Panarchy theory: myth or reality? Empirical evidence of the socio-ecological nature of supply chains

Alice Madonna, Albachiara Boffelli and Matteo Kalchschmidt
Department of Management, Information and Production Engineering, University of Bergamo, Bergamo, Italy

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Abstract

Purpose – This study builds on the panarchy theory by viewing the supply chain as a socio-ecological system and further expands it by considering the within-level linkages internal to the supply chain level. Three types of linkages are considered: the two cross-level linkages with the planetary and the political-economic levels and the supply chain within-level linkages. The research questions are addressed using the data gathered by the Carbon Disclosure Project within its Supply Chain Programme.

Design/methodology/approach – This work aims to study, applying the lens of panarchy theory, how the planetary and the political-economic levels affect the supply chain within-level linkages for sustainability. Furthermore, the difference in how these cross-level linkages influence focal firms and first-tier suppliers is explored.

Findings – The results show that considering the planetary-supply chain linkage, climate change risk exposure is likelier to foster within-level linkages with buyers than with suppliers. Further, climate change mitigation investments have different roles in the different tiers: focal firms are pushed to strengthen the linkages with their suppliers when they lose efficacy in improving their carbon performance, whereas first-tier suppliers exploit investments to gain legitimacy. Discussing the political-economic level effect, perceptions from first-tier suppliers could be two-fold: they could perceive a mandating power mechanism or exploit policymakers' knowledge to advance their capabilities.

Originality/value – The results contribute to the sustainable supply chain management literature by providing empirical evidence of the cross-level linkages theorised by the panarchy theory. Moreover, the concept of within-level linkages is proposed to apply the theory in this field.

Keywords Buyer-supplier, Panarchy theory, Socio-ecological system, Sustainable supply chain management, Carbon disclosure project, Supply chain position

Paper type Research paper

1. Introduction

Climate change is an increasingly concerning issue, not only to the general public but also to practitioners, scholars and other stakeholders. In recent years, we witnessed the introduction of stricter environmental regulations from the European Union (European Parliament, 2023). At the same time, unexpected and disruptive events – think of the Amazon Forest burning up, the supply chain (SC) disruptions following the Suez Canal blockage, the resources and components scarcity characterising the last couple of years, and, last but not least, the pandemic – have become more frequent, making companies more aware of environmental risks (IPCC, 2022). Firms must act upon these issues, reducing their carbon footprint. Given that climate change is too big a challenge for any company, relying on and motivating SC

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partners is necessary (Chen *et al.*, 2017; Savage *et al.*, 2010). Engaging SC partners is also becoming fundamental as focal firms, which are more subjected to the public eye and scrutiny, are accountable for non-sustainable behaviours carried out by their suppliers, even if dispersed upstream in the SC (Hartmann and Moeller, 2014; Sarkis *et al.*, 2019; Wilhelm *et al.*, 2016a, b).

This paper models SC partners engagement and collaboration as SC linkages, following the definition provided by Rungtusanatham *et al.* (2003): "explicit and/or implicit connections that a firm creates with critical entities of its supply chain". In this paper, we consider the SC linkages established with suppliers and customers with the particular purpose of improving climate change management, excluding other reasons that might drive a firm to develop those linkages, such as quality, flexibility or responsiveness objectives. Notably, most of the extant literature looks at SC linkages as a viable action to improve the firms' environmental performance (Li *et al.*, 2015; Mahapatra *et al.*, 2021; Um and Kim, 2019); meanwhile, sustainability should proceed in the opposite way: actions are required, mandatory at times (Agarwal *et al.*, 2018; Serafeim, 2020), even though they do not necessarily influence the firms' performance (Pagell and Shevchenko, 2014). Few studies have been found that do not adhere to this general view (Gong *et al.*, 2021; Jia *et al.*, 2019), leaving a gap in the understanding of inter-organisational dynamics that lead to the construction and strengthening of SC linkages. The classical conceptualisation of SC linkages as a cause stems from the use of classical theories in Sustainable Supply Chain Management (SSCM), such as transaction cost economics (Vachon and Klassen, 2008), (natural) resource-based view and resource dependence theory (Foerstl *et al.*, 2010; Gold *et al.*, 2009), institutional theory (Gonzalez *et al.*, 2008) and stakeholder theory (Park-Poaps and Rees, 2010). The literature on SSCM has focused on the concepts of resources, performance and power, with a strong emphasis on studying the relation between sustainability and performance, as well as resources and competencies that can provide competitive advantage (Touboulic and Walker, 2015). Vachon and Klassen (2008) highlight the mediating role of collaboration between SC partners in improving environmental and economic performance. SC partners may reveal themselves as a source of sustainability-related resources and competencies that allow them to gain a competitive advantage, as supported by the resource-based view (Pullman *et al.*, 2009). The network theory also suggests that firms, especially small and medium enterprises, lacking resources and knowledge can access external resources and firm capabilities by establishing a network through alliances and engagement capabilities (Agyabeng-Mensah *et al.*, 2022).

Carter and Easton (2011) argue that other theoretical lenses, besides the most widespread, could provide new insights into the SSCM field. Touboulic and Walker (2015) support that the theoretical perspectives used in SSCM fail to capture all aspects of practices in the field, calling for new multi-level theoretical perspectives. We answer this call in this study by applying the panarchy theory lens, recently introduced to the supply chain management (SCM) field by Wieland (2021). This theory conceptualises the SC as a socio-ecological system whose evolution is affected by cross-level linkages with the other system levels. Cross-level linkages represent the mutual impact of the systems on one another, which influences the overall dynamics and makes the supply chain something more than a closed system (Wieland, 2021). Particularly, conversely to classical theories, the panarchy theory sees the SC linkages as a core feature that allows the system to increase its internal controllability by accumulating structural capital that is periodically released to activate evolution through adaptive cycles (Holling, 2001; Mirzabeiki and Aitken, 2023; Wieland, 2021). On these premises, this study addresses the following research question:

RQ1. What are the effects of cross-level linkages on the supply chain within-level linkages concerning climate change management?

Moreover, it is acknowledged that SC position is a non-negligible contextual factor that generates relevant differences in how firms perceive uncertainties and how they respond to them (Lo, 2014), which naturally leads firms to adopt different approaches to governing their SC (Marttinen *et al.*, 2023). The importance of first-tier (T1) suppliers in spreading sustainability, especially towards those that focal firms cannot reach due to their dimension, distance and legitimacy gaps, is well known (Devin and Richards, 2018; Jabbour *et al.*, 2019; Wilhelm *et al.*, 2016b). Notably, while sustainability diffusion is led mainly by focal firms, T1 suppliers act as the fundamental bridging role with the lower tiers and, in some instances, amplify the practices cascaded upstream back to the focal firms (Johnsen *et al.*, 2022). Hence, this study differentiates T1 suppliers and focal firms to observe how they structure their SC within-level linkages as a response to stimuli from the planetary and political-economic levels. The following research question is formulated:

RQ2. Does the influence of cross-level linkages on the supply chain within-level linkages concerning climate change management differ according to the position in the supply chain?

To study our research questions, we use the data collected by the Carbon Disclosure Project (CDP), as the collection procedure involves both member companies – namely, those that ask their suppliers to disclose the information about climate change programs and performance – and non-member companies – namely, the involved suppliers.

Our results show that cross-level linkages between the SC and political-economic levels always support the strengthening of SC within-level linkages. We find this positive effect more pervasive for T1 suppliers than focal firms. Furthermore, we observe that cross-level linkages between the SC and planetary levels are not always relevant to influence SC within-level linkages. In particular, we show how different elements that generate the cross-level linkages generate different effects according to the SC position, fostering the structuration or the destructuration of SC within-level linkages.

The study contributes to the SSCM literature by understanding what pushes companies at different SC positions to strengthen the within-level linkages both upstream and downstream. Also, it demonstrates the relevance of the panarchy theory in explaining what drives companies to leverage the SC within-level linkages to achieve sustainability outcomes, helping the field to move away from the atheoretical interpretation of phenomena (Walker *et al.*, 2014). In doing so, we add to the conceptualisation of cross-level linkages that connect the evolution of the different levels according to the panarchy theory. Moreover, we include in the theorisation the SCM concept of SC linkages, which we refer to as within-level linkages for symmetry. In addition, we propose an approach to validate and apply the panarchy theory to empirical research in the SSCM domain. This could stimulate a change in perspective, introducing a multi-level conceptualisation that, adding complementarity to classic theories, allows a better understanding of how changes and shocks occurring at other levels (i.e. planetary and political-economic) affect the creation, strengthening and leveraging of the SC within-level linkages to better cope with these changes.

2. Theoretical background

2.1 The supply chain as a socio-ecological system: the panarchy theory perspective

A recent contribution by Wieland (2021) proposed reinterpreting the SC as a socio-ecological system. This conceptualisation shift was deemed necessary because of some pitfalls in common SCM theories, which (1) consider a set of conditions, such as the support of global

sourcing strategies and the availability of natural resources, as stable and (2) tend to consider the SC as isolated from the rest of the world, conceptualising the external environment as monolithic or represented by a set of manageable stakeholders (Borgatti and Li, 2009; Pagell and Shevchenko, 2014). The implications of these two assumptions are, on one side, the failure of the SCM discipline to deal with and model the interaction of the SCs with the other systems it is embedded in (Wieland, 2021) and, on the other side, the tendency to strive for the optimisation of a static and isolated system, resulting into a reduced ability of the system to adapt when conditions change (Gunderson, 2001). The general system theory has helped addressing the issue of isolation of the SC from the other systems by introducing a new way of thinking that allows for the study of interconnections among systems and considers the nature of open systems interacting with the external environment (Von Bertalanffy, 1973); nevertheless, it still is equilibrium-oriented and considers the systems as static.

The paradigm shift introduced by the panarchy theory entails transitioning from interpreting the SC as a static system to interpreting it as a becoming, socio-ecological system (Nilsson and Gammelgaard, 2012; Wieland, 2021). From this perspective, the SC should not be optimised but instead driven along desirable paths, in which any change would produce effects in other connected parts and systems in response (Biggs *et al.*, 2010; Westley *et al.*, 2002). Through a "dancing" process, the SC can transform itself towards more desirable trajectories, as a socio-ecological system would do (Wieland, 2021).

Building on the panarchy theory, Wieland (2021) conceptualised the SC as embedded in a multi-level structure, namely the panarchy, including the SC, political-economic and planetary levels. All three systems are subjected to adaptive cycles that start with the *exploitation* of resources, followed by *conservation*, in which resource capital is accumulated, making the system more rigid; then, the system enters the *release* phase, in which resources are released to prepare for a *reorganisation*, leading to socio-ecological resilience (Davoudi *et al.*, 2013; Holling, 2001). The socio-ecological resilience can be interpreted as the "magnitude of disturbance the system can absorb before it changes its structure by changing the processes and variables that control behaviour" (Wieland, 2021, p. 62). It entails some transformability of the panarchy at every level, which is not only happening but also desirable. So, at the SC level, the system may transition towards a new state, characterised by a new set of processes, structures, norms and routines, for example, by changing the relationships with its partners (Allen *et al.*, 2014; Wieland, 2021). At the political-economic level, the globalisation and growth trends we have witnessed for decades might transition towards regionalisation and degrowth (Wieland, 2021). Finally, at the planetary level, we are now reaching a point of no return by failing to maintain the global temperature rise to no more than 1.5°C, provoking an irreversible change in our climate, responsible for severe fires, melting polar ice and declining biodiversity, among other effects (IPCC, 2023).

2.2 Linking the supply chain to the other systems

Besides the adaptive cycles the three mentioned levels can go through themselves, linkages exist across-levels. The linkages imply that the adaptive cycles will mutually impact each other, further enforcing the transformative nature of the panarchy (Allen *et al.*, 2014). Wieland (2021) has represented this concept with arrows connecting the different levels, depicted as infinite shapes, providing examples of the potential linkages between them.

Taking the perspective of the SC, we can imagine it being linked to the political-economic level in a mutual relationship. The political-economic level can influence and shape the SC level through regulations and incentives. In contrast, the SC level can exert lobbying activity to report to policymakers that the current legal framework does not make sense anymore (Wieland, 2021). For example, one of the significant factors contributing to the diffusion of sustainability is the pressure from external parties (Gong *et al.*, 2019). External pressures can

be related to regulators that require firms to meet a particular set of targets; focal firms act upon this pressure, perceived as coercive, and, in turn, reverse it onto T1 suppliers (DiMaggio and Powell, 1983; Rebs *et al.*, 2018). Being required to manage the stakeholders' expectations, focal firms favour behaviours that lead to longer-term benefits rather than higher returns in the short period (Bénabou and Tirole, 2010).

Moreover, there is evidence that stakeholders should not be engaged exclusively to mitigate pressures but also to exploit their expertise. They could provide a meaningful contribution to the SC members towards the greening process from suppliers' and customers' points of view (Gualandris *et al.*, 2015; Manetti and Toccafondi, 2012; Schmidt *et al.*, 2017). Companies can initiate a dialogue with external stakeholders by recognising they are "in this boat together" (Freeman *et al.*, 2020).

A direct linkage between the planetary level and the SC also exists, as demonstrated by the current impellent shift towards the circular economy being enacted by some virtuous companies (Murray *et al.*, 2017). Recently, Allen *et al.* (2021) have proposed a dynamic, sustainable SC-circular economy nexus to adapt and develop new theories that consider the systemic perspective SCs have to face nowadays. The next section proposes the application of a relatively new theory for the SCM field: the panarchy theory.

2.3 Applying the panarchy theory to supply chain management research

The panarchy theory application to the SC domain is still at an early stage (Adobor, 2020) and is mainly focused on the field of SC resilience (Lin *et al.*, 2023) and on conceptualisation efforts (Wieland, 2021). This lack of empirical support can be explained by the difficulty in identifying the suitable unit of analysis to study a panarchy, assuming that the most common choices for SCM scholars, such as the firm, the supplier-buyer dyad, or the SC, are not suitable anymore when dealing with complex and multi-level systems (Wieland, 2021). To overcome this assumed constraint, in this paper, we are proposing to unpack the SC level into its building blocks, namely suppliers (T1 and T2), focal firms and customers, to understand how the linkages with the upper levels, namely the political-economic and the planetary levels, affect the SC transformation. When looking more into the SC level, we must recognise that the linkages established, developed and strengthened within this level, when it comes to climate change management, can be unbalanced, with differences in efforts upstream vs downstream. In this respect, Dahlmann and Roehrich (2019) identified different types of climate change engagement, depending on the degree to which the focal firm involves different supply chain partners, assuming it varies. In contrast, Wong *et al.* (2012) and Patel *et al.* (2013) highlight how firms repose their behavioural choice towards sustainability orientation on their downstream SC partners. Thus, lower tiers observe and mimic their customers, while downstream members expect their upstream partners to prioritise the same sustainability-related issues. Schmidt *et al.* (2017) and Lee *et al.* (2014) consolidate this statement, claiming that downstream suppliers (T1 and T2) find more competitive advantage in being proactive rather than waiting for their upstream partners to request actions. Additionally, T1 suppliers have been proved to have a fundamental bridging role in cascading sustainability towards lower-tier suppliers. This connecting role not only acts as a bridge to transfer downstream standards, rules and practices from focal firms, but, at times, it is intended also to allow the reverse transition of knowledge from lower tiers to the focal firm (Johnsen *et al.*, 2022). Notwithstanding the relevance of such a role, the imbalance between the upstream and downstream flow persists, and it is therefore reasonable to wonder if different tiers and the two different sides of the SC (upstream and downstream) differ in their contribution towards the SC transformation, or "supply chain dancing" (Wieland, 2021). Figure 1 depicts the conceptualisation effort foundation of this research.

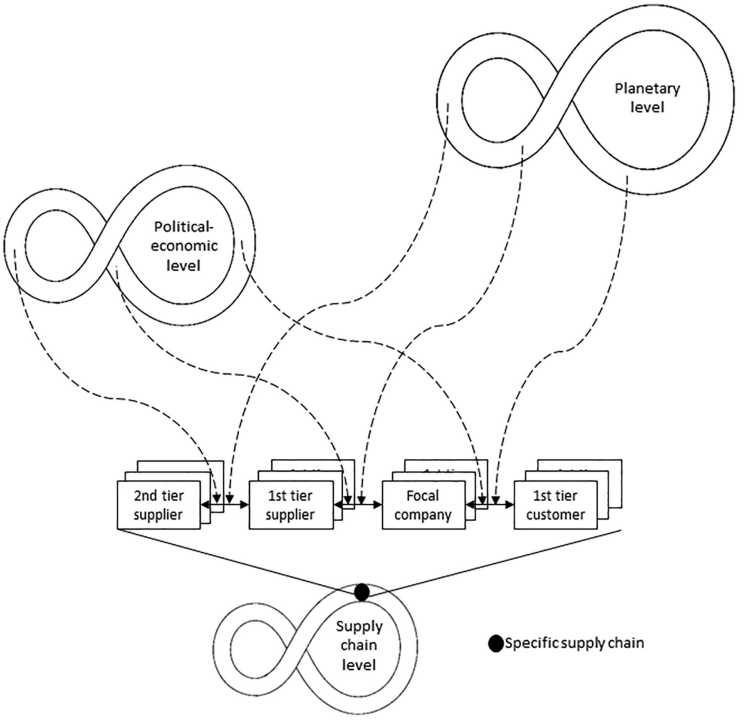


Figure 1.
Conceptual framework of the research

Source(s): Authors own creation inspired by Wieland (2021)

The conceptual framework first recognises that the three systems identified by Wieland (2021) are linked and interact by leveraging cross-level linkages (Wieland, 2021). The SC level – the focus of this research and SCM research in general – is also shaped and transformed because of the existing linkages with the other levels. In this research, we further expand the conceptualisation of the panarchy theory application to SCM by adding the recognition of the presence of within-level linkages that are bounding the actors of the SC. Moreover, when considering specific SCs, the underlying actors are affected themselves by the linkages, in case they exist, but in different ways, as each actor can be more or less responsive to and aware of the changes and the status of the political-economic and planetary levels in their adaptive cycles.

3. Methodology

3.1 Research approach

To answer the aforementioned research questions and test the existence of cross-level linkages that affect the construction of the supply chain within-level linkages, we adopt an exploratory approach based on estimating a set of econometric models. As the applications of the panarchy theory in the context of SSCM are nascent, the literature is still to be further developed to suggest concepts of interest and relative measures (Forza, 2016). According to Forza (2016, p. 80), an exploratory approach "can help researchers determine which concepts to measure in relation to the phenomenon of interest, the best way to measure them, and how to discover new facets of the phenomenon under investigation . . . [it] can be used to uncover

or provide preliminary evidence of associations among concepts. Later, it can help researchers explore the validity boundaries of a theory". Previous studies have used an explorative quantitative approach, such as Corbett and Whybark (2001) in their research on the relationship between manufacturing practices and performances, Ellram *et al.* (2007) in a preliminary study on service supply management, or Golini *et al.* (2018) when studying governance structures and economic, environmental and social upgrading.

3.2 Data source

The CDP is a globally acknowledged corporation that runs several environmental disclosure programs and provides sustainability ratings. Since 2012, investors and experts have recognised it as one of the best environmental ratings for its quality and usefulness (SustainAbility, 2012, 2020). These disclosure programs are available for multiple entities, such as companies, cities, investors and governments. In the past couple of decades, the CDP has captivated unprecedented participation, thus considerably increasing the attention on environmental issues (CDP, 2023). The CDP is recognised as the most extensive database in the world for climate-change-related data (Damert *et al.*, 2018), collecting close to $136 trillion of investor assets from partners, close to 19,000 reporting enterprises, and more than 1,100 reporting cities (CDP, 2023).

Firms can respond to one or multiple CDP questionnaires for various reasons. Among others, a firm could be requested by one of its buyers to participate in the disclosure program. This disclosure channel leads to the Supply Chain Programme (SCP), wherein all the responses provided by buyers and suppliers are stored. Once firms receive the request to participate in one or more of the CDP programs, they can either accept or reject it. Companies should also choose if they wish the CDP to publish their responses to the questionnaires on its website, making them accessible to the public, or if they would rather keep them confidential, accessible only to the requesting entities. This study will particularly draw data from the publicly available responses gathered through the SCP; therefore, the data collection procedure endured by the CDP will be further detailed. To invite its suppliers to disclose through the CDP, a firm must be affiliated with it, which means being a member of the SCP. Being a member presents several benefits, such as extra support in filling out the CDP questionnaires, individual suppliers and industry benchmarking reports, designing a pathway towards net zero goals, and brand recognition (CDP, 2022).

Considering that CDP members are known to be the buyers of the non-members (i.e. those firms that disclose through the CDP and do not invite any of their suppliers), it is hypothesised that CDP members (i.e. the inviters) are focal firms, and the non-members (i.e. the invited) are first-tier suppliers (Salvatore *et al.*, 2022). Unfortunately, the CDP does not disclose data about the dyadic relationships between members and non-members.

3.3 Sample

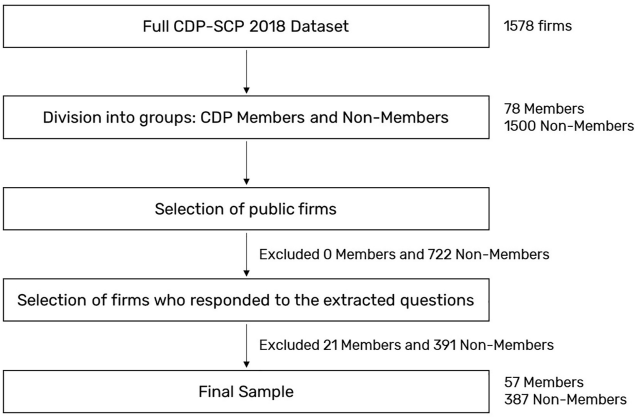
The data concerning environmental disclosure of climate change management were gathered from the CDP's SCP of 2018. Bureau Van Dijk's Orbis database was searched for companies' characteristics.

The sample selection unrolled as follows (as depicted in Figure 2):

(1) Division of the 1,578 firms into CDP members (78) and non-members (1,500).

(2) Selection of listed firms only: 78 members and 778 non-members.

(3) Exclusion of firms with one or more missing information (specific answer to a question: 21 members and 391 non-members).



Source(s): Authors own creation

Figure 2.
Sample refinement procedure

This process led to a sample of 444 firms, 57 members and 387 non-members, from 33 different countries and operating in 13 sectors (as described in Table 1). The choice to maintain a pretty heterogeneous sample was aligned with previous studies based on CDP

NACE	Continent Asia	Oceania	Europe	South America	North America	Total
A – Agriculture, forestry and fishing	0	0	0	0	1	1
B – Mining and quarrying	3	0	2	0	1	6
C – Manufacturing	82	31	70	0	117	300
D – Electricity, gas, steam and air conditioning supply	5	1	3	0	4	13
E – Water supply; sewerage, waste management and remediation activities	0	2	0	0	2	4
F – Construction	2	1	6	0	5	14
G – Wholesale and retail trade; repair of motor vehicles and motorcycles	2	0	2	1	1	6
H – Transportation and storage	6	0	7	1	5	19
I – Accommodation and food service activities	1	0	0	1	4	6
J – Information and communication	13	2	15	0	20	50
K – Financial and insurance activities	0	0	0	0	6	6
L – Real estate activities	0	0	1	1	0	2
M – Professional, scientific and technical activities	7	0	1	0	3	11
N – Administrative and support service activities	1	0	1	0	1	3
O – Public administration and defence; compulsory social security	0	0	1	0	0	1
Q – Human health and social work activities	0	1	0	0	0	1
S – Other service activities	1	0	0	0	0	1
Total	123	38	109	4	170	444

Source(s): Authors' own creation

Table 1.
Sample descriptives: continent and industry specifications

data (Villena and Dhanorkar, 2020). Moreover, our research design does not focus on the effects on performance, which may be affected by the industry or country the firm belongs to, but on the linkages within the SC, which are established and modified in every SC, independently of the sector or country. To account for potential extreme differences, we controlled for the nature of the industry, distinguishing between manufacturing and non-manufacturing sectors.

The conceptual and analytical models are based on two main assumptions:

(1) Open multi-tier SC: Each tier is contractually related only to the adjacent ones, both upstream and downstream (Mena *et al.*, 2013);

(2) Indirect management approach: Focal firms relinquish the management of lower-tier suppliers to T1 suppliers (Tachizawa and Wong, 2014);

Each tier represents the aggregate of all the firms that belong to it. Not being able to link each focal firm to its T1 and second-tier suppliers, they have been aggregated, and the most common behaviour has been observed. It is essential to highlight that the proposed model is not meant to simplify reality into a simple buyer-supplier dyad and, therefore, no longer representative in a context characterised by supply networks. The model observes the interaction of one actor with the whole pool of its direct suppliers and customers, which might also not be part of our sample.

3.4 Measures

3.4.1 Dependent variable. To assess the existence and strength of the SC within-level linkages, this work looks at the deployed strategies (explicit connections, as per Rungtusanatham *et al.*, 2003) to engage suppliers and buyers on climate change-related issues. The CDP questionnaire categorises the engagement strategies as shown in Table 2.

To answer the first research question, SC within-level linkages are measured by counting whether each firm had established at least one engagement strategy with both suppliers and customers, with exclusively suppliers or customers, or with neither of them (Dahlmann *et al.*, 2023). The variable created, *Cumulative Within-Level Linkages*, is a categorical variable distributed as reported below in Table 3.

To answer the second research question, two dependent variables have been created by counting how many different strategies were adopted by each firm in each direction, upstream or downstream. While the option "Other, please specify" could have included more than one strategy, it has been counted as one. The dependent variable is equal to 0 if the respondents reported they did not engage with any partner in the SC. *Within-Level Linkages with Suppliers* and *Within-Level Linkages with Customers* are categorical variables. Data to construct the three dependent variables have been retrieved from questions C12.1a_C1 and C12.1b_C1 from the CDP (Appendix).

Supplier engagement strategies	Buyer engagement strategies
Compliance and onboarding	Education/information sharing
Information collection (understanding supplier behaviour)	Collaboration and innovation
Engagement and incentivisation (changing supplier behaviour)	Other, please specify
Innovation and collaboration (changing markets)	
Other, please specify	

Source(s): Authors' own creation

Table 2.
Supply chain engagement strategies

The engagement strategies mapped by the CDP reflect different practices connected to SC collaboration to achieve the common goal of fighting climate change-related issues. SC collaboration is defined by Um and Kim (2019) as a "shared process in which a buyer and a supplier closely work from planning to execution for the achievement of a joint goal" (p. 99). Previous research has also acknowledged the concept of sustainable SC collaboration. Blome *et al.* (2014) define sustainability collaboration as incorporating sustainable management along the SC towards suppliers and customers. Moreover, they claim that sustainability collaboration requires devoting resources to joint activities to address sustainability issues, developing a high level of knowledge exchange, and directly involving suppliers and customers in planning and implementing environmental solutions. Rezaei Vandchali *et al.* (2020) proposed a conceptual framework to classify relations management strategies (RMS) for sustainability in a SC network. These strategies are meant for focal firms to manage their suppliers considering their interest in sustainability and the supply network's core characteristics, namely dependency, distance, power and transparency (Kim *et al.*, 2011) – the RMS scale from *Non-Compliance* to *Transactional*, *Dictatorial*, and finally, *Collaborative*. The relationship established is increasingly tight on this scale, from a starting point where no form of compliance for the supplier selection procedure is required (*Non-Compliance*) through information sharing and imposition of standards (*Transactional*), monitoring and incentivisation (*Dictatorial*) to direct involvement to achieve sustainable performance improvements (*Collaborative*). As these management decisions strongly depend on the firms' environment, enforcing a dictatorial behaviour on a supplier does not imply that the others would be coerced into the desired behaviour. In fact, collaboration and coercion among the firm's stakeholders are not mutually exclusive (Savage *et al.*, 2010). For this reason, we do not adopt a hierarchical scale to map who adopts the highest degrees of relationship management for sustainability, but we observe the cumulative engagement strategies that each firm establishes with its partners.

3.4.2 Independent variables. The *Linkages with the Planetary Level* were measured using three proxies:

(1) The financial exposure to climate change-related risks indicates how much the firm perceives the planetary issues. Data to construct this variable, *Environmental Risk Financial Exposure*, have been retrieved from question C2.3a_C9 from the CDP (Appendix).

(2) The total number of improvement initiatives related to energy efficiency and process optimisations implemented by the company reflects how the firm reacts in terms of *Environmental Effort* to the perceived issues. Data to construct this variable have been retrieved from question C4.3b_C3 from the CDP (Appendix).

(3) The total emission reduction generated by the implemented initiatives also considers the *Environmental Effectiveness* of the contribution the company is giving back to the planet. Data to construct this variable have been retrieved from question C4.3b_C3 from the CDP (Appendix).

Table 3. Cumulative supply chain within level linkages

Cumulative supply chain within level linkages	Supply chain position		Total
	First-tier suppliers	Focal firms	
Within Level – Neither	30	0	30
Within Level – Either one (suppliers or Customers)	127	13	140
Within Level – Both (suppliers and Customers)	230	44	274
Total	387	57	444

Source(s): Authors' own creation

SC practitioners attribute an enormous value to risk management, as disruptions could significantly damage the firms' finances and reputation, mainly if the damaging event is related to climate change or, more generally, to sustainability (Bonini and Swartz, 2014; Hartmann and Moeller, 2014). These events happen more often due to dispersed and minor suppliers that are invisible to the public (Chand and Tarei, 2021; Plambeck *et al.*, 2012; Roth *et al.*, 2008; Wilhelm *et al.*, 2016a). Therefore, mapping the SC, evaluating where such risks could happen and managing them is becoming indispensable. The literature discusses how risks can be managed along the SC and claims that firms acting as standalone entities cannot effectively mitigate risks; inter-firm actions are needed (Colicchia and Strozzi, 2012; Kleindorfer and Saad, 2009; Li *et al.*, 2015). Inter-firm collaboration is a valuable strategy to mitigate risks when the parties involved do not behave opportunistically, and therefore, their objectives are aligned (Cao *et al.*, 2010; Eisenhardt, 1989). When such conditions are verified, the allocated contingency can be adequately adjusted to the purpose, and the vulnerability to disruptions decreases (Jüttner, 2005; Li *et al.*, 2015; Nishat Faisal *et al.*, 2006; Norrman and Jansson, 2004; Tang and Nurmaya Musa, 2011).

When dealing with environmental sustainability, the choice of an organisation to make investments could not have the sole objective of obtaining an economic profit. Climate changes and the strong environmental impacts that threaten companies could lead to undertaking initiatives and investments to mitigate the risks deriving from the lack of sustainability and minimise losses. When being risk-averse, the company could be inclined to invest to prevent risks from manifesting and generating a loss; conversely, when firms show risk propensity, they might choose to take the risk itself, limiting investments related to mitigations. The investment is, therefore, aimed at keeping the company competitive in the market by reducing the probability and the impact that the risk could have on the company itself. The role of suppliers towards the SC greening process is vital (Mahapatra *et al.*, 2021), as the whole SC can benefit from the suppliers' practices to reduce their carbon footprint and the spread of this behaviour upstream, making the final product more sustainable and ecologically efficient (Mahapatra *et al.*, 2021).

The *Environmental Effectiveness* and *Environmental Risk Financial Exposure* values have been weighted by each company's total sales, retrieved from ORBIS, to account for the firm's scale factor (Gallego-Álvarez *et al.*, 2014). The *Environmental Effort* variable has been square-root-transformed to reduce the skew, and the weighted *Environmental Risk Financial Exposure* variable has been log-transformed.

Finally, the *Linkages with the Political-Economic Level* were measured through *Policymaker Engagement*. An ordinal variable was created to evaluate the cumulative number of active engagement channels (defined by the CDP as trade associations, funding research organisations, direct engagement and others) and a group of three dummy variables accounted for the presence of actions in each of the defined channels. The variables thus reflect the activation of one or multiple linkages with the political-economic level. The ordinal variable has been square root-transformed to reduce the skew. Data to construct the four independent variables have been retrieved from question C12.3 (Appendix).

3.4.3 Control variables. The control variables observed are the firm's size and industry sector to account for exogenous phenomena, in line with previous studies (Jira and Toffel, 2013; Villena and Dhanorkar, 2020). The firm's size was measured using the number of employees. This value was retrieved from ORBIS and has been log-transformed to reduce the skew. Although they are subject to greater stakeholder scrutiny over their sustainability participation and are more likely to publish environmental information (Locke *et al.*, 2007; Reid and Toffel, 2009), larger companies are more involved in greenwashing (Wickert *et al.*, 2016). The firm's industrial sector was retrieved from ORBIS as the "Main industrial sector"; the sample distribution according to the industry is shown in Table 1. As a control variable, we considered a dummy variable equal to 1 if the company belongs to a manufacturing sector

(class C in Table 1), equal to 0 otherwise. The structure of the SC, in terms of the number of actors and their engagement efforts, can be very different for manufacturing and non-manufacturing industries. For the purposes of our study, which considers the linkages along the SC instead of performance measures as a dependent variable and considering the constraints concerning the number of observations, we decided not to include other control variables.

3.5 Model specifications

The Appendix reports all the questions extracted from the CDP questionnaire and, when applicable, their relative multiple-choice answers. Table 4 shows the pairwise correlation matrix and the descriptive statistics for all the considered variables.

Being the dependent variable categorical, the performed analyses adopted ordered logistic regressions (Long and Freese, 2014). The results reported in the next section show the regression coefficients in the form of odds ratios (OR) calculated as $OR = e^{\beta}$, where β is the regular regression coefficient. If the OR is higher than 1, it shows the probability of an increase in the dependent variable level of OR-1; if it is lower than 1, it shows the likelihood of a decrease in the outcome levels (Long and Freese, 2014). In medical studies, such as epidemiology, the ORs are frequently used to identify risk and protective factors against diseases (Schmidt and Kohlmann, 2008). In SCM, we interpret the OR as developing and risk factors.

Before running the analyses, the dataset was searched for the presence of heteroscedasticity through the Breush-Pagan/Cook-Weisberg test (Breusch and Pagan, 1979; Cook and Weisberg, 1983), resulting in the rejection of the constant variance hypothesis and thereby claiming heteroscedasticity for both supplier and buyer collaboration. To account for heteroscedasticity, the estimated variance-covariance matrix considered error terms clustered by the primary industrial sector, which is believed to address industry differences. A robust regression was evaluated to confirm this hypothesis and compare the standard errors. As the robust errors are larger than the clustered ones, it is reasonable to assume the latter estimates are more accurate than the former, thus concluding that clustering by industry-main-sector is a valid strategy.

After running the analyses, each model was tested to respect the parallel regression assumptions using the Brant test to support the reliability of the regressions (Long and Freese, 2014). An ordered logistic regression runs under the assumption that the relationship between each pair of outcome levels is the same; this allows for estimating a single coefficient for each variable (Long and Freese, 2014). Each variable in each equation did not violate this assumption; therefore, the results presented are statistically relevant.

4. Results

The results raise interesting issues to reflect on. First, it is interesting to look at the descriptive statistics on the *Supply Chain Within-Level Linkages with Buyers and Suppliers*, which confirm focal firms' efforts in spreading sustainability. In particular, the mean value of the *Supply Chain Within-Level Linkages with Suppliers* for the focal firms is 1.58, with only one firm disclosing that it was not engaging with its suppliers. The response to this effort is relatively scarce, as the *Supply Chain Within-Level Linkages with Customers* for the T1 suppliers has a mean value of 0.83, possibly inflated by those who answered that collaboration meant filling in the CDP questionnaire. However, focal firms' effort is reflected in the much higher value of the *Supply Chain Within-Level Linkages with Suppliers* from T1 suppliers, with a mean value of 1.05. These values suggest that, on average, SC linkages are more easily developed and strengthened with suppliers than with customers, and these efforts tend to fade as we move up in the SC.

Table 4. Pairwise correlation and descriptive statistics

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Supply chain level												
(1) Cumulative within-level linkages	1.000											
(2) Within-level linkages with Suppliers	0.531*	1.000										
(3) Within-level linkages with Customers	0.679*	0.252*	1.000									
Planetary level												
(4) Environmental risk financial exposure	0.069	0.036	0.028	1.000								
(5) Environmental effectiveness	0.050	0.007	0.045	0.187*	1.000							
(6) Environmental effort	0.137*	0.185*	0.139*	−0.032	−0.070	1.000						
Political level												
(7) Overall policy maker engagement	0.296*	0.317*	0.237*	−0.057	0.024	0.171*	1.000					
(8) Direct Engagement with PM	0.167*	0.244*	0.155*	−0.045	0.042	0.104*	0.764*	1.000				
(9) Trade association	0.190*	0.176*	0.116*	0.037	0.019	0.089	0.436*	0.215*	1.000			
(10) Funding research Organisations	0.188*	0.205*	0.138*	−0.119*	−0.023	0.081	0.684*	0.368*	0.122*	1.000		
Control variables												
(11) Number of employees	0.247*	0.170*	0.161*	−0.225*	−0.231*	0.122*	0.156*	0.100*	0.064	0.099*	1.000	
(12) Industrial sector	0.147*	0.125*	0.218*	−0.059	−0.041	0.123*	0.213*	0.177*	−0.012	0.139*	0.117*	1.000

	FF; T1S	FF; T1S	FF; T1S	FF; T1S	FF; T1S	FF; T1S	FF; T1S	FF; T1S	FF; T1S	FF; T1S	FF; T1S	FF; T1S
No. of observations	57; 387	57; 387	57; 387	57; 387	57; 387	57; 387	57; 387	57; 387	57; 387	57; 387	57; 387	57; 387
Mean	1.77; 1.52	1.58; 1.05	0.912; 0.835	2.46; 5.09	0.001; 0.0004	2.2; 2.01	2.74; 2.09	0.526; 0.295	0.93; 0.858	0.789; 0.601	11; 10.2	1.33; 1.32
SD	0.423; 0.637	0.963; 0.753	0.576; 0.635	12.9; 49.5	0.006; 0.003	0.638; 0.782	0.936; 1.14	0.504; 0.457	0.258; 0.35	0.411; 0.49	1.2; 1.22	0.476; 0.468

Note(s): *$p < 0.05$
FF *Focal firms*, T1S *First-tier Suppliers*
Source(s): Authors' own creation

The results of the ordered logistic regressions are shown in Tables 5 and 6 and address RQ1 and RQ2, respectively. As explained in the method section, the results of the analyses are explained using the odds ratios obtained as $OR = e^{\beta}$.

First, the relations between cross-level linkages and SC within-level linkages are presented in Table 5. Particularly, *Cumulative Supply Chain Within-Level Linkages* are not always affected by the *Planetary Level*. Indeed, the only cross-level linkage that significantly and positively relates with the cumulative within-level linkages is *Environmental Risk Financial Exposure* (odds ratio (1) 1.024, (2) 1.030, (3) 1.026, (4) 1.025, (5) 1.030).

Moreover, *Cumulative Supply Chain Within-Level Linkages* are always positively related with the *Political-Economic Level* in all its forms, whether it is through *Cumulative Policy Maker Engagement* (odds ratio (1) 1.574, (2) 1.560) or the single policymaker engagement strategies *Direct Engagement with Policy Makers* (odds ratio (3) 1.933), *Trade Association* (odds ratio (4) 2.250), and *Funding Research Organisations* (odds ratio (5) 1.826). Finally, it is observed that the industrial sector is not particularly effective in predicting the extent of the

Cross-level linkage with	Cumulative supply chain within-level linkages (1) [Odds Ratio, *p*-value]	Cumulative supply chain within-level linkages (2) [Odds Ratio, *p*-value]	Cumulative supply chain within-level linkages (3) [Odds Ratio, *p*-value]	Cumulative supply chain within-level linkages (4) [Odds Ratio, *p*-value]	Cumulative supply chain within-level linkages (5) [Odds Ratio, *p*-value]
Planetary level					
Environmental risk financial exposure	*1.024** *(0.035)*	*1.030** *(0.049)*	*1.026** *(0.041)*	*1.025** *(0.023)*	*1.030** *(0.039)*
Environmental effectiveness	29.376 (0.330)		29.534 (0.253)	22.913 (0.352)	24.224 (0.404)
Environmental effort		1.121 (0.492)			
Political-economic level					
Cumulative policy maker engagement	*1.574*** *(0.000)*	*1.560*** *(0.000)*			
Direct engagement with PM			*1.933*** *(0.001)*		
Trade association				*2.250*** *(0.000)*	
Funding research organisations					*1.826*** *(0.002)*
Control variables					
Industrial sector	0.793 (0.302)	0.803 (0.324)	0.719 (0.137)	*0.620** *(0.014)*	0.712 (0.076)
Number of employees	*1.523*** *(0.000)*	*1.508*** *(0.000)*	*1.549*** *(0.000)*	*1.538*** *(0.000)*	*1.554*** *(0.000)*
Observations	444	444	444	444	444
Pseudo R^2	0.081	0.082	0.061	0.058	0.061

Note(s): *p*-values in parentheses
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$
Source(s): Authors' own creation

Table 5. Ordered logistic regression models – cross-level linkages influencing supply chain within-level linkages

Cross-level linkage with		Focal firms' SC within-level linkages with suppliers (1) [Odds Ratio, *p*-value]	First-tier suppliers' SC within-level linkages with suppliers (2) [Odds Ratio, *p*-value]	Focal firms' SC within-level linkages with customers (3) [Odds Ratio, *p*-value]	First-tier suppliers' SC within-level linkages with customers (4) [Odds Ratio, *p*-value]
Model 1	Industrial Sectors	1.006	0.687	0.472	*0.459***
		(0.991)	(0.133)	(0.161)	*(0.000)*
	Number of Employees	1.123	*1.286***	1.109	*1.3183***
		(0.203)	*(0.000)*	(0.252)	*(0.000)*
	Observations	57	387	57	387
	Pseudo R^2	0.002	0.016	0.018	0.035
Model 2	Political-economic level – Cumulative Policy Maker Engagement	*1.739***	*1.753***	*1.817**	*1.593***
		(0.000)	*(0.007)*	*(0.021)*	*(0.000)*
	Planetary level – Environmental Risk Financial exposure	0.999	*1.003***	*1.208**	*1.001***
		(0.873)	*(0.000)*	*(0.041)*	*(0.000)*
	Planetary level – Environmental Effectiveness	*0.00003***	0.000	0.000	9,702,811
		(0.003)	(0.564)	(0.280)	(0.591)
	Observations	57	387	57	387
	Pseudo R^2	0.029	0.046	0.092	0.036
Model 3	Political-economic level – Direct engagement with PM	1.703	*2.985**	5.104	*2.029***
		(0.135)	*(0.043)*	(0.417)	*(0.000)*
	Planetary level – Environmental Risk Financial exposure	0.992	*1.002***	1.278	*1.001***
		(0.634)	*(0.000)*	(0.106)	*(0.000)*
	Planetary level linkages – Environmental Effectiveness	0.936	0.000	0.003	97289.265
		(0.133)	(0.431)	(0.986)	(0.762)
	Observations	57	387	57	387
	Pseudo R^2	0.003	0.019	0.074	0.009
Model 4	Political-economic level linkages – Trade Association	1.865	*2.651***	1.279	*2.242***
		(0.503)	*(0.001)*	(0.139)	*(0.000)*
	Planetary level – Environmental Risk Financial exposure	0.995	*1.003***	1.142	1.001
		(0.158)	*(0.000)*	(0.056)	(0.060)
	Planetary level linkages – Environmental Effectiveness	0.000	0.000	1.33	2620.843
		(0.995)	(0.459)	(0.596)	(0.673)
	Observations	57	387	57	387
	Pseudo R^2	0.012	0.024	0.058	0.018

(*continued*)

Table 6. Ordered logistic regression results – effect on supply chain within-level linkages structuration at different supply chain positions

	Cross-level linkage with	Focal firms' SC within-level linkages with suppliers (1) [Odds Ratio, *p*-value]	First-tier suppliers' SC within-level linkages with suppliers (2) [Odds Ratio, *p*-value]	Focal firms' SC within-level linkages with customers (3) [Odds Ratio, *p*-value]	First-tier suppliers' SC within-level linkages with customers (4) [Odds Ratio, *p*-value]
Model 5	Political-economic level linkages – Funding Research Organisations	1.312 (0.773)	*2.469*** *(0.002)*	2.177 (0.196)	*1.813**** *(0.000)*
	Planetary level – Environmental Risk Financial exposure	0.993 (0.600)	*1.003**** *(0.000)*	1.135 (0.161)	*1.001**** *(0.000)*
	Planetary level linkages – Environmental Effectiveness	0.014 (0.396)	−0.007 (0.774)	0.175 (0.910)	79,288,857 (0.521)
	Observations	57	387	57	387
	Pseudo R^2	0.0026	0.024	0.069	0.012
Model 6	Planetary level linkages – Environmental Effort	1.502 (0.450)	*1.386**** *(0.000)*	1.098 (0.525)	1.313 (0.114)
	Planetary level – Environmental Risk Financial exposure	0.996 (0.703)	*1.003**** *(0.000)*	*1.186** (0.019)	*1.002**** *(0.000)*
	Political-economic level – Cumulative Policy Maker Engagement	*1.712**** *(0.000)*	*1.695** *(0.021)*	*1.766** *(0.016)*	*1.548**** *(0.000)*
	Observations	57	387	57	387
	Pseudo R^2	0.035	0.053	0.091	0.041

Note(s): *p*-values in parentheses
**p* < 0.05, ***p* < 0.01, ****p* < 0.001
Source(s): Authors' own creation

Table 6.

Cumulative Supply Chain Within-Level Linkages, being statistically significant only in model (4).

Having established the aforementioned relations that prove the significance of cross-level linkages in explaining *Supply Chain Within-Level Linkages*, we proceed to investigate whether the effect of the cross-level linkages varies across supply chain positions and the direction in which the within-level linkages are strengthened (i.e. upstream and/or downstream).

The analyses were performed separately for each set of variables to avoid over-complicated models, given the limited number of observations. For the sake of rigour, the results for the full models were checked, and they were aligned, in terms of signs, with the ones in Table 6. For each set of variables, four models were tested:

(1) *Supply Chain Within-Level Linkages* with suppliers as the dependent variable for focal firms.

(2) *Supply Chain Within-Level Linkages* with suppliers as the dependent variable for T1 suppliers.

(3) *Supply Chain Within-Level Linkages* with customers as the dependent variable for focal firms.

(4) *Supply Chain Within-Level Linkages* with customers as the dependent variable for T1 suppliers.

Looking at Model 1, none of the control variables in the focal firms' group is significant. In contrast, in the T1 suppliers group, an increase in the number of *Employees* is associated with a higher log-probability of deploying one more strategy to collaborate with *Suppliers* and *Buyers* (odds ratio: (2) 1.286; (4) 1.3183) and being a *Manufacturer*, that is, belonging to a manufacturing sector instead of a service sector, decreases the log-probability of a better outcome by a factor of 0.459 (odds ratio (4)). Therefore, big service companies for first-tier suppliers are more likely to have stricter linkages with buyers. For the same group of companies, only size, not the sector, matters in developing stronger linkages with their suppliers.

The results of Model 2 present a strong positive relation between the *Environmental Risk Financial Exposure* and *Supply Chain Within-Level Linkages with Suppliers* for first-tier suppliers and *Supply Chain Within-Level Linkages with customers* for both groups (odds ratio: (2) 1.003; (3) 1.208; (2.4) 1.001). Therefore, the perception of the planetary level linkage has more substantial effects on T1 suppliers to strengthen the within-level linkages with suppliers. In contrast, both focal firms and T1 suppliers are pushed towards stronger linkages with customers.

Looking at the *Environmental Effectiveness*, the results (Model 2) show that it exceptionally reduces *Supply Chain Within-Level Linkages with Suppliers* for the focal firms' group (odds ratio: (2) 0.00003). The estimated coefficient and standard error for the variable *Environmental Effectiveness* are substantial due to a strong skewness: though it has been accounted for, it remains significant. Unexpectedly, when the signals received from the planetary level are not only transformed into actions but also allowed to achieve positive outcomes in emission reduction, focal firms stop transferring the good practices to the rest of the SC as they weaken the linkages with their suppliers.

Investigating the effect of the *Environmental Effort*, the results of Model 6 show that this variable is again correlated with *Supply Chain Within-Level Linkages With Suppliers* only for the T1 Suppliers group; namely, implementing one more initiative increases the log-odds of deploying one more strategy to *Supply Chain Within-Level Linkage With Suppliers* by a factor of 1.386 (odds ratio: (2) 1.386). This result means that when the signals received through the planetary level linkage are transformed into actions, only T1 suppliers strengthen their upstream linkages. At the same time, focal firms do not significantly impact the within-level linkages.

Concerning the engagement of policymakers, the results (Model 2) present strong correlations between the extent of diverse strategies to engage policymakers with the *Supply Chain Within-Level Linkages With Suppliers* and *Buyers* in both groups. Engaging policymakers in one more channel nearly doubles the log odds of establishing one more *Supply Chain Within-Level Linkage* with any SC partners (odds ratios: (1) 1.739; (2) 1.753; (3) 1.817; (4) 1.593). Notably, in the T1 Suppliers group, each one of these channels (*Trade Associations*, *Funding Research Organisation* and *Direct Engagement*) is positively correlated with the outcome (Model 3: Odds ratio *Political-Economic Level Linkages–Direct Engagement with PM*: (2) 2.985, (4) 2.029; Model 4: Odds ratio *Political-Economic Level Linkages–Trade Association*: (2) 2.651; (4) 2.242; Model 5: Odds ratio *Political-Economic Level Linkages–Funding Research Organisations*: (2) 2.469; (4) 1.813). Figure 3 summarises the results by graphically showing the linkages influencing each SC within-level linkages.

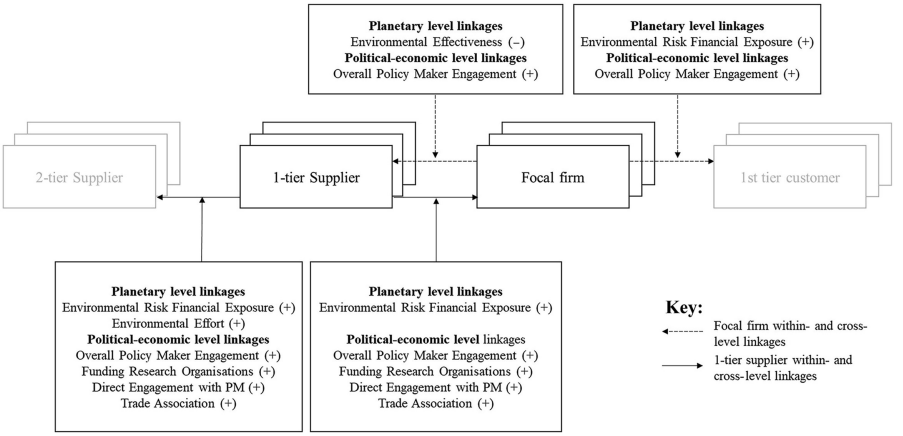


Figure 3.
Graphical representation of the results

Source(s): Authors own creation

5. Discussion

The first research question addressed in this study focused on identifying the cross-level linkages that explain the SC within-level linkages related to sustainability issues. In addition, we explored with our second research question if these effects changed across SC positions. The scope of the study was further extended to understand whether the direction of the linkages, upstream or downstream, was highlighting further differences.

Our results show the existence of *Cross-Level Linkages* that affect the transformation of the *Supply Chain Within-Level Linkages.* A linkage from the *Planetary Level* that persists and permeates the whole SC is through the *Environmental Risk Financial Exposure,* which is associated with strengthening the *Supply Chain Within-Level Linkages*. This result confirms the claims in the literature, according to which collaborating in the SC is a valuable mitigation strategy (Colicchia and Strozzi, 2012; Kleindorfer and Saad, 2009; Li *et al.*, 2015). Nuances are given by the SC position and the direction of the linkage. Indeed, this cross-level linkage proves to be equally relevant in structuring upstream and downstream within-level linkages at the T1 suppliers' position; meanwhile, at the focal firms' position, it is relevant only in the development of downstream-oriented linkages. A possible explanation is connected to a visibility and reputational issue. The more a firm is exposed to climate-change-related risks, the more willing it could be to extend the linkages with downstream partners to communicate and show effort-taking actions. While this seems to be true for T1 suppliers, we observe focal firms to be less responsive to this mechanism. Rather, it appears that focal firms are not susceptible enough to the higher risks lying far upstream (Chand and Tarei, 2021; Wilhelm *et al.*, 2016a), while using the knowledge thereof to tighten the linkages downstream.

Also the other cross-level linkages tying the *Planetary* and the *SC Level*, through the firms' *Environmental Effectiveness* and *Effort*, have been observed to be relevant only when differentiating for SC position and directionality of the linkage. Indeed, these cross-level linkages have been observed to support the development of exclusively upstream-oriented *Supply Chain Within-Level Linkages*. In particular, the linkage through *Environmental Effectiveness* is associated with a de-structuration of *Supply Chain Within-Level Linkages* only at the focal firms' position; meanwhile, the linkage through *Environmental Effort* is associated with the development of *Supply Chain Within-Level Linkages* only at the T1 suppliers' position. Focal firms seem to seek self-sufficiency and adopt a focused approach that allows for deconstructing SC linkages if the firm can be independent in decarbonising.

Instead, the behaviour shown by T1 suppliers is a clue that these firms generally approach emission reduction with a "see what sticks" