

Author Details

Dr Jilin Qiu^a, Professor Leila Alinaghian^b, and Professor Alexandra Brintrup^c

^aSchool of Financial Technology, Shanghai Lixin University of Accounting and Finance, Shanghai, China;, ^bCranfield School of Management, Cranfield University, Cranfield, UK;, ^cInstitute for Manufacturing, University of Cambridge, Cambridge, UK

The influence of neighbours' supply network structure on firm's environmental, social and governance controversies

Abstract

This study investigates how the structural characteristics of a firm's supply network and its neighbouring firms affect their Environmental, Social, and Governance (ESG) controversies. A secondary dataset comprising 18,943 firms and 103,632 contractual links from the global automotive industry was employed to test the hypotheses. Publicly available ESG controversies data for 268 firms were gathered from the Thomson Reuters Eikon database. The results indicated a negative relationship between the interconnectedness of neighbours' networks and their ESG controversies. The results further revealed a positive association between the centrality of a firm's neighbours and their ESG controversies. Furthermore, the study highlighted that a firm occupying a bridging position positively moderates the relationship between neighbours' interconnectedness and ESG controversies. Drawing on a real-world large-scale supply network, our study extends the emerging debate on the criticality of broader supply networks in firms' sustainability by investigating the role of neighbours' structural properties in firms' ESG controversies.

Keywords: ESG controversies; neighbours' supply network structure; social network analysis; interconnectedness; centrality; bridging

SDG Keywords: SDG 17: Partnerships for the goals

1. Introduction

Firms engaged in harmful practices, such as modern slavery or environmental scandals within their supply chains, risk causing incalculable damage to their reputation and market value (e.g. Altmann, 2015; Bouzzine and Lueg, 2020). For example, in the automotive industry, Volkswagen was reported to have installed defeat device software in its diesel engines to manipulate emission controls, leading to a significant drop in its share value (Ruddick, 2015). Similarly, firms such as Vauxhall and BMW have faced controversies where media reports accused their supply chains of being linked to child labourers, preventing them from attending school (Kelly and Bengtsen, 2016). Given the increasingly fragmented and internationally dispersed nature of supply chains, firms' reputations are increasingly shaped by the network of direct and indirect supply chain relationships in which they are embedded (e.g. Harjoto and Wang, 2020; Lau et al., 2020).

An increasing number of recent studies have underscored the significance of broader supply networks in driving sustainability (e.g. Alinaghian et al., 2021; Bellamy et al., 2020). Particularly, studies have highlighted the role of intricate, exclusive and often hidden connectivity patterns (i.e. network structures) in driving firms' sustainability performance (e.g. Bellamy et al., 2020; Saunders et al., 2019). For instance, Gualandris et al. (2021) demonstrated the role of supply chain density (i.e. the cohesiveness of distributed ties among supply chain members) and supply chain clustering (i.e. the extent to which suppliers form loosely coupled subgroups nested within the extended supply chain) in enabling or constraining supply chain transparency (i.e. the disclosure of Environmental, Social, and Governance (ESG) information). Bellamy et al. (2020) also demonstrated the contingency role of firms' supply network

interconnectedness, as well as their bridging role in environmental disclosure. These investigations have employed various proxies such as sustainability transparency and disclosure (Bellamy et al., 2020; Gualandris et al., 2021) or sustainability outcomes (Ozcan, 2011), to examine firms' sustainability performance. However, firms' ESG controversies (i.e. event or an ongoing situation in which a firm's operations and supply chain allegedly have a negative environmental, social and/or governance impact resulting in firms experiencing negative media coverage, Drempetic et al., 2020) may serve as stronger indicators of sustainability performance, capturing both the importance and significance of sustainability issues through market sensitivities (Tamayo-Torres et al., 2019). Studies suggest that market reactions to firms' controversies are more pronounced compared to good news (AIQ, 2021). Specifically, previous research suggests that there is a clear negative abnormal market return when firms are subject to bad news (AIQ, 2021). For instance, BP oil lost half of its share value (amounting to tens of billions of dollars) following the Deepwater Horizon oil spill. Firms may become involved in sustainability-related controversies for reasons beyond their control. While previous studies on firms' sustainability performance have primarily focused on firms' practices, they inadequately capture market reactions. Hence, this study aims to empirically examine how the structural properties of the supply network in which a firm is embedded can influence the firm's ESG controversies.

Furthermore, in investigating such associations, our study shifts the focus to the focal firm's surrounding neighbours (i.e. a firm's network of direct connections). The research question asks whether a firm's neighbours structure influences its ESG controversies. To address this question, two important properties of the neighbours' network are investigated, namely: 1) the interconnectedness of neighbours and 2) the

centrality of neighbours. The interconnectedness of neighbours refers to ‘the degree to which supply network partners of a focal firm are connected to each other, and thus share direct links amongst themselves’ (Bellamy et al., 2014, p. 360), whereas the centrality of neighbours refers to the extent to which a focal firm is connected to firms occupying central positions (Bonacich, 1987; Yan et al., 2015).

Our study first posits that the interconnectedness of neighbours can be a key enabler of focal firm’s ESG controversies. The increased interconnectedness in the supply network in which a firm is embedded can facilitate information flow and increase information sharing among neighbours, mitigating the likelihood of ESG controversies. Conversely, our study suggests that when a firm is connected to central neighbours, its ESG controversies can increase. Such an influential position provides the focal firm with more aggregated power than its neighbours (Yan et al., 2015), reducing the control and monitoring exerted by neighbouring firms in the reduction of ESG controversies. In addition, focal firms occupying such positions are considered to cause information asymmetry, dominating and controlling the flow of information to serve their own interests (Kim, 2019).

Our study also examines the moderating role of the neighbours’ structural properties in ESG controversies. Specifically, it considers the moderating role of bridging, that is, the extent to which a firm occupies a position between high-degree nodes (Baruah and Bora, 2018). A firm acting as a bridge can foster information flow by introducing diverse information and acting as a monitor relative to two disconnected actors embedded in a highly dense network (Gao et al., 2015).

To test these hypotheses, the study used a sample of 268 publicly listed firms. This sample included all firms from a secondary supply network dataset from the

automotive industry with disclosed their ESG controversies data. The secondary supply network dataset, comprising 18,943 firms and 103,632 contractual links between them, was used to calculate the network metrics for the 268 firms. The open-source software Gephi was used to visualise and calculate network structural metrics at the firm level. Gephi is particularly suitable for visualising the network shape of large datasets (i.e. 18,943 firms in this study) and offers various calculation buttons for calculating relevant network metrics. ESG controversies data for the 268 firms in the study we retrieved from Thomson Reuters Eikon.

Our study contributes to the literature on sustainable supply chain management (e.g. Sarkis and Zhu, 2018; Taylor and Vachon 2018), specifically concerning the role of supply network structural properties in three ways. First, the study extends emerging discussions on the criticality of broader supply networks for firms' sustainability by investigating the structural properties of firms' neighbours. Specifically, our study found empirical support that two structural properties of neighbours (neighbours' interconnectedness and neighbours' centrality) are associated with firms' ESG controversies in supply networks. Second, our study incorporates the firm's bridging, an additional contingency factor unconsidered in prior literature. While previous literature has highlighted the important role of the firm's bridging position in firms' sustainability, it has not explored the interplay between a firm's bridging position and properties of its neighbours' network structure in shaping ESG controversies. Additionally, by examining ESG controversies that capture both a focal firm's sustainability practices and external reactions, our study contributes to the growing body of supply chain management literature focused on the implications of network

structure for firms' sustainability and sheds light on the role of market sensitives with regards to sustainability issues.

From a managerial perspective, our findings suggest that as firms engage in the diffusion and monitoring of sustainability targets or in collaborative activities to develop sustainability capabilities across their supply networks, it is imperative to acknowledge the structural characteristics of supply networks. In line with our findings, to avoid ESG controversies, managers should promote greater interactions within their supply network to help facilitate effective sustainability-related information and knowledge flow and establish sustainability values and norms throughout the network. Additionally, managers should be cautious about forming more linkages with influential neighbours to reduce the risk of ESG controversies. In such cases, managers could go even further by collaborating with bridging firms (e.g. third-party firms) to establish certified standards for monitoring and controlling the supply chains.

2. Theoretical background and hypothesis development

2.1 ESG controversies

In the context of supply chains, the notion of 'controversies' represents the conflicts that firms face with various stakeholders throughout the supply chain due to practices and behaviours that damage ESG dimensions (e.g. suppliers' labour exploitation, poor working conditions, pollution, destruction of natural habitats) (Tamayo-Torres et al., 2019). ESG controversies have been used as a variable measuring how harmful practices are evaluated by the market and demonstrating the impacts of published negative events on firms. They indicate integrity regarding ESG issues arising from negative media coverage, such as involvement in supply network scandals (Drempetic

et al., 2020). In other words, ESG controversies are ‘allegations put forward by stakeholders and shared via local or international media, singling out individual firms or whole sectors regarding their potential negative impact on environmental and social factors’ (ESMA, 2023). Negative ESG news is significantly more compelling than positive ESG information, as it typically evokes strong market reactions (Xue et al., 2023). For example, Xue et al. (2023) identified that while there was a positive market reaction to Dasani Water’s advertising of its bottles as ‘Plant Bottles’, a negative reaction (i.e. widespread opposition) occurred in response to its advertising being viewed as exaggerated. ESG controversies can therefore lead to the loss of consumer trust, brand devaluation, and increased regulatory scrutiny (Wu et al., 2023). Events, both structural (e.g. organisation of supply chains) and random in nature can trigger ESG-related controversies. Thus, firms need to (re)organise their business processes or supply chains to align with sustainability considerations, thereby ensuring that ESG aspects are comprehensively implemented (Kotzian, 2023).

