustainability, the existing studies lack empirical grounding. In particular, the emergent structural properties of networks are predominantly observable on a large scale. Nonetheless, no empirical studies as yet have investigated the structural properties of a large-scale, real-world sustainable supply network in relation to supply chain sustainability. Hence, future research is required to collect and construct real-world large-scale sustainable supply network datasets in order to investigate their effects on how network members achieve their sustainability goals across their supply chains.

Insert Table IV about here

Furthermore, our review of literature suggests (as shown in Table IV) that the investigation of sustainable supply network structural properties in relation to supply chain sustainability has been limited to certain sustainable supply chain practices. Specifically, although the role of network structural properties in the *adoption of sustainability initiatives* or *development of sustainability capabilities* has been thoroughly investigated, it is less clear how certain network structural properties may affect the *monitoring of sustainability performance* or the *diffusion of sustainability targets*. For instance, a focal firm's degree centrality in the sustainable supply network may have a both positive (due to direct

interactions with a high number of suppliers) and negative (due to a higher monitoring operational burden) effect on the monitoring of sustainability performance. Similarly, sustainable supply network density may facilitate the diffusion of sustainability targets because of the highly distributed information sharing that is frequently observed in these networks. Hence, more evidence is required to shed light on the role of sustainable supply network structural properties in the wider range of supply chain sustainability practices.

Extant studies investigating the connectivity patterns in both supply networks and sustainable supply networks have largely focused on applying theoretical network metrics, such as centrality or density, in doing so overlooking the interpretation of these metrics or the development of new ones in the specific context of supply chain sustainability. In particular, scholars have suggested that in addition to the collective patterns of connectivity in interorganisational networks, the quality and strength of relationships which bond actors to each other as well as their attributes influence the manner in which they achieve their goals (Alinaghian and Razmdoost, 2018; Alinaghian *et al.*, 2019). Our review consistently identified the interactive role of power asymmetry (Fontana and Egels-Zandén, 2019) or firms' leadership style (Jia *et al.*, 2019) with network structural properties in terms of affecting supply chain sustainability. Hence, a more granular understanding of the role of network connectivity patterns in supply chain sustainability requires a re-examination to accommodate the dyad-level and actor-level contingencies in the form of new structural metrics.

A few studies in our sample have sought to shed light on how the structural properties of *supply networks* affect the achievement of sustainability goals across the supply chain. In particular, these studies have shown the interrelationships between the structural properties of supply network and sustainable supply networks. For instance, these studies have suggested that the degree centrality of a focal firm in a supply network positively influences its degree

centrality in a sustainable supply network (Xiao *et al.*, 2012). Similarly, the closeness centrality of a focal firm in a supply network has been demonstrated to negatively influence its closeness centrality in a sustainable supply network (Alexander, 2020). Although these studies have highlighted the interrelationships between the two types of networks, the simultaneous existence of *supply* and *sustainability ties* (known as multiplexity; Wasserman and Faust, 1994) is yet to be investigated. Hence, future research is required to reconcile the various relationship types that co-exist in supply networks and, hence, clarify how their interplay can affect supply chain sustainability.

Furthermore, in investigating the network structural determinants of supply chain sustainability, our reviewed studies have not succeeded in clearly distinguishing between the economic, social and environmental dimensions of sustainability. We have rarely observed how network structural properties would differently influence the economic, social and environmental dimensions of sustainability (a notable exception is the work of Wilhelm *et al.*, 2016b). For instance, a diverse sustainable supply network may benefit economic and environmental goals by introducing innovative solutions, whereas it may not be as beneficial for social goals, where the challenges require sustainability capability development rather than the introduction of innovation solutions. Hence, future research should investigate sustainable supply network structural properties in light of the three dimensions of supply chain sustainability.

Finally, in investigating the role of supply network structural properties in the context of sustainability, our reviewed studies have predominantly adopted an egocentric approach whereby a focal firm's perspective defines the boundary of the network. Less clear is how the structural properties of networks whose boundaries are not associated with a single focal firm (e.g. a network of firms residing in a specific geographic region, sharing a technology platform or belonging to a specific industry group) may impact sustainability goals.

Specifically, two key issues remain unexplored in these contexts. First, future studies should operationalise sustainable supply network structural properties to explain the sustainability of geographical clusters, technology-based ecosystems or industry groups. Second, future research is required to revisit SSCM practices, by clarifying the roles of various network members and the mechanisms governing the network in achieving collective outcomes.

7. Conclusions

In investigating supply chain sustainability, the field of operations and supply chain management has shifted its focus from single buyer-supplier dyads to the collective patterns of relationships. Our paper seeks to shed light on the role of these connectivity patterns in supply chain sustainability by synthesising and evaluating the extant literature investigating the structural properties of sustainable supply networks. Our review identifies specific node-level (degree centrality, closeness centrality, betweenness centrality) and network-level (network density, network sub-groups, network diversity) structural properties that play a role in supply chain sustainability through articulating their impact on six SSCM practices.

The results of our review offer practitioners several practical implications with regards to supply chain sustainability. First, our study provides managers with a simple analytical tool to characterise the structural properties of the sustainable supply networks in which their firms are embedded. Firms' awareness of the implications of these structural properties in achieving their sustainability goals is important. Specifically, as firms must apply different SSCM practices (e.g. monitoring, capability development) to achieve their sustainability goals, managers designing appropriate network structures is imperative. For instance, a high degree centrality position would not be appropriate where achieving sustainability goals requires significant resources in supporting lower-tier suppliers in developing sustainability capabilities. In this situation, the focal firm may choose instead to delegate the management of sustainability to its first-tier suppliers occupying high betweenness centrality positions.

Similarly, while dense sustainable supply networks putting normative pressure on network members to adopt sustainability practices and promoting collaboration to develop sustainability capabilities can be beneficial, these dense networks are not ideal where novel sustainability practices are key in achieving sustainability goals. Furthermore, practitioners must achieve a strategic fit between the structure of their sustainable supply network and the governance instruments they adopt to manage relationships. For instance, a compliance-based governance approach enhances the monitoring performance of first-tier suppliers occupying betweenness centrality positions, specifically where the sustainability initiative is at a mature stage.

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Table I Keywords and search strings

Subject	Related Keywords	Search String
Sustainability	Sustainability OR Environment OR Corporate Social Responsibility OR Green	("child* labour*" OR discriminat* OR ethic* OR "human* right" OR "work* welfar*" OR "employee welfar*" OR sustainab* OR "environment* W/10 practices" OR green OR "social* responsib*" OR recycl* OR "carbon footprint")
Supply Chain	Supply OR Logistics	(suppl* OR logistics OR "demand chain")
Network	Network OR Embeddedness OR Multi-tier	(network OR "structural properties" OR alliance OR interaction OR embed* OR "multi* tier" OR triad* OR "graph theory" OR inter-organi?ation* OR collaborat* OR "cross-sector" OR partners* OR "inter*firm")

Table II Data extraction template

Data	Explanation
Authors	The names of the authors
Year	The year of publication
Location	The country of the lead author's affiliated institution
Journal	The title of the journal
Study type	<p>Empirical: A study that draws conclusions based on primary or secondary empirical evidence (data)</p> <p>Analytical: A study that draws conclusions based on conceptual, mathematical or statistical assumptions</p>
Methodology	<p>Statistical sampling – Survey: An <u>empirical</u> study where data is collected through a structured questionnaire</p> <p>Statistical sampling – Secondary data analysis: An <u>empirical</u> study that involves analysis of existing data collected for another primary purpose</p> <p>Experimental design: An <u>empirical</u> study that involves the manipulation of causal variables and the observation of effect among the treatment and control groups</p> <p>Case study: An <u>empirical</u> study involving an in-depth examination of one or multiple cases (e.g. firms, supply networks or sustainable supply networks) within its real-life context</p> <p>Expert interview: An <u>empirical</u> study where data is collected through interviews with experts</p> <p>Conceptual: An <u>analytical</u> study that draws conclusions based on logical relationship building</p> <p>Mathematical: An <u>analytical</u> study that draws conclusions through developing new mathematical relationships</p>
Industry	The industry from which the empirical data is obtained
Sustainability dimension	<p>Environmental: The impacts of supply chain activities to environmental resources</p> <p>Social: The impacts of supply chain activities to social resources involved</p> <p>Economic: The impacts of supply chain activities to the economic performance</p>
Key findings	<p>Supported hypotheses</p> <p>Stated propositions</p> <p>Definitions and operationalisations of the key constructs used in hypotheses and propositions</p> <p>A summary of the key findings in line with the study review questions (where a hypothesis or a proposition was not available)</p>

Table III Thematic analysis

Structural properties	SSCM Practices	a) Structural properties implications b) Contextual factors c) Determinants of structural properties	Authors, Year
Focal firm degree centrality in sustainable supply network		a) Power and influence over suppliers' behaviour c) Focal firm degree centrality in supply network	Tachizawa and Wong, 2014; Xiao <i>et al.</i> , 2012
		c) Direct collaboration with several first- and lower-tier suppliers	Bush <i>et al.</i> , 2015; Sauer and Seuring, 2019; Tachizawa and Wong, 2014
	Adoption of sustainability initiatives	a) Power and influence	Beckman <i>et al.</i> , 2009; Ciliberti <i>et al.</i> , 2009; Kauppi and Hannibal, 2017; Sayed <i>et al.</i> , 2017; Tura <i>et al.</i> , 2019; Villena and Gioia, 2018; Vurro <i>et al.</i> , 2009
	Adoption of sustainability initiatives	b) Transformational leadership style	Alvarez <i>et al.</i> , 2010; Jia <i>et al.</i> , 2019; MacCarthy and Jayarathne, 2012; Meqdadi <i>et al.</i> , 2017; 2019; Touboulic <i>et al.</i> , 2018
	Diffusion of sustainability targets	a) Access to many suppliers and compliance information symmetry	Brockhaus <i>et al.</i> , 2013; Castka and Balzarova, 2008; Lim and Phillips, 2008; Lund-Thomsen and Lindgreen, 2014; Sarkis <i>et al.</i> , 2011; Touboulic <i>et al.</i> , 2018 Villena and Gioia, 2020; Vurro <i>et al.</i> , 2009
	(-) Development of sustainability capabilities	a) Resource allocation	Vachon and Klassen, 2006
	(-) Monitoring of sustainability performance	a) Resource allocation	Kim and Davis, 2016
		c) Material criticality, dependence on suppliers, industry stability, short-term objectives or high level of resources	Tachizawa and Wong, 2014; Sauer and Seuring, 2018

Structural properties	SSCM Practices	a) Structural properties implications b) Contextual factors c) Determinants of structural properties	Authors, Year
Focal firm closeness centrality in supply network	Perception of sustainability risks	a) Lack of visibility	Meehan and Bryde, 2015; Meinel Schmidt <i>et al.</i> , 2018; Wilhelm <i>et al.</i> , 2016b
Lower-tier supplier closeness centrality in sustainable supply network	(-) Adoption of sustainability initiatives		Gong <i>et al.</i> , 2018; Villena and Gioia, 2018
Focal firm closeness centrality in sustainable supply network		c) Focal firm closeness centrality in supply network (-) c) Direct tie with lower-tier suppliers	Alexander, 2020; Awaysheh and Klassen, 2010; Roberts, 2003; Tachizawa and Wong, 2014; Wilhelm <i>et al.</i> , 2016b
	Development of sustainability capabilities	a) Held accountable and adopt a collaborative approach	Hartmann and Moeller, 2014; Jia <i>et al.</i> , 2019; Mejías <i>et al.</i> , 2019
First-tier supplier betweenness centrality in sustainable supply network		c) Focal firm delegation of sustainability-related responsibilities to first-tier suppliers	Nair <i>et al.</i> , 2016; Tachizawa and Wong, 2014; Tunj <i>et al.</i> , 2019; Villena and Gioia, 2020; Wilhelm <i>et al.</i> , 2016a
		a) Reduce operational burden on the focal firm	Tachizawa and Wong, 2014
		c) Lower-tier suppliers' commitment towards sustainability	Gong <i>et al.</i> , 2018; Wilhelm <i>et al.</i> , 2016b
		c) Focal firm lack of resources c) First-tier suppliers' strong sustainability management capabilities	Tachizawa and Wong, 2014; Wilhelm <i>et al.</i> , 2016b
	(-) Monitoring of sustainability performance	a) Control over information flow	Beckman <i>et al.</i> , 2009; Mena <i>et al.</i> , 2013

Structural properties	SSCM Practices	a) Structural properties implications b) Contextual factors c) Determinants of structural properties	Authors, Year
	Development of sustainability capabilities Monitoring of sustainability performance	b) Collaborative and transformational leadership style	Jia <i>et al.</i> , 2019; Tachizawa and Wong, 2015
	Adoption of sustainability initiatives	b) Compliance-based and transactional approach b) Later stage of sustainability initiative development	Jia <i>et al.</i> , 2019
Lower-tier supplier betweenness centrality in sustainable supply network		b) Compliance-based and transactional approach	Nath <i>et al.</i> , 2019
Supply network density	Development of sustainability capabilities	a) Held accountable for the actions of each other a) Collaboration	Chen, 2018
Sustainable supply network density		c) Interconnected activities or a response to supply uncertainty	Zander <i>et al.</i> , 2016
		c) Supply network density c) Shared objectives and economic interests	Wu and Pullman, 2015
	Adoption of sustainability initiatives	a) Normative Pressure	Fontana and Egels-Zandén, 2019; Nath <i>et al.</i> , 2019; Roberts, 2003; Vurro <i>et al.</i> , 2009
	Adoption of sustainability initiatives	a) Homogenous network	Fontana and Egels-Zandén, 2019; Helfen <i>et al.</i> , 2018; Johnston and Linton, 2000; Lu <i>et al.</i> , 2018; Nair <i>et al.</i> , 2016 Tate <i>et al.</i> , 2013; Van Bommel, 2011
	Adoption of sustainability initiatives	b) Powerful members balance the normative pressure (-)	Fontana and Egels-Zandén, 2019; Touboulie <i>et al.</i> , 2014; Wu and Pullman, 2015

Structural properties	SSCM Practices	a) Structural properties implications b) Contextual factors c) Determinants of structural properties	Authors, Year
	Monitoring of sustainability performance	a) Highly distributed information sharing	Beckman <i>et al.</i> , 2009
	Development of sustainability capabilities	a) Shared understanding	Koh <i>et al.</i> , 2012; Miemczyk <i>et al.</i> , 2012; Villena and Gioia, 2020; Vurro <i>et al.</i> , 2009
		b) Informal, collaborative and relational approach	Geng <i>et al.</i> , 2019; Tachizawa and Wong, 2015; Vurro <i>et al.</i> , 2009
		b) Diagnose requirements, exchange resources and jointly develop collaborative platforms	Herczeg <i>et al.</i> , 2018; Melander and Pazirandeh, 2019; Plambeck <i>et al.</i> , 2012
Sustainable supply network bridge actor	Introduction of sustainable innovations	a) Access to heterogeneous and non-redundant information	Oosterveer, 2015; Nair <i>et al.</i> , 2016; Roscoe <i>et al.</i> , 2016; Tate <i>et al.</i> , 2013
	Diffusion of sustainability targets	a) Access to remote clusters	Saunders <i>et al.</i> , 2019
	Adoption of sustainability initiatives	a) Member of multiple networks b) Supplier as a bridge actor	Villena and Gioia, 2018
		b) Strong sustainability agenda b) Third party as a bridge actor	Bush <i>et al.</i> , 2015; Johnson <i>et al.</i> , 2018; Liu <i>et al.</i> , 2018; Villena and Gioia, 2020
	Adoption of sustainability initiatives	a) Access to and influence over remote suppliers b) Third party as a bridge actor	Castka and Balzarova, 2008; Gong <i>et al.</i> , 2018; Saunders <i>et al.</i> , 2019; Tachizawa and Wong, 2014
	Development of sustainability capabilities Adoption of sustainability initiatives	a) Local shared vision and complementary resources b) Third party as a bridge actor	Jia <i>et al.</i> , 2019; Melander and Pazirandeh, 2019; Mena <i>et al.</i> , 2014; Nath <i>et al.</i> , 2019; Plambeck <i>et al.</i> , 2012; Touboulc <i>et al.</i> , 2018

Structural properties	SSCM Practices	a) Structural properties implications b) Contextual factors c) Determinants of structural properties	Authors, Year
		b) Third party as a bridge actor c) Focal firms under strong stakeholder pressure with limited of resources	Rodríguez <i>et al.</i> , 2016; Tachizawa and Wong, 2014
		b) Third party as a bridge actor c) Low perceived risk of sustainability practice development and adoption	Gong <i>et al.</i> , 2018; Kauppi and Hannibal, 2017; Sauer and Seuring, 2018
	(-) Monitoring of sustainability performance	a) Inconsistencies and vague scope of responsibility b) Third party as a bridge actor	Hannibal and Kauppi, 2019; Mueller <i>et al.</i> , 2009
Sustainable supply network diversity	Development of sustainability capabilities	a) Complementary resources and institutional diversity c) Complex sustainability issues	Airike <i>et al.</i> , 2016; Alvarez <i>et al.</i> , 2010; Bush <i>et al.</i> , 2015; Crespín-Mazet and Dontenwill, 2012; Herczeg <i>et al.</i> , 2018; Johnston and Linton, 2000; Nair <i>et al.</i> , 2016; Patala <i>et al.</i> , 2014; Svensson <i>et al.</i> , 2018
		b) Communication platforms	Herczeg <i>et al.</i> , 2018
	(Incremental) Adoption of sustainability initiatives	a) Multiple interpretation of sustainability practices b) Institutional diversity	Sauer and Seuring, 2018; Sayed <i>et al.</i> , 2017
	(-) Adoption of sustainability initiatives	a) Information asymmetry and coordination efforts a) Incremental changes b) Institutional diversity	Tachizawa and Wong, 2014
	(-) Adoption of sustainability initiatives	a) Absence of shared values and distributed risks and benefits a) Incremental changes b) Institutional diversity	Brockhaus <i>et al.</i> , 2013; Herczeg <i>et al.</i> , 2018; Wu and Pullman, 2015

Structural properties	SSCM Practices	a) Structural properties implications b) Contextual factors c) Determinants of structural properties	Authors, Year
	Diffusion of sustainability targets	a) Tensions b) Institutional diversity	Touboulic <i>et al.</i> , 2018
		b) Third party engagement, stakeholder communications and active involvement to resolve tensions b) Institutional diversity	Tura <i>et al.</i> , 2019; Wilhelm <i>et al.</i> , 2016b
		a) Network density b) Physical diversity (-)	Dou <i>et al.</i> , 2018; Zander <i>et al.</i> , 2016
	Adoption of sustainability initiatives	a) Normative pressure (-) a) Connected to the network b) Physical diversity	Fontana and Egels-Zandén, 2019; Golini and Gualandris, 2018

Table IV The relationship between sustainable supply network structural properties and sustainable supply chain practices

	Degree Centrality	Closeness Centrality	(first-tier Supplier) Betweenness Centrality	Network Density	(number of) Bridge Actors	Network Diversity
Perception of Sustainability Risks						
Diffusion of Sustainability Targets	+				+	+
Introduction of Sustainable innovations				-	+	
Development of Sustainability Capabilities		+	+	+	+ (lower-tier)	+
Adoption of Sustainability Initiatives	+	-		+	+ (lower-tier)	-
Monitoring of Sustainability Performance			+ (lower-tier) - (first-tier)	+		

Note: + positive relationship; - negative relationship

Figure 1 Selection process

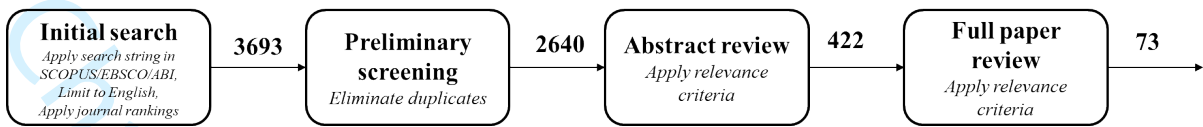


Figure 2 Distribution of reviewed articles based on the year of publication

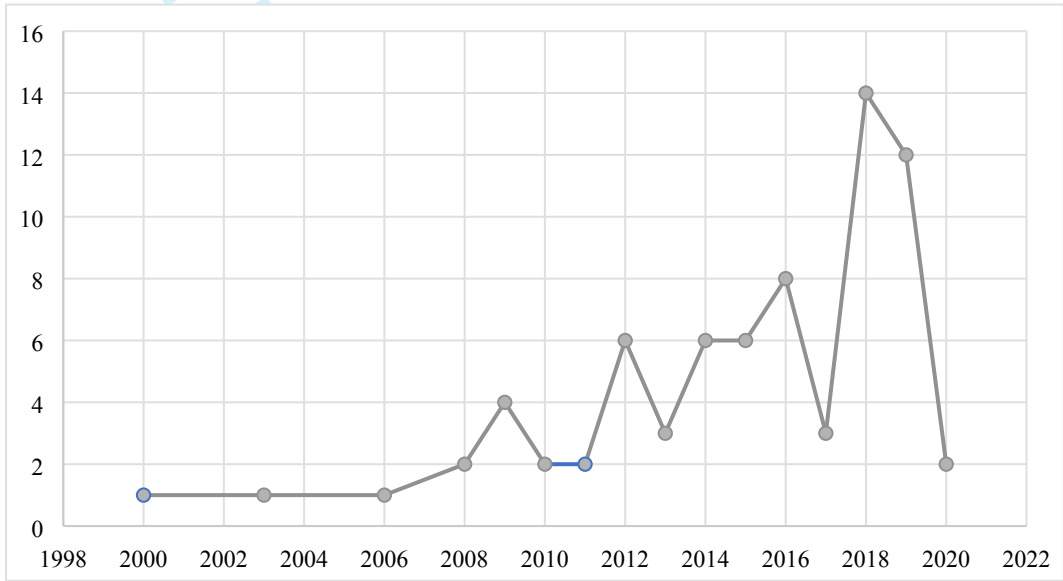


Figure 3 Distribution of articles based on the country of the lead author's affiliated institution

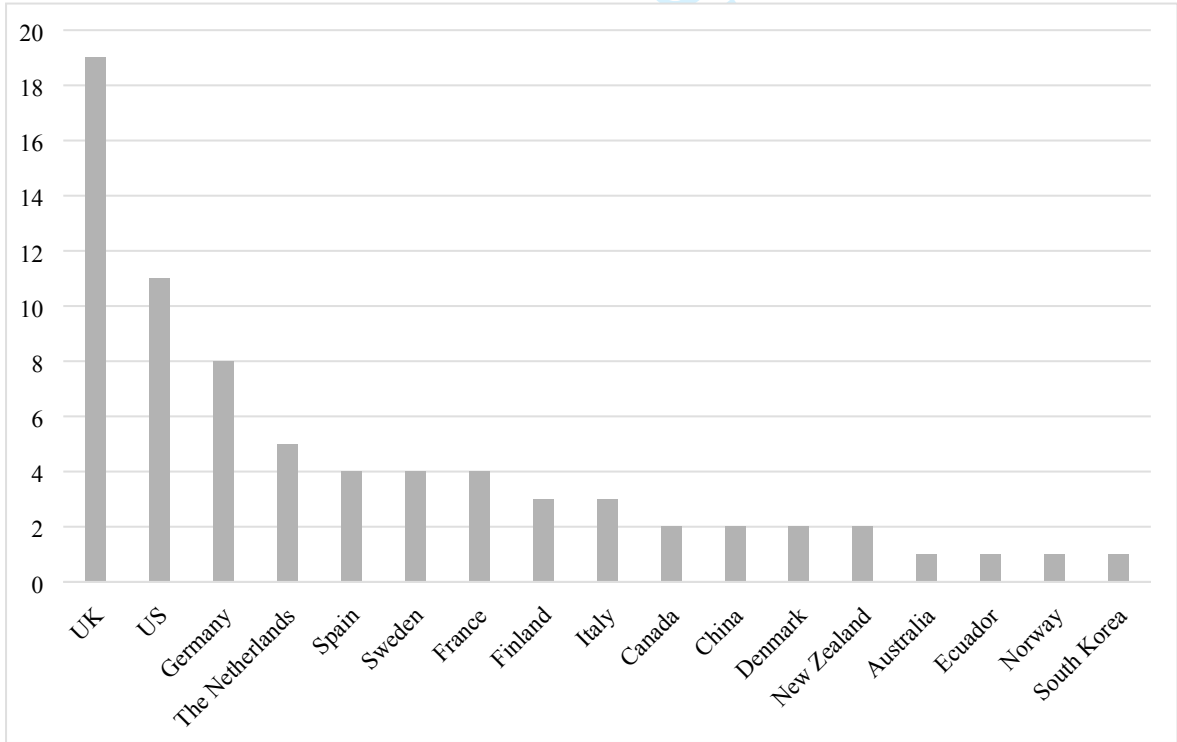


Figure 4 Distribution of articles based on journal



Figure 5 Distribution of articles based on the study type

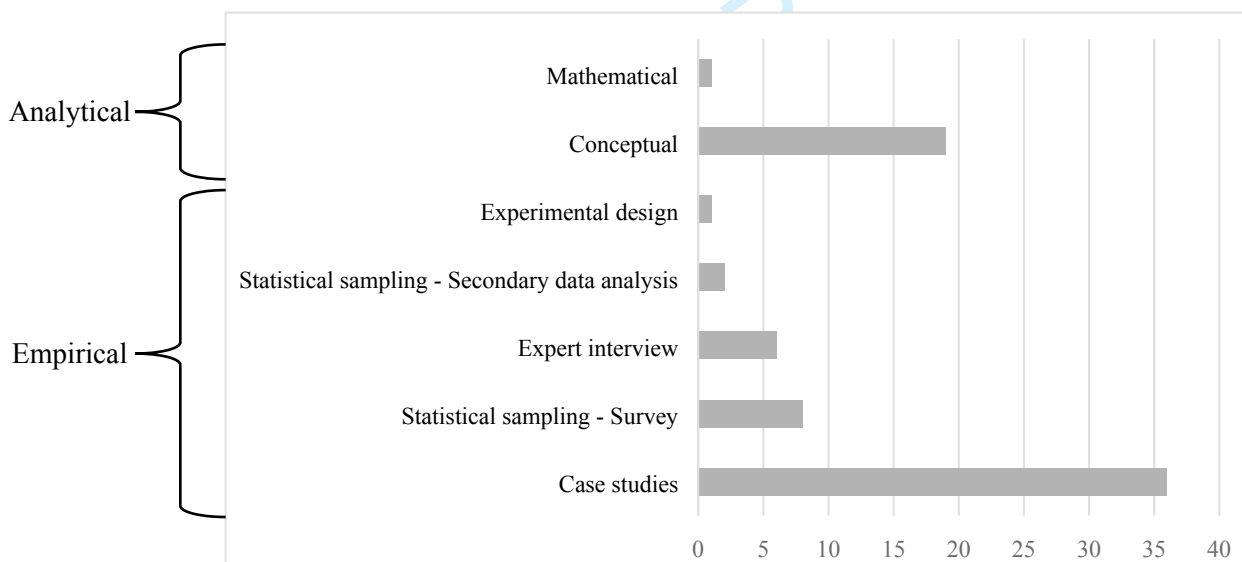


Figure 6 Distribution of articles based on industry

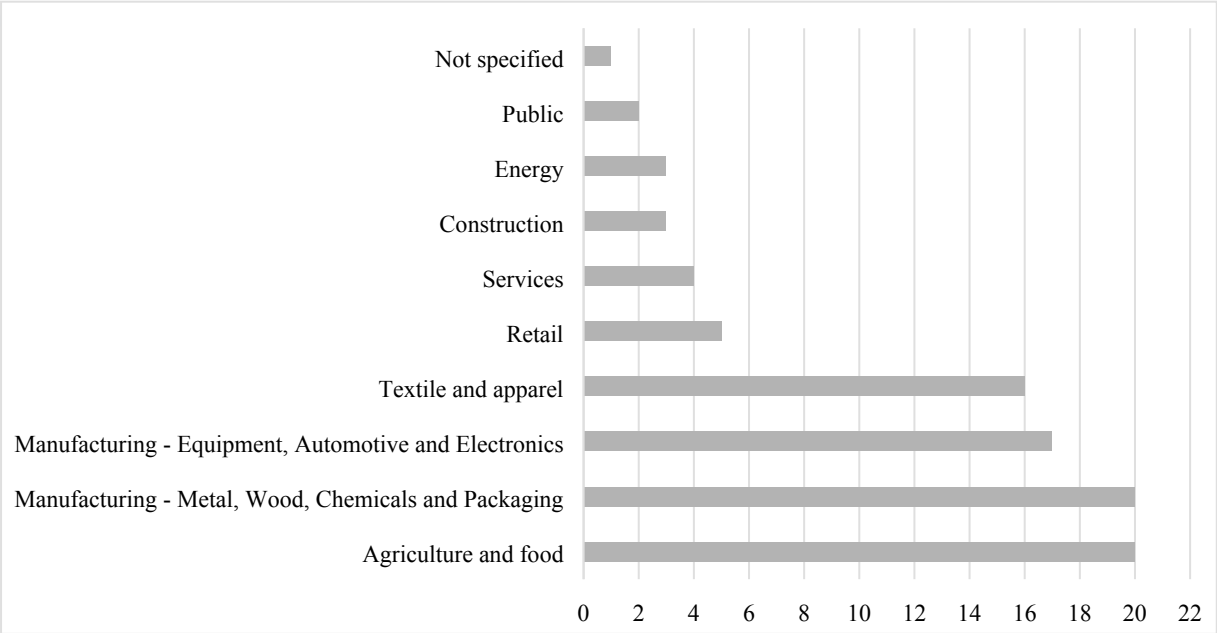
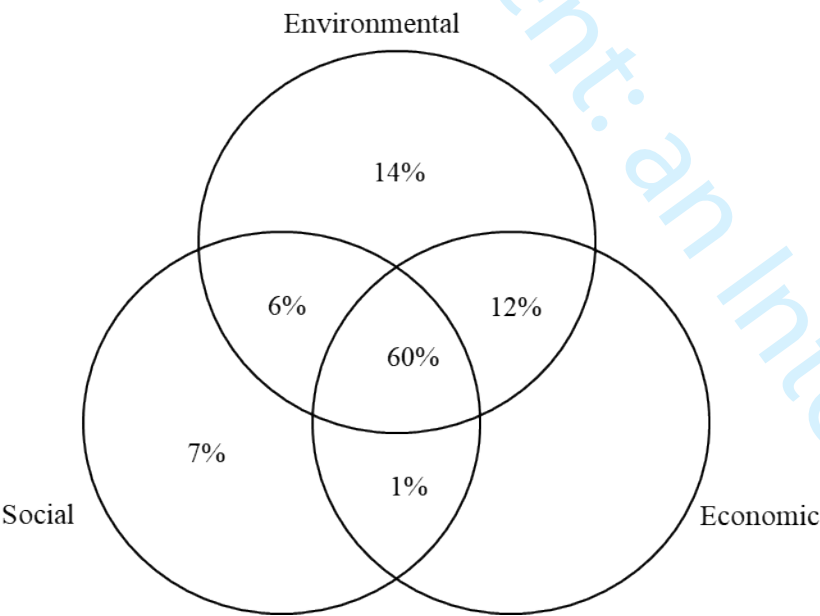


Figure 7 Distribution of articles based on the sustainability dimension





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The role of network structural properties in supply chain sustainability: a systematic literature review and agenda for future research

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