While previous researchers have primarily investigated the association between ESG controversies and firms value (Aouadi and Marsat, 2018) or performance (Tamayo-Torres et al., 2019), very few have taken a network perspective to uncover the role of supply network structure in ESG controversies. Recently, researchers have begun to highlight the importance of examining the relationship between the supply network structural properties and ESG controversies (e.g. mining resistance struggles; Aydin et al., 2017), stating that the focal firm is accountable for, and affected by, the actions of its network members. If network members engage in inappropriate actions (e.g. disclosing inaccurate information or failing to comply with the sustainability requirements), ESG controversies will arise (Tamayo-Torres et al., 2019).

2.2 Supply network structure

While traditionally buyer-supplier relationships have been viewed as the basic unit of analysis in supply chain management literature, recent studies have adopted a network approach to consider different interactions occurring among firms in the supply network (e.g. Jraisat et al., 2021) and the emerging connectivity patterns (i.e. network structure) (e.g. Borgatti and Li, 2009; Kim et al., 2011). Adopting a social network analysis (SNA) perspective, a network is comprised of nodes representing the network members and the linkages or ties that connect nodes (Borgatti and Li, 2009). In various bodies of literature, scholars have established that the structural properties of interfirm networks in which firms are embedded are important determinants of their behaviour and performance (Rowley, 1997). Similarly, supply chain management scholars suggested that the relative position of supply chain members within the overall patterns of network connectivity influences their behaviour and performance (e.g. Bellamy et al., 2014; Ting and Tsang, 2014). Extant studies demonstrated the importance of supply network structural characteristics in determining the way in which diverse knowledge, resources and information flow across firm boundaries, driving network learning and elevating the firm's structural capital or network status (Granovetter, 1973). Table 1 provides a summary of studies that have investigated network structural properties in a supply chain context.

Table 1 Relevant studies in investigating supply network structure

Author, year	Methodology	Findings
Alinaghian et al., 2021	Systematic literature review	<ul style="list-style-type: none"> Identified three node-level (degree centrality, closeness centrality and betweenness centrality) and three network-level (network density, network sub-groups and network diversity) structural properties that play a role in supply chain sustainability.
Bellamy et al., 2014	Empirical	<ul style="list-style-type: none"> Supply network accessibility has a significant association with a firm's innovation output. The interconnected supply networks strengthen the association between supply network accessibility and innovation output. The influence of the two structural characteristics on innovation output can be enhanced by a firm's absorptive capacity and level of supply network partner innovativeness.
Bellamy et al., 2020	Empirical	<ul style="list-style-type: none"> Administrative environmental innovations (AEI) implementation is positively associated with the extent of environmental disclosure. A focal firm's supply network flow accessibility, control, and the interconnectedness of a firm's suppliers moderates the AEI implementation–environmental disclosure relationship.
Borgatti and Li, 2009	Conceptual	<ul style="list-style-type: none"> Conceptualised of a series of network metrics (e.g. structural holes and betweenness centrality) in a supply chain context.
Gao et al., 2015	Empirical	<ul style="list-style-type: none"> Novel information sharing partially mediates the effect of technological diversity in supplier network on buyer firms' new product creativity. The positive effect of technological diversity is enhanced by buyer–supplier relational strength but inhibited by supplier network density.
Gualandris et al., 2021	Empirical	<ul style="list-style-type: none"> Supply chain density positively associates with supply chain transparency, whereas supply chain clustering holds a negative association. Supply chain geographical heterogeneity positively associates with supply chain transparency.

Kim et al., 2011	Empirical	<ul style="list-style-type: none"> • Conceptualised and applied of a series of node-level and network-level metrics in a supply chain context.
Kim, 2019	Empirical	<ul style="list-style-type: none"> • A firm is included among the main component in a whole network, and the more centralised it is in terms of connectivity and distance, the more advantageous it is for firm innovation.
Ledwoch et al., 2018	Modelling	<ul style="list-style-type: none"> • The network topology has a moderating effect on the effectiveness of risk management strategies. • Scale-free supply networks generate lower costs, have higher fill rates, and need less inventory to recover when exposed to random disruptions than random networks.
Saunders et al., 2019	Conceptual	<ul style="list-style-type: none"> • Conceptualised the influence of a firm's structural embeddedness particularly the role of network brokers on developing, diffusing and adopting sustainability initiatives.
Villena and Gioia, 2020	Empirical	<ul style="list-style-type: none"> • Unpacked the role of multinationals in developing sustainable supply networks by emphasising social and environmental responsibility, along with economic considerations, at every level of the network.
Yan et al., 2015	Conceptual	<ul style="list-style-type: none"> • Introduced the notion of nexus suppliers (i.e. a supplier that can come from an tier in a supply network and is critical due to its network position and the resultant portfolio of interorganisational ties) and identified three nexus supplier types (operational, monopolistic and informational).

2.3 Supply network structure and ESG controversies

Previous studies have demonstrated how various supply network structural properties impact innovation (e.g. Bellamy et al., 2014) or the effectiveness of risk management and resilience of embedded firms (e.g. Kim et al., 2015; Ledwoch et al., 2018). Several recent studies have come to highlight the direct and moderating effects of supply network structural properties in firms' sustainability performance (e.g. Alinaghian et al., 2021; Bellamy et al., 2020). In addition to physical flows of materials or contractual relationships connecting firms in supply networks, these studies emphasised the existence of a new form of tie forming among actors to communicate, monitor, and/or collaborate with other firms to address supply chain sustainability (i.e. sustainability tie) (Alinaghian et al. 2021). For instance, even though a focal firm may not set up a direct supply contract with a second-tier supplier, it might still directly monitor or collaborate with one to tackle sustainability issues. A firm's sustainability performance can therefore be derived from the structural linkages among the firms in its supply network, as supply networks can serve as critical conduits for the flow of knowledge and information.

Our study examines two network structural properties focusing on the focal firm's surrounding neighbours as important determinants of its ESG controversies: (1) the level of interconnectedness in the neighbours' network and (2) the centrality of the firm's neighbours. Additionally, the relationship between a firm's supply network structure and its ESG controversies may depend on its ability to manage supply chain relationships. Thus, we further propose that a favourable structural position, namely bridging, could impact this relationship through the following mechanisms: (a) by facilitating the flow of information in the firm's supply network, (b) by controlling the

network status through information flow and power, and (c) by monitoring the firm's actions through shared information flow and power. The hypothesised research model is presented in Figure 1.

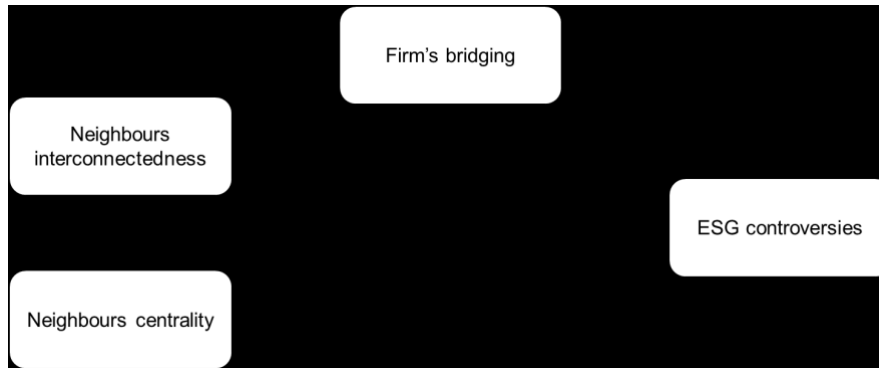


Figure 1 Hypothesised research model

2.3.1 Neighbours' interconnectedness and the focal firm's ESG controversies

Neighbours' interconnectedness refers to 'the degree to which supply network partners of a focal firm are connected to each other, and thus share direct links amongst themselves' (Bellamy et al., 2014, p. 360). Also referred to as network density, neighbours' interconnectedness represents the level of the presence or absence of network ties between neighbours. It is operationalised as the ratio of the number of ties between a firm's neighbours to the total possible number of ties among neighbours (Borgatti and Halgin, 2011). Figure 2 illustrates the different levels of neighbours' interconnectedness that a firm could have in its supply network. For instance, the red node embedded in the middle (on the left figure) has fewer direct ties with the other red node (on the right figure). In contrast, the figure also shows that the red node's neighbours (i.e. the orange nodes) are not well interconnected, resulting in a low level of neighbours' interconnectedness.

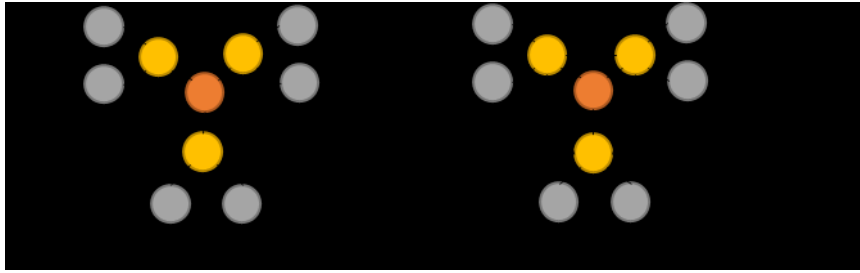


Figure 2 Illustration of levels of neighbours' interconnectedness

It is suggested that a higher level of neighbours' interconnectedness in a supply chain is negatively associated with a firm's ESG controversies for several reasons. First, previous literature has highlighted the importance of the interconnectedness of neighbours in a network in facilitating information flows within the supply network. For instance, empirical evidence from Fleming et al. (2007) corroborates that as a firm's network (i.e. neighbours) becomes more interconnected, information flows, trust and knowledge spillovers are facilitated within the network. Specifically, more densely connected networks provide multiple paths (i.e. connectivity) to the same information source in the network, creating network learning opportunities. While dense networks may result in redundant information exchange, this redundancy allows firms to validate the reliability of information and access robust sustainability-related information (Kim and Zhu, 2018). For example, studies have shown that dense networks help firms better understand specific know-how and more precise information to detect and control potential sustainability misconduct within the network (Song et al., 2019). Furthermore, a more densely connected network provides a common platform for firms to leverage existing information for problem-solving and innovation (Gao et al., 2015). Thus, firms embedded in dense networks tend to develop problem-solving arrangements to more rapidly reduce controversies (Rindfleisch and Moorman, 2001).

Second, dense networks facilitate better monitoring due to increased information sharing among its members. A greater number of shared linkages within a focal firm's supply network imposes strong constraints on the focal organisation's actions (e.g. the diffusion of norms and standards). Although drawbacks of excessive level of neighbouring firms' interconnectedness such as high coordination costs have been highlighted by prior literature (Gualandris et al., 2015; Kim and Davis, 2016), the network interconnectedness enables firms to monitor the focal organisation's actions more effectively, as they can collectively oversee the focal firm and coordinate pressure to meet expectations. In such situations, neighbouring firms are more likely to form closer collaborative engagements (Arora and Brintrup, 2021), effectively promoting members to collect, extract, retrieve and transform the private information of others and increasing operational visibility (Song et al., 2019). In return, firms embedded in dense networks tend to align their values and goals, which can be highly beneficial for applying network sanctioning (Rowley et al., 2000). For instance, when a focal firm shares a commitment to sustainability with its interconnected neighbouring firms, these firms are more likely to hold each other accountable and support one another in meeting the focal firm's sustainability targets and its compliance with ethical guidelines (Kim and Zhu, 2018). This shared commitment minimises the potential for controversies arising from misleading or fraudulent sustainability claims. For example, companies banding together to create associations coordinating their efforts to address the problems highlighted by the incident, transforming a purely transactional relationship into a more collaborative one. Therefore, we hypothesise:

H1. Neighbours' interconnectedness is negatively related to firms' ESG controversies.

2.3.2 Neighbours' centrality and the focal firm's ESG controversies

Firm may not only be affected by the connectivity of neighbours (i.e. neighbours' interconnectedness) but also be associated with the centrality of their neighbours. We use the 'neighbours' centrality' to reflect the relative importance of the firms surrounding a focal firm (Bonacich, 1987). The literature has investigated this phenomenon through the notion of eigenvector centrality (i.e. the centrality of a node as a function of the centralities of its neighbours). This form of centrality enables a more indirect form of influence (Borgatti, 2005). Conceptually, this measure assesses a firm's link to other highly central upstream or downstream actors within the supply network. A firm with many central neighbours is more likely to have a higher level of influence over other supply network members (Kim and Zhu, 2018) and accumulate valuable information within the network (Bloch and Jackson, 2016). Accordingly, the term 'neighbours' centrality' indicates a firm's prominence (i.e. influence) or power, thereby implicating a firm's position of status (i.e. a hierarchical position in a network structure). Specifically, the evaluation of a firm's prominence (i.e. influence) or power can instead be expressed as 'knowing more people in power than only having power yourself' within the network (Leonardo and Marina, 2022). Moreover, prior literature has stated that even though a stronger network position would endow a firm with higher status, such elevated status also creates expectations about the firm's behaviour and actions (Gulati, 1998). A firm's status resulting from the network position may therefore carry implications concerning how neighbouring firms control and monitor the focal firm. Specifically, in practice, a firm with a high level of neighbours' centrality could indicate nodes that, instead of accessing a large base of customers, access other nodes that themselves have access to such a large base (i.e. a small firm working for

several large firms). Figure 3 displays the different levels of neighbours' centrality to further identify these different nodes in the supply network. For example, the red node is the highest level, while the blue node ranks second, the black node ranks third, and the yellow node is the least. Furthermore, Figure 3 also shows that the red node directly connects with the orange node, the black node, and the blue node. These nodes are considered powerful because they connect directly to more grey nodes. In terms of these connections, the red node is the most influential node in its network.



Figure 3 Illustration of the neighbours' centrality

We posit that neighbours' centrality in supply networks positively influences the focal firm's ESG controversies for the following reasons. First, focal firms with high neighbour centrality, occupying a greater network status, will be less monitored by their surrounding neighbours within the supply networks (Carnovale et al., 2017). For instance, when the focal firm occupies a high level of network status, it is connected to powerful neighbours within its supply network. By obtaining such status and knowing the numbers of powerful neighbours, the neighbouring firms (e.g. suppliers) may find it difficult to monitor the high-status focal firms (e.g. original equipment manufacturers (OEMs)) in minimising potential controversies due to significant power imbalances (Yan et al., 2015). Such powerful firms may also cause ripple effects in the supply network. This aligns with the claim that if the high-status firms do not use, or misuse,

power, failing to promote sustainable practices, other network members may also remain passive in addressing ESG controversies (Laari et al., 2022). Additionally, neighbouring firms might spend less time or resources validating the product quality (Podolny, 1993) if it is produced by a high-status focal firm, leading to potential negative sustainability impacts.

Second, a firm with a higher level of centrality amongst its neighbours experiences control over information flow (Kim, 2019). While high neighbour centrality can provide a firm with more information flows, it may also lead the firm to dominate and control the information flow for its own benefits. This can limit the diffusion of unbiased sustainability information, and neighbouring firms, such as lower-tier suppliers, may lack the necessary sustainability resources and skills to help the focal firm minimise controversies. For example, high neighbour centrality can impact the likelihood of neighbours recognising and assimilating new information due to inequitable information access, ultimately hindering the firm's capability to develop sustainable innovations and reduce controversies. Therefore, we posit that high neighbour centrality is not always beneficial for firms in terms of developing sustainable practices and avoiding sustainability controversies.

H2. Neighbours' centrality is positively related to firms' ESG controversies.

2.3.3 Moderating role of firm's bridging

The concept of a firm's bridging (shown in Figure 4) has been introduced by Granovetter (1973) (linked to the concept of weak ties) and later Burt (2004) (linked to the concept of structural holes). Previous literature identifies a firm's bridging position as also being an intermediary, broker, or gatekeeper. Such a position often allows firms to have more control over information flows within their supply network (Baum et al.,

2010). This position provides multiple benefits, such as facilitating more information flow and creating opportunities from multiple, and more often isolated, sections of a network (McEvily and Zaheer, 1999). For instance, in Figure 4, the red node serves as a bridge to neighbouring yellow nodes, gaining substantial control over information flows within the network. Additionally, the yellow nodes play a crucial gatekeeping role, bridging their customers (e.g. grey nodes) to a wide subnetwork of neighbouring firms. Therefore, structural positions on shorter paths linking one neighbour to another in the network provide firms with greater control over information flow. Accordingly, this paper concentrates on how the bridging position interacts with other network structural properties (i.e. neighbours' interconnectedness and neighbours' centrality) to impact the focal firm's ESG controversies.

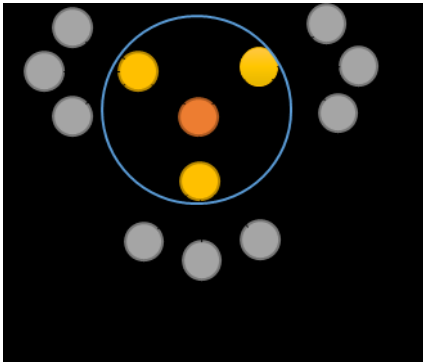


Figure 4 Illustration of a firm's bridging position

A focal firm's bridging could impact the relationship between neighbours' interconnectedness and firm's ESG controversies for the following reasons. First, a high level of firm bridging strengthens the benefits of facilitating information flow resulting from neighbours' interconnectedness. In other words, a bridging position represents a unique state where, due to the unrelatedness of two groups in their supply networks, the firm gains access to heterogeneous and non-overlapping information (Burt, 2004). As the bridging firm becomes an important source for accessing heterogeneous

sustainability-related information (Carnovale et al., 2017), these information benefits can enhance the flow of information exchanged between other firms and strengthen the impacts of neighbours' interconnectedness on the firm's ESG controversies (Gao et al., 2015). Bridging firms are arguably well-positioned to access non-redundant environmental information across a broad range of their upstream networks (Burt, 1992). Additionally, firms with greater network control can better extract pertinent environmental information and knowledge about sustainability from diverse sources.

Furthermore, a firm in a bridging position plays a monitoring role regarding ESG controversies. Specifically, the unique position of connecting firms to multiple, disconnected groups (Carnovale et al., 2017) helps firms adhere to sustainability standards when connected to different network groups. This position can demonstrate the origin of components and regulatory compliance in all markets where products are made and sold, ensuring that environmental and ethical considerations are followed. Such monitoring may enforce firms to share private information more often when the bridging firm is involved in their networks. Additionally, the bridging position of a firm may act as a third-party monitor to assess and evaluate the potential controversies in the supply network, which can help the monitoring firms jointly solve ESG controversies more accurately. Moreover, if firms in a highly dense network share aligned values and goals, the bridging firm could facilitate the propagation of new information and norms between firms (Shi et al., 2022). Therefore, we hypothesise:

H3. A focal firm's bridging positively moderates the relationship between its neighbours' interconnectedness and ESG controversies.

We further posit that a focal firm's bridging position strengthens the influence of neighbours' centrality on its ESG controversies for the following reasons. First, the the

focal firm occupies a unique position in the network, embodying both bridging and centrality attributes, thereby amplifying its power over its neighbours within the supply network. Existing literature indicates that disconnected and heterogeneous neighbours often lack trust, and a bridging firm may exacerbate the power imbalance among the neighbours in dealing with sustainability issues (Carnovale et al., 2017; Nyaga et al., 2013). Moreover, firms occupying such bridging positions can manipulate information, either by preventing or biasing communications across the network.

Second, the focal firm's bridging increases the scope and diversity of information, while the centrality of its neighbours indicates that the firm has aggregated information within its network. By leveraging these two positions, focal firms control more critical and comprehensive information compared to their neighbours. However, they may selectively share information that aligns with their interests or agendas, withholding or downplaying information that could highlight ESG controversies. The negative consequences of this increased information asymmetry for lower-tier firms are likely to be more problematic (Carnovale et al., 2016), namely potentially hindering a focal firm's to build consensus with its neighbouring firms to develop innovative solutions and reduce ESG controversies (Jensen, 2011; Koka and Prescott, 2008; Yang et al., 2010). Hence, we hypothesise:

H4. A focal firm's bridging positively moderates the relationship between its neighbours' centrality and ESG controversies.

3. Methodology

3.1 Research setting and data collection

This study utilised several secondary data sources to create the network database,

including the MarkLines Automotive Information platform, Thomson Reuters Eikon, the Bloomberg database, and the online SDG Index. The automotive industry's progressive disverticalisation has resulted in a fragmented network of partners that firms rely on to supply products and services. Meanwhile, the industry itself is under increasing pressure to minimise negative impacts on the environment and society (Mathiyazhagan et al., 2023; Szász et al., 2021). Therefore, this industry setting provides an appropriate research environment to investigate the role of supply network connectivity patterns in firms' ESG controversies.

In 2014, compared to industry peers, the automotive industry introduced the first asset-backed green bond to address emissions and fuel efficiency. Sustainalytics reviewed this bond program and found it effective in encouraging automotive firms to support carbon transition through green bond investments (Advisory, 2021). Consequently, supply network data was retrieved from the MarkLines database in 2014, using customer and supplier data to determine connections between firms. Each firm was then assigned a unique code, enabling the identification of interconnections between upstream suppliers and downstream customers in the Excel and network software package, resulting in a supply network consisting of 18,943 firms and 103,632 links.

Data on ESG controversies were obtained from the Thomson Reuters Eikon database. The Thomson Reuters ESG Controversies score was adopted to capture the firm's ESG controversies across several indicators based on publicly reported data. From the entire network of 18,943 firms, a sample of 304 firms with ESG controversies data was first identified. The ESG controversies data were retrieved in the year of 2017, applying a 3-year time lag for the dependent variable to account for the fact that a firm's

current year's sustainability-related data often reflects resources and initiatives from previous years. Additionally, the United Nation's 17 Sustainable Development Goals officially came into force on the 1st of January 2016 (United Nations, 2016), making abundant sustainability data only accessible and disclosed from 2017.

Data for control variables were retrieved from the Bloomberg SPLC Function database. By observing the most recent snapshot of money flows between firms regarding the buyer (i.e. revenue) and supplier (i.e. cost), the SPLC database was used to map firms with their suppliers and buyers (Kim and Davis, 2016). Following the network data, control variables were collected from the year 2014 for the sample size of 304 firms identified during the data collection stage. After data availability checks, a final sample of 268 firms was used in the main model. Descriptions of these variables are presented in Table 2.

Table 2 Description of variables

Construct	Variable	Variable Type	Year	Measure	Data source
ESG controversies	Negative ESG Controversies score	Dependent	2017	Negative ESG Controversies score (i.e. a company's exposure to environmental, social and governance controversies and negative events reflected in global media)	Thomson Reuters Eikon
Firm size	Natural log of market capitalisation	Control	2014	Firm size=ln(Market capitalisation)	Thomson Reuters Eikon
Firm age	Number of years from the dates of firm's founding	Control	N/A	Age	Thomson Reuters Eikon
Firm debt ratio	Firm debt ratio	Control	2014	The ratio of total debt and total equity	Thomson Reuters Eikon
Supplier concentration	Supplier concentration	Control	2014	The percentage of a focal company's cost of goods sold that is spent on its five main suppliers	Bloomberg
Firm power over direct suppliers	Firm power over direct suppliers	Control	2014	inventory turnover (cost of goods sold divided by the average inventory)	Thomson Reuters Eikon
Country	SDG score	Control	2014	A country's total progress towards achieving all 17 sustainable development goals (SDGs)	SDG Index
Neighbours' interconnectedness	Local clustering coefficient	Independent	2014	Local clustering coefficient (i)=(2n _i)/(K _i (K _i -1))	MarkLines
Neighbours' centrality	Eigenvector centrality	Independent	2014		MarkLines
Focal firm's bridging	Bridging coefficient	Independent	2014	$\beta = \frac{\frac{1}{d(v)}}{\sum_{i \in N(v)} \frac{1}{d(i)}}$	MarkLines

3.2 Dependent variable

The Thomson Reuters ESG controversies scores are used as an indicator of the firm's ESG controversies (Rajesh, 2020). The ESG controversies scores (e.g. a firm's exposure to environmental, social and governance controversies, as well as negative events reflected in the global media) are considered to have a material impact on firms (Refinitiv, 2022). Detailed descriptions of the scores are presented in Table 3. The calculation formula of the ESG controversies score is based on various ESG controversy categories, and shows the extent to which a firm is involved in a scandal is penalised in the media (Refinitiv, 2022). The scores go beyond the widely applied ratings that merely focus on the firm's reporting and disclosure of sustainability (e.g. Bloomberg ESG data, Bellamy et al., 2020; Gualandris et al., 2021) by providing a transparent and objective measure of the firm's ESG controversies. The ESG controversies' performance score data represent a relative score compared to the other firms in the sample. The controversies measure calculation method, according to the database, is shown below:

$$ESG\ controversies\ score = \frac{no.\ of\ companies\ with\ a\ worse\ value + \frac{no.\ of\ companies\ with\ the\ same\ value\ included\ in\ the\ current\ one}{2}}{no.\ of\ companies\ with\ a\ value} \quad (1)$$

Based on the score calculation, firms with no controversies would attain a score of 100. The higher the scores, the better performance it registered in ESG controversies, thereby displaying lower controversies. For instance, a high score (100) indicates that a firm is performing well compared to the other firms within the sample. A low score of 0.6, for example, indicates that a firm is performing poorly (Refinitiv, 2022). Thus,

given this definition and to simplify our statistical analysis, this study used the negative ESG controversies score to represent ESG controversies in this study.

Table 3 Thomson Reuters ESG controversies definition (Source: Refinitiv, 2022)

Category	Label	Description
Community	Anti-Competition Controversy	No. of controversies reported in the media in relation to anti-competitive behaviour (e.g. antitrust and monopoly), price-fixing or kickbacks.
	Business Ethics Controversies	No. of controversies reported in the media in relation to business ethics in general, political contributions or bribery and corruption.
	Intellectual Property Controversies	No. of controversies reported in the media in relation to patents and intellectual property infringements.
	Critical Countries Controversies	No. of controversies reported in the media in relation to activities in critical, undemocratic countries that do not respect fundamental human rights' principles.
	Public Health Controversies	No. of controversies reported in the media in relation to public health or industrial accidents harming the health and safety of third parties (non-employees and non-customers).
Human Rights	Tax Fraud Controversies	No. of controversies reported in the media in relation to tax fraud, parallel imports or money laundering.
	Child Labour Controversies	No. of controversies reported in the media in relation to use of child labour issues.
	Human Rights Controversies	No. of controversies reported in the media in relation to human rights issues.
Management	Management Compensation Controversies Count	No. of controversies reported in the media in relation to high executive or board compensation.
Product Responsibility	Consumer Controversies	No. of controversies reported in the media in relation to consumer complaints or dissatisfaction directly in relation to the company's products or services.
	Customer Health & Safety Controversies	No. of controversies reported in the media in relation to customer health & safety
	Privacy Controversies	No. of controversies reported in the media in relation to employee or customer privacy and integrity.
	Product Access Controversies	No. of controversies reported in the media in relation to product access.
	Responsible Marketing Controversies	No. of controversies reported in the media in relation to the company's marketing practices such as over-marketing of unhealthy food to vulnerable consumers.
	Responsible R&D Controversies	No. of controversies reported in the media in relation to responsible R&D.
	Resource Use	No. of controversies related to the environmental impact of the company's operations on natural resources or local communities.

Shareholders	Accounting Controversies Count	No. of controversies reported in the media in relation to aggressive or non-transparent accounting issues.
	Insider Dealings Controversies Count	No. of controversies reported in the media in relation to insider dealings and other share price manipulations.
	Shareholder Rights Controversies Count	No. of controversies linked to shareholder rights infringements reported in the media.
Workforce	Diversity and Opportunity Controversies	No. of controversies reported in the media in relation to workforce diversity and opportunity (e.g. wages, promotion, discrimination, and harassment).
	Employee Health & Safety Controversies	No. of controversies reported in the media in relation to workforce health and safety.
	Wages or Working Condition Controversies Count	No. of controversies reported in the media in relation to the company's relations with employees or relating to wages or wage disputes.
	Management Departures	Has an important executive management team member or a key team member announced a voluntary departure (other than for retirement) or been ousted?

3.2.1 Independent variables

Neighbours' interconnectedness. The degree to which a firm's neighbours are connected to each other is captured by the local clustering coefficient (i.e. node-level clustering coefficient). This measure is used to reflect the extent to which a focal firm's neighbours form a cluster (i.e. network) within the supply network (e.g. Bellamy et al., 2014; Potter and Wilhelm, 2020). Furthermore, it reflects the degree to which the supply network neighbours of a firm are connected to each other (Borgatti and Halgin, 2011). Adopting the calculation method from Wasserman and Faust (1994), the formula of the local clustering coefficient for a focal firm i is presented below:

$$\text{Local clustering coefficient } (i) = \frac{2n_i}{K_i(K_i - 1)} \quad (2)$$

where n_i denotes the number of vertices connecting the K_i neighbours of the focal firm i . Consistent with Basole (2016) and Potter and Wilhelm (2020), Gephi 9.2 network software was used to calculate the measure of the clustering coefficient.

Neighbours' centrality. The measurement of eigenvector centrality is adopted to reflect the neighbours' centrality. Previous studies highlighted that the measurement of eigenvector centrality is proportional to the sum of the centralities of a firm's partners (i.e. neighbours) (e.g. Kim and Zhu, 2018). Thus, consistent with Kim and Zhu's (2018) approach, we adopted Bonacich's (2007) eigenvector centrality formula and calculated the eigenvector centrality for the focal firm i as:

$$x_i = \frac{1}{\lambda} \sum_{j=1}^n a_{ij} x_j, i = 1, \dots, n \quad (3)$$

where x_i represents the eigenvector centrality of firm i , λ denotes the largest eigenvalue of an adjacency matrix, n is the number of vertices, $a_{ij} = 1$ if vertices i and j are connected by an edge, $a_{ij} = 0$ otherwise, and x_j is eigenvector centrality of partner firm j .

3.2.2 Moderating variables

The firm's bridging. We adopt the firm's bridging coefficient to determine how well the node is located between highly connected nodes. The bridging coefficient determines the extent to which a node is located between high degree nodes and assesses the local bridging characteristics in the neighbourhood (Hwang et al., 2006). In addition, it could reflect the flow input caused by the connection degree of focal firm's neighbours. Adapting the approach used by Hwang et al. (2006), a firm bridging coefficient is defined as:

$$\beta = \frac{\frac{1}{d(v)}}{\sum_{i \in N(v)} \frac{1}{d(i)}} \quad (4)$$

where $d(v)$ is the degree of a node v and $\delta(v)$ is the number of edges leaving the direct neighbour subgraph (i.e. subnetwork) of node v among the edges incident to each direct neighbour node i of node v .

3.2.3 Control variables

Several control variables were included that may be related to a firm's ESG controversies, namely firm size, firm age, debt ratio, supplier concentration, firm's power over suppliers, and country. Data for the control variables were obtained from three databases: Thomson Reuters Eikon database, Bloomberg database, and the online SDG index website.

Firm size, as measured by the natural log of market capitalisation, may influence firm ESG controversies because larger firms tend to have more access to resources through their network of partners (Bellamy et al., 2014) and, therefore, be more resourceful in tackling sustainability problems. Additionally, larger firms tend to overlook their supply chain issues due to the complexity of the supply network structure.

This study also controlled for the *firm age*, as calculated by the number of years since the date a firm was established to the current year of 2017. It is suggested that older firms are more likely to have inherited negligent sustainability practices, and this could increase the likelihood of sustainability issues (Fan et al., 2021).

Additionally, we also controlled for *debt ratio*, as measured by the ratio of total debt and total equity controlling for the financial situation of firms, which may affect

ESG controversies. Previous studies identified that firms with a debt ratio may have less capability to reduce ESG controversies (Ng, 2018).

Furthermore, the study controlled for *supplier concentration*. Adopting the measure used by Kim and Davis (2016), supplier concentration is measured by the percentage of a focal firm's cost of goods sold that is spent on its top five main suppliers after sorting the suppliers. Firms that have more complex supply bases bear a heavier operational load concerning monitoring and managing the supply chain network. Having complex supply chains can hamper the firm's ability to investigate its entire supply network and, therefore, become less effective in managing its ESG controversies (Kim and Davis, 2016).

The study also controlled for the firm's *power over suppliers*, as measured by the inventory turnover as a proxy of a firm's power over its direct suppliers (Kim and Davis, 2016). Firms with more power over their suppliers have more control over the suppliers' decision-making and leverage to demand sustainability standards. The inventory turnover data was retrieved from the Thomson Reuters Eikon database.

Lastly, the study controlled for the *Country*, as measured by a country's total progress towards achieving all 17 sustainable development goals (SDGs). Firms located in a country with higher sustainability standards might be forced to reduce the risk occurrence of a firm's sustainability performance (Huang et al., 2020).

4. Empirical results

All analyses were run using STATA Version 16.1. Table 4 summarises the relevant statistics (i.e. the descriptive statistics and simple correlation of all the variables).

Table 4 Descriptive statistics and correlation

	Mean	Std. dev.	1	2	3	4	5	6	7	8	9	10
1 ESG controversies	-86.7999	26.05313	1									
2 Firm size	25.50799	2.467569	0.0939 0.1204	1								
3 Firm age	4.171633	0.669487	0.0993 0.0968	0.0716 0.225	1							
4 Debt ratio	77.3363	83.17557	0.1918 0.0014	-0.101 0.0881	0.1056 0.073	1						
5 Supplier concentration	0.121788	0.157839	0.0728 0.2231	0.2697 0	-0.1 0.0821	0.025 0.6719	1					
6 Power over supplier	6.83101	4.512577	0.0065 0.9147	0.0057 0.9233	-0.022 0.7085	-0.0315 0.5956	0.0881 0.1325	1				
7 Country	77.73657	4.804467	0.0752 0.2077	-0.0396 0.5013	0.2008 0.0004	-0.015 0.7989	-0.1176 0.0404	-0.2159 0.0002	1			
8 Neighbours' interconnectedness	0.105311	0.156467	-0.2057 0.0005	0.0978 0.0964	-0.1167 0.0423	-0.1326 0.0239	0.0868 0.1311	-0.0793 0.1756	0.1044 0.069	1		
9 Neighbours' centrality	0.048646	0.136355	0.4728 0	0.1166 0.0472	0.0751 0.1926	0.1811 0.002	0.0827 0.1504	0.1347 0.0211	-0.0047 0.9347	-0.2316 0	1	
10 Bridging	1.299421	4.599872	-0.0143 0.8115	-0.0862 0.1429	-0.0805 0.1624	-0.0469 0.4262	-0.0475 0.4091	-0.0613 0.296	0.0531 0.3563	-0.0187 0.7457	-0.0949 0.0987	1

We also checked for multicollinearity and ensured each predictor variable's VIF scores was below 10; this showed that multicollinearity issue does not exist in this dataset (Neter et al., 1996). Each VIF score for the dataset meets the condition (mean score of 1.16) (See Table 5).

Table 5 VIF of variables

Variable	VIF	1/VIF
Firm size	1.14	0.8757
Firm age	1.12	0.8932
Firm debt ratio	1.09	0.9192
Supplier concentration	1.13	0.8853
Firm power over direct suppliers	1.09	0.9141
Country	1.15	0.873
Neighbours' interconnectedness	1.36	0.7328
Neighbours' centrality	1.16	0.8656
Firm bridging	1.14	0.8751
Neighbours' interconnectedness# Firm's bridging	1.32	0.7602
Neighbours' centrality# Firm's bridging	1.09	0.9164
Mean VIF	1.16	

4.1 Main results

Table 6 presents the main results. The effects are displayed in sequence in models 1–4; this helps to ensure the stability of the model and confirm the robustness of any significant effect with the inclusion of other effects.

Table 6 Ordinary Least Square regression model-ESG controversies

VARIABLES	Model 1	Model 2	Model 3	Model 4
Controls				
Firm size	1.002	0.534	0.581	0.593
	[0.133]	[0.376]	[0.333]	[0.325]

Firm age	2.248 [0.357]	1.118 [0.612]	1.169 [0.594]	1.141 [0.604]
Debt ratio	0.064*** [0.001]	0.035** [0.044]	0.034* [0.051]	0.034* [0.052]
Supplier concentration	6.825 [0.513]	6.374 [0.498]	6.555 [0.483]	6.554 [0.484]
Power over supplier	0.116 [0.746]	-0.283 [0.381]	-0.316 [0.326]	-0.31 [0.337]
Country	0.381 [0.269]	0.339 [0.276]	0.331 [0.284]	0.335 [0.280]
Main Effects				
Neighbours' interconnectedness		-16.589* [0.082]	-24.861** [0.016]	-25.348** [0.015]
Neighbours' centrality		82.211*** [0.000]	81.096*** [0.000]	81.340*** [0.000]
Firm's bridging		0.191 [0.538]	0.01 [0.974]	0.024 [0.940]
Moderation Effects				
Neighbours' interconnectedness#Firm's bridging			4.937** [0.040]	5.098** [0.038]
Neighbours' centrality#Firm's bridging				-28.983 [0.726]
_cons	-157.949*** [0.000]	-135.501*** [0.000]	-135.460*** [0.000]	-135.866*** [0.000]
<i>N</i>	268	268	268	268
adj. <i>R</i> ²	0.041	0.235	0.245	0.242

Model 1 is a base model including only the control variables. Specifically,

Model 1 reports that only the firm's debt ratio is shown to positively affect the firm's ESG controversies. Model 2 displays the main results of neighbours'

interconnectedness, neighbours' centrality, and the firm's bridging. The main results suggest that the posited neighbours' centrality has a positive effect on the focal firm's ESG controversies ($p < 0.001$), while the hypothesised neighbours' interconnectedness has a negative effect on the firm's ESG controversies ($p < 0.05$). Models 3 and 4 present the progressive addition of the interactions concerning H3 and H4. The full model is displayed in Model 4.

The full model shows a positive and significant relationship between neighbours' centrality and the level of ESG controversies ($p < 0.001$), thereby providing support for H2. Also, the negative association between neighbours' interconnectedness and ESG controversies (H1) remains throughout the full model ($p < 0.05$). Further, H3 that posited the interaction effect of neighbours' interconnectedness and firm's bridging on ESG controversies performance is supported. However, the study failed to find any support for Hypothesis 4.

4.2 Moderating effects

Additional insights into the significant moderating effect could be supplemented by adopting the interaction plot that displays the relationship between the variables of interest. The interaction plot was used to examine the moderating effects in more detail (see Figure 5). Similar to Potter and Wilhelm (2020), equations were created for each relationship at -1 standard deviation (low) and $+1$ standard deviation (high) values of the explanatory and moderator variables to analyse the moderating effects using simple slope statistics. Then, the continuous interaction plot was undertaken to further assess the relationships at the 25th percentile (low) and 75th percentile (high) values of the explanatory variable, along with the moderator variables at the 25th percentile (low) and 75th percentile (high) values. Following this approach, we could observe the nature of

the relationships within the interaction plots without the potential influence of outlier firms (Potter and Wilhelm, 2020). Regarding the moderating effect of bridging, in line with H3, it was observed that a firm's bridging exerts a positive moderating effect on the relationship between neighbours' interconnectedness and ESG controversies. The result from the interaction plot reveals that the positive moderating effect of a firm's bridging on the relationship between neighbours' interconnectedness and ESG controversies would most likely emerge only where the level of a firm's bridging is high (See Figure 5).

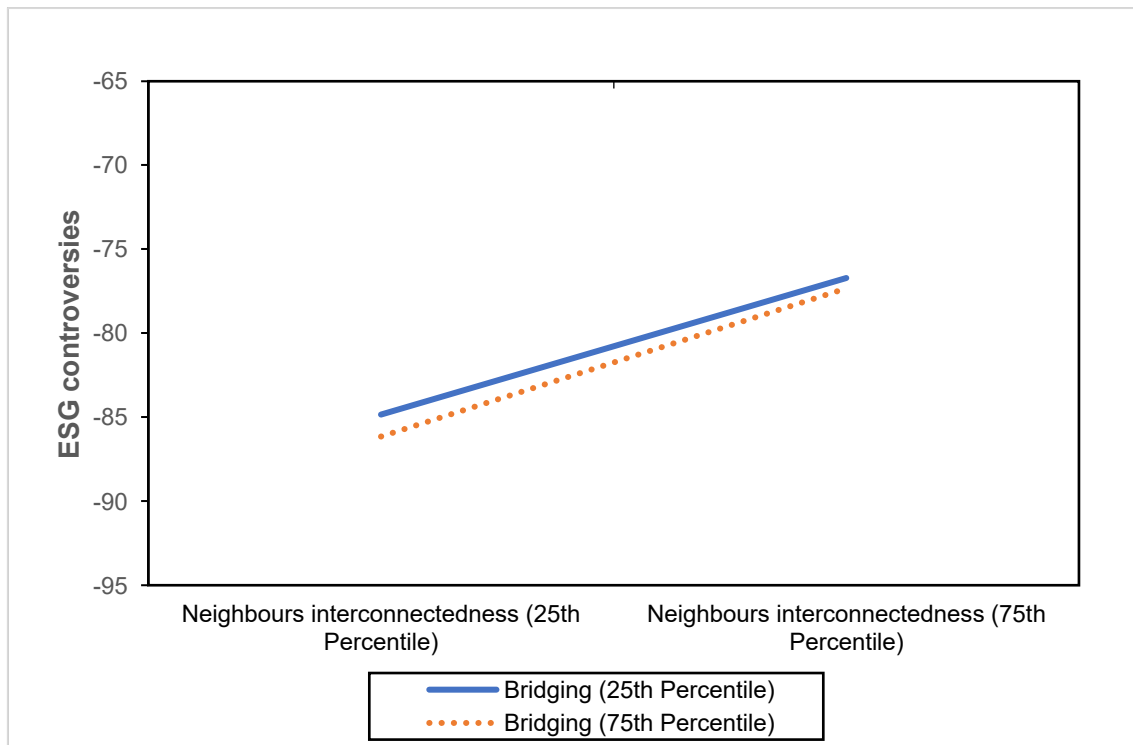


Figure 5 Moderating effect of bridging (Neighbours' Interconnectedness)

4.3 Robustness check

This study further conducted another analysis to ensure that the above results are still robust in terms of alternative measures and varying sampling criteria. In our sample of firms, there were some observations of missing data. We adopted a similar approach as

recommended by Gentry and Shen (2013) and replaced the missing values with an average value in the main analysis (reported in Table 7). We also adopted an alternative measure of firm size by using the natural log of net sales in a different year as a robustness check. We then reran the analyses using the same OLS regression. The conclusions remain the same. Table 6 presented the results of this alternative model.

Table 7 Robustness check

VARIABLES	Model 1	Model 2	Model 3	Model 4
Controls				
Firm size	0.809 [0.141]	0.308 [0.537]	0.351 [0.481]	0.365 [0.465]
Firm age	1.013 [0.585]	0.053 [0.975]	0.061 [0.971]	0.036 [0.983]
Debt ratio	0.051*** [0.002]	0.026* [0.088]	0.025* [0.099]	0.025 [0.102]
Supplier concentration	6.959 [0.462]	6.579 [0.441]	6.454 [0.447]	6.409 [0.451]
Power over supplier	0.091 [0.785]	-0.265 [0.380]	-0.295 [0.326]	-0.29 [0.336]
Country	0.327 [0.305]	0.412 [0.154]	0.404 [0.160]	0.405 [0.159]
Main Effects				
Neighbours' interconnectedness		-15.477* [0.066]	-22.823** [0.012]	-23.293** [0.011]
Neighbours' centrality		80.717*** [0.000]	79.707*** [0.000]	79.963*** [0.000]
Firm's bridging		0.135	-0.041	-0.025
Moderation Effects		[0.648]	[0.893]	[0.935]

Neighbours'				
interconnectedness#Firm's			4.792**	4.964**
bridging			[0.039]	[0.036]
Neighbours'				
centrality#Firm's bridging				-31.393
				[0.694]
_cons	-141.676***	-129.590***	-129.277***	-129.544***
	[0.000]	[0.000]	[0.000]	[0.000]
<i>N</i>	304	304	304	304
adj. <i>R</i> ²	0.034	0.219	0.228	0.226

5. Discussion and conclusions

Our study sought to reveal the often-invisible connectivity patterns within supply networks in which firms are embedded, examining how their connections to surrounding neighbours impact ESG controversies. The findings reveal that neighbours' interconnectedness is negatively associated with the focal firm's ESG controversies, while neighbours' centrality positively affects its ESG controversies. Our research demonstrates the moderating role of a firm's bridging. In particular, the empirical results show that a firm's bridging positively moderates the relationship between its neighbours' interconnectedness and ESG controversies, though no significant effect is found on the association between neighbours' centrality and ESG controversies. The overall findings are summarised in Table 8. Based on these findings, we reflect on the hypotheses and demonstrate several important theoretical and managerial implications.

Table 8 Summary of findings

Hypothesis	Factor(s)	Impact on ESG controversies	Support
1	Neighbours' interconnectedness	Negative	Yes
2	Neighbours' centrality	Positive	Yes

3	Neighbours' interconnectedness # Bridging	Positive	Yes
4	Neighbours' centrality # Bridging	Positive	No

5.1 Theoretical implications

Our study contributes to the literature on sustainable supply chain management in several ways. First, we draw on the literature adopting a network perspective in explaining the behaviour and performance of supply networks to explain firms' sustainability. Particularly, our study examines the relationship between the structural properties of supply networks in which firms are embedded and their sustainability and confirms that a firm's neighbour network structure significantly affects its ESG controversies. While previous research has focused on a focal firm's structural properties in relation to sustainability (e.g. Bellamy et al., 2020; Gualandris et al., 2021), our study adopts a neighbour's perspective, paying attention to the structural properties that relate to the firm's neighbours. Our study's findings provide empirical support for the notion that a higher degree of connectedness among a firm's network neighbours is negatively related to its ESG controversies. This finding aligns with existing literature, namely being embedded in a highly interconnected network facilitates information flows among firms embedded in the supply network. This enables the firms to validate the reliability of supply chain information (Kim and Zhu, 2018) and access more robust information even though it may become redundant in a dense network. It also ensures that the focal firm receives more monitoring from closely connected neighbours. Such a dense network structure brings benefits, such as trust, information sharing, and alignment of values and goals among the neighbours, which aligns with previous scholars' viewpoints (Rowley et al., 2000; Song et al., 2019).

Additionally, our findings reveal that a higher level of neighbours' centrality is positively related to a higher level of ESG controversies. This finding is consistent with

previous studies (e.g. Carnovale et al., 2017; Kim, 2019), which suggest that higher neighbours' centrality renders a focal firm less monitored and give it more control over information flow. It also indicates that the leading firm embedded in a supply network with powerful neighbours may become more powerful, leading to reduced control and supervision placed on them by others concerning the reduction of ESG controversies. The result also suggests that a firm with a higher level of neighbours' centrality may increase the likelihood of information asymmetry when engaging with other influential neighbours in the supply chain; as the firm gains more power, it may dominate the information flow to serve its own interests (Laari et al., 2022).

Second, our study adds to the literature investigating the impact of supply network structures on firms' sustainability by examining the interactions between a firm and its neighbours' network structural properties in driving firms' sustainability. Our results highlight a positive moderating effect of a firm's bridging on the relationship between neighbours' interconnectedness and ESG controversies. This positive moderating role of a firm's bridging supports the literature that suggests a firm acting as a bridge can facilitate novel information flow by introducing diversified information and act as a monitor relative to the two disconnected actors for firms embedded in a highly dense network (Gao et al., 2015). This finding underscores the degree of importance of such structural network power. However, our study failed to find support for the moderating role of bridging position on neighbours' centrality– ESG controversies relationship. The reason for this situation may lie in the fact that both mechanisms were already very strong given the firm's centrality position. Yet, the moderating role of bridging could provide additional power or novel information, which may become overlapped within the firm. Thus, the moderating role of bridging does not seem to bring a significant level of benefits to the focal firm.

Finally, while previous studies investigating the effects of supply network structures have primarily focused on sustainability performance or disclosure (e.g. Bellamy et al., 2020; Gualandris et al., 2021), our study contributes to this growing body of literature by examining ESG controversies, thereby capturing market sensitivities and shedding light on external market reactions with regards to sustainability issues. The use of ESG controversies reflecting the dark side of sustainability performance can aid firms to utilise and influence their connections with other network members to achieve sustainability goals.

5.2 Managerial implications

Our study offers several practical recommendations for managers and practitioners seeking to reduce ESG controversies within their firms and extended supply chains. Investment in end-to-end supply network mapping helps managers gain better visibility into how the network structure of their partners causes beneficial or harmful effects for ESG controversies. First, managers should be aware of the level of interconnectivity among partner firms (Chauhan et al., 2021). Specifically, within our sample, some OEMs have a greater level of interconnectedness within their supply networks. Unsurprisingly, some of the same suppliers are often responsible for driving interconnectedness in the prominent firms' supply networks. Taking Apple and Foxconn Technology as an example, Foxconn Technology is linked to over 20% of Apple's Tier 1 suppliers. Similarly, recent research emphasises shift in considering focal firms responsible for their suppliers' actions (Sancha et al., 2016). It is therefore recommended that firms in the global automotive industry such as Toyota, Ford or otherwise, which works with multiple contract suppliers should proactively develop relevant relational and structural mechanisms to utilise this benefit and increase supply

chain transparency (Kusi-Sarpong et al., 2023). In response to managing ESG controversies in practice, managers should also be careful of having more linkages with influential neighbours in terms of reducing ESG controversies. Although some influential automotive companies advertise their green initiatives widely in their operations, they were, however, caught greenwashing in their misleading information regarding carbon emissions plans. For instance, the car company Toyota Australia was accused of overstating its commitment to clean transport. This results in a legal challenge for Toyota Australia and other connected companies, with the risk of eroding their social licence and damaging both their brand and customer base. It is necessary for firms working with influential companies to regularly check their ESG compliance and plans to avoid the risk of being involved in those controversial cases. In particular, a range of controversial practices are often linked to the sourcing of raw materials in the automotive industry (e.g. extraction of conflict minerals). Thus, lower-tier suppliers of those influential companies should also be well-trained in appropriate ESG practices to reduce controversial practices within the focal company's supply network.

Under the guidance of our findings, it is suggested that practitioners should make use of these specific firm positions to better manage their ESG controversies. For instance, firms should identify ways to encourage a third-party involvement in assessing and monitoring their acts. Working collaboratively with the bridging firm to identify and launch certified standards to avoid potential issues is of critical importance. Specifically, working with independent third-party certification (e.g. IEC conformity assessment schemes) to measure and verify companies' sustainability claims based on different conformity assessment systems. Moreover, managers could go even further with their assessment for monitoring and controlling the manufacturing supply chain, as well as identifying structurally prominent suppliers that may contribute to governing the

sustainability of the network.

5.3 Research limitations and agenda for future work

Despite the insights provided, this study has some limitations, pointing to opportunities for future research:

Network structural variables. While our study focused on two main network structural properties—neighbours’ interconnectedness and centrality— to investigate their influence on ESG controversies, other meaningful network-level structural properties may also provide insights (e.g. participation coefficient and within-module degree, capturing the firm’s neighbours’ linkages). Therefore, future research could consider adopting more advanced structural properties to capture network-level performance.

Sustainability variables. This study uses the Thomson Reuters ESG controversies score as a reflection of a firm’s ESG controversies to provide insights into the overall market reaction to sustainability issues. Future research could differentiate the specific dimensions of ESG controversies (e.g. community, human rights, product responsibility, etc.) to further capture how various ESG controversies dimensions are individually and collectively are impacted by supply network structural properties.

Research setting. Our study focused on the automotive industry. Future research could enhance our findings by further corroborating and extending them beyond the automotive industry or adopting a multi-industry approach. Exploring diverse industry settings could not only validate the robustness of the current results but also reveal new insights and trends, offering broader practical implications for sustainability within supply network contexts.

Sample. The findings were drawn from a supply network dataset consisting of 18,943 firms in the year 2014. However, the number of firms selected and filtered in the final sample is around 300 firms, which may introduce bias in the empirical results.

Therefore, future research could improve the external validity of these findings by corroborating results with other time frames and contexts to track supply network structural changes and their influence on ESG controversies (e.g. using panel data to investigate the changes in influence).

Data

The relevant data that support the findings of this study may be available from the corresponding author upon reasonable request.

References

- Advisory, S. (2021) *ESG Case Study – Toyota Motor Corporation*. Available at: <https://etfdb.com/esg-channel/esg-case-study-toyota/> (Accessed: 19 February 2024).
- AIQ Editorial Team. (2021). *Living in the past: Why are controversy scores so controversial?, ESG Controversy scores: Why are they so controversial?* Aviva Investors. <https://www.avivainvestors.com/en-gb/views/aiq-investment-thinking/2021/04/controversy-scores/>
- Alinaghian, L., Qiu, J., and Razmdoost, K. (2021). The role of network structural properties in supply chain sustainability: A systematic literature review and agenda for future research. *Supply Chain Management: An International Journal*, 26(2), 192–211.
- Altmann, M. (2015). A supply chain design approach considering environmentally sensitive customers: The case of a German manufacturing SME. *International Journal of Production Research*, 53(21), 6534–6550.
- Aouadi, A., and Marsat, S. (2018). Do ESG controversies matter for firm value? Evidence from international data. *Journal of Business Ethics*, 151(4), 1027–1047.
- Arora, S, and A Brintrup. (2021). How Does the Position of Firms in the Supply Chain Affect Their Performance? An Empirical Study. *Applied Network Science*, 6 (1).
- Aydin, C. I., Ozkaynak, B., Rodriguez-Labajos, B., and Yenilmez, T. (2017). Network effects in environmental justice struggles: An investigation of conflicts between mining companies and civil society organizations from a network perspective. *PLoS ONE*, 12(7), 1–20.
- Baruah, A.K. and Bora, T. (2018). Bridging centrality: Identifying bridging nodes in transportation network. *International Journal of Advanced Networking and Applications*, 9(6), 3669-3673.
- Basole, R. C. (2016). Topological analysis and visualization of interfirm collaboration networks in the electronics industry. *Decision Support Systems*, 83, 22–31.
- Bellamy, M. A., Dhanorkar, S., and Subramanian, R. (2020). Administrative environmental innovations, supply network structure, and environmental disclosure. *Journal of Operations Management*, 66(7–8), 895–932.

- Bellamy, M. A., Ghosh, S., and Hora, H. (2014). The influence of supply network structure on firm innovation. *Journal of Operations Management*, 32(6), 357-373.
- Bloch, F., and Jackson, M. O. (2016). Centrality measures in networks. arXiv preprint arXiv:1608.05845, 2016.
- Bonacich, P. (1987). Power and centrality: A family of measures. *American Journal of Sociology*, 92(5), 1170–1182.
- Borgatti, S. P., and Halgin, D. S. (2011). On network theory. *Organization Science*, 22(5), 1168–1181.
- Borgatti, S. P., and Li, X. (2009). On social network analysis in a supply chain context. *Journal of Supply Chain Management*, 45(2), 5–22.
- Bouzzine, Y. D., and Lueg, R. (2020). The contagion effect of environmental violations: The case of Dieselgate in Germany. *Business Strategy and the Environment*, 29(8), 3187–3202.
- Burt, R. S. (2004). Structural holes and good ideas. *American Journal of Sociology*, 110(2), 349–399.
- Busse, C., Meinlschmidt, J., and Foerstl, K. (2017). Managing information processing needs in global supply chains: A prerequisite to sustainable supply chain management. *Journal of Supply Chain Management*, 53(1), 87–113.
- Carnovale, S., Yeniyurt, S., and Rogers, D. S. (2017). Network connectedness in vertical and horizontal manufacturing joint venture formations: A power perspective. *Journal of Purchasing and Supply Management*, 23(2), 67–81.
- Chauhan, V. K., Perera, S., and Brintrup, A. (2021). The relationship between nested patterns and the ripple effect in complex supply networks. *International Journal of Production Research*, 59(1), 325–341.
- Drempetic, S., Klein, C., and Zwergel, B. (2020). The influence of firm size on the ESG score: Corporate sustainability ratings under review. *Journal of Business Ethics*, 167(2), 333–360.
- ESMA (2023) *Esma publication on risks related to climate shocks and greenwashing controversies*, European Securities and Markets Authority. Available at: <https://cms-lawnow.com/en/ealerts/2023/12/esma-publication-on-risks-related-to-climate-shocks-and-greenwashing-controversies> (Accessed: 19 February 2024).

- Fan, D., Lo, C. K. Y., and Zhou, Y. (2021). Sustainability risk in supply bases: The role of complexity and coupling. *Transportation Research Part E: Logistics and Transportation Review*, 145, 102175.
- Feng, Q., Li, C., Lu, M., and Shanthikumar, J. G. (2022). Implementing Environmental and Social Responsibility Programs in Supply Networks Through Multiunit Bilateral Negotiation. *Management Science*, 68(4), 2579–2599.
- Gaimon, C., Hora, M., Ramachandran, K., (2017). Towards building multidisciplinary knowledge on management of technology: An introduction to the special issue. *Production and Operation Management*, 26(4), 567–578.
- Gao, G. Y., Xie, E., and Zhou, K. Z. (2015). How does technological diversity in supplier network drive buyer innovation? Relational process and contingencies. *Journal of Operations Management*, 36, 165–177.
- Gentry, R. J., and Shen, W. (2013). The impacts of performance relative to analyst forecasts and analyst coverage on firm R&D intensity. *Strategic Management Journal*, 34(1), 121–130.
- Granovetter, M. S. (1973). The strength of weak ties. *American Journal of Sociology*, 78(6), 1360–1380.
- Gualandris, J., Longoni, A., Luzzini, D., and Pagell, M. (2021). The association between supply chain structure and transparency: A large-scale empirical study. *Journal of Operations Management*, 67(7), 803–827.
- Harjoto, M. A., and Wang, Y. (2020). Board of directors network centrality and environmental, social and governance (ESG) performance. *Corporate Governance*, 20(6), 965-985.
- Huang, S. W., Liou, J. J. H., Tang, W., and Tzeng, G. H. (2020). Location selection of a manufacturing facility from the perspective of supply chain sustainability. *Symmetry*, 12(9).
- Hwang, W., Cho, Y., Zhang, A., and Remanathan, M. (2006). Bridging centrality: Identifying bridging nodes in scale-free networks. *Kdd*, 20–23.
- Jensen, M. (2011). The use of relational discrimination to manage market entry: When do social status and structural holes work against you? *Academy of Management Journal*, 51(4), 723–743.
- Jraisat, L., Upadhyay, A., Ghalia, T., Jresseit, M., Kumar, V., & Sarpong, D. (2021). Triads in sustainable supply-chain perspective: why is a collaboration

- mechanism needed? *International Journal of Production Research*, 61(14), 4725–4741.
- Kelly, A. and Bengtsen, P. (2016, July 28). Vauxhall and BMW among car firms linked to child labour over glittery mica paint. the Guardian.
<https://www.theguardian.com/global-development/2016/jul/28/vauxhall-bmw-car-firms-linked-child-labour-mica>
- Kim, D.Y., and Zhu, P. (2018). Supplier dependence and R&D intensity: The moderating role of network centrality and interconnectedness. *Journal of Operations Management*, 64, 7–18.
- Kim, H. S. (2019). How a firm's position in a whole network affects innovation performance. *Technology Analysis and Strategic Management*, 31(2), 155–168.
- Kim, Y., Chen, Y.S., and Linderman, K. (2015). Supply network disruption and resilience: A network structural perspective. *Journal of Operations Management*, 33–34, 43–59.
- Kim, Y., Choi, T.Y., Yan, T., and Dooley, K. (2011). Structural investigation of supply networks: A social network analysis approach. *Journal of Operations Management*, 29(3), 194–211.
- Kim, Y. H., and Davis, G. F. (2016). Challenges for global supply chain sustainability: Evidence from conflict minerals reports. *Academy of Management Journal*, 59(6), 1896–1916.
- Klassen, R. D., and Vereecke, A. (2012). Social issues in supply chains: Capabilities link responsibility, risk (opportunity), and performance. *International Journal of Production Economics*, 140(1), 103–115.
- Koka, B. R., and Prescott, J. E. (2008). Designing alliance networks: The influence of network position, environmental change, and strategy on firm performance. *Strategic Management Journal*, 29(6), 639–661.
- Kotzian, P. (2023). Firms' Sustainability Engagement and Sustainability - related Controversies. *Business Strategy and the Environment*, September, bse.3562.
- Kusi-Sarpong, S., Gong, Y., Brown, S., Gupta, H., Bai, C., and Orji, I.J. (2023). Multi-tier sustainable supply chains management for global sustainability. *International Journal of Production Research*, 61(14), 4592–4602.
- Laari, S., Wetzel, P., Töyli, J., and Solakivi, T. (2022). Leveraging supply chain networks for sustainability beyond corporate boundaries: Explorative structural network analysis. *Journal of Cleaner Production*, 377.

- Lau, A. K. W., Kajikawa, Y., and Sharif, N. (2020). The roles of supply network centralities in firm performance and the moderating effects of reputation and export-orientation. *Production Planning and Control*, 31(13), 1110–1127.
- Ledwoch, A., Yasarcan, H., and Brintrup, A. (2018). The moderating impact of supply network topology on the effectiveness of risk management. *International Journal of Production Economics*, 197, 13–26.
- Liang, H., and Fu, K. W. (2019). Network redundancy and information diffusion: The impacts of information redundancy, similarity, and tie strength. *Communication Research*, 46(2), 250–272.
- Mathiyazhagan, K., Mani, V., Mathivathanan, D., and Rajak, S. (2023). Evaluation of antecedents to social sustainability practices in multi-tier Indian automotive manufacturing firms. *International Journal of Production Research*, 61(14), 4786–4807.
- McEvily, B., and Zaheer, A. (1999). Bridging ties: A source of firm heterogeneity in competitive capabilities. *Strategic Management Journal*, 20(12), 1133–1156.
- Neter, J., Kutner, M. H., Nachtsheim, C. J., and Wasserman, W. (1996). *Applied linear statistical models*. McGraw-Hill.
- Ng, A. W. (2018). From sustainability accounting to a green financing system: Institutional legitimacy and market heterogeneity in a global financial centre. *Journal of Cleaner Production*, 195, 585–592.
- Nyaga, G. N., Lynch, D. F., Marshall, D., and Ambrose, E. (2013). Power asymmetry, adaptation and collaboration in dyadic relationships involving a powerful partner. *Journal of Supply Chain Management*, 49(3), 42–65.
- Ozcan, O. (2011). *The impact of supply chain and network structure on the environmental performance of sustainability-focused companies* [PhD thesis]. University of South Florida.
- Potter, A., and Wilhelm, M. (2020). Exploring supplier–supplier innovations within the Toyota supply network: A supply network perspective. *Journal of Operations Management*, 66(7–8), 797–819.
- Rajesh, R. (2020). Exploring the sustainability performances of firms using environmental, social, and governance scores. *Journal of Cleaner Production*, 247.
- Refinitiv. (2022). *Environmental, social and governance (ESG) scores from Refinitiv*. Refinitiv.

https://www.refinitiv.com/content/dam/marketing/en_us/documents/methodology/refinitiv-esg-scores-methodology.pdf?elqTrackId=9043C356E391436788500F89553C092A&elqTrack=true

- Rindfleisch, A., and Moorman, C. (2001). The acquisition and utilization of information in new product alliances: A strength-of-ties perspective. *Journal of Marketing*, 65 (2), 1–18.
- Rowley, T., Behrens, D., and Krackhardt, D. (2000). Redundant Governance Structures - Analysis of structural and relational embeddedness. *Strategic Management Journal*, 21(3), 369–386.
- Ruddick, G. (2015, December 10). VW admits emissions scandal was caused by 'whole chain' of failures. the Guardian.
<https://www.theguardian.com/business/2015/dec/10/volkswagen-emissions-scandal-systematic-failures-hans-dieter-potsch>
- Sancha, C., Longoni, A. and Gimenez, C. (2015). Sustainable supplier development practices: Drivers and enablers in a global context, *Journal of Purchasing and Supply Management*, 21(2), 95–102.
- Sarkis, J, and Zhu, Q. (2018). Environmental Sustainability and Production: Taking the Road Less Travelled. *International Journal of Production Research*, 56 (1–2), 743–759.
- Saunders, L. W., Tate, W. L., Zsidisin, G. A., and Miemczyk, J. (2019). The influence of network exchange brokers on sustainable initiatives in organizational networks. *Journal of Business Ethics*, 154(3), 849–868.
- Shi, X. Qiu, Y, X. jiao, and Deng, D. sham. (2022). Research on supply network resilience considering the ripple effect with collaboration. *International Journal of Production Research*, 60(18), 5553–5570.
- Song, H., Lu, Q., Yu, K., and Qian, C. (2019). How do knowledge spillover and access in supply chain network enhance SMEs' credit quality? *Industrial Management and Data Systems*, 119(2), 274–291.
- Szász, L., Csíki, O., and Rácz, B. G. (2021). Sustainability management in the global automotive industry: A theoretical model and survey study. *International Journal of Production Economics*, 235(March), 108085.

- Tamayo-Torres, I., Gutierrez-Gutierrez, L., and Ruiz-Moreno, A. (2019). Boosting sustainability and financial performance: The role of supply chain controversies. *International Journal of Production Research*, 57(11), 3719–3734.
- Taylor, Kelsey M., and Stephan Vachon. (2018). Empirical Research on Sustainable Supply Chains: IJPR's Contribution and Research Avenues. *International Journal of Production Research*, 56 (1–2), 950–959.
- Ting, S. L., and Tsang, A. H. C. (2014). Using social network analysis to combat counterfeiting. *International Journal of Production Research*, 52(15), 4456–4468.
- Villena, V. H., Choi, T., and Revilla, E. (2015). Managing the dark side of close buyer-supplier relationships. *Supply Chain Management Review*, 9(6), 50–55.
- Villena, V. H., & Gioia, D. A. (2020). "A More Sustainable Supply Chain: The Human Factor." *MIT Sloan Management Review*, 61(2), 64-71.
- Wagner, S. M., Jönke, R., and Hadjiconstantinou, E. (2018). Relationship archetypes in aftermarkets. *International Journal of Production Research*, 56(6), 2250–2268.
- Wasserman, S., and Faust, K. (1994). *Social network analysis*. Cambridge University Press.
- Wu, Z., Lin, S., Chen, T., Luo, C. and Xu, H. (2023). Does Effective Corporate Governance Mitigate the Negative Effect of ESG Controversies on Firm Value? *Economic Analysis and Policy*, 80, 1772–1793.
- Xue, R, Wang, H., Yang, Y, Martina K., Jin, L and Cai, C. (2023). The Adverse Impact of Corporate ESG Controversies on Sustainable Investment, *Journal of Cleaner Production*, 427.
- Yan, T., Choi, T. Y., Kim, Y., and Yang, Y. (2015). A Theory of the Nexus Supplier: A Critical Supplier from A Network Perspective. *Journal of Supply Chain Management*, 51(1), 52–66.
- Yang, H., Lin, Z., and Lin, Y. (2010). A multilevel framework of firm boundaries: Firm characteristics, dyadic differences, and network attributes. *Strategic Management Journal*, 31(3), 237–261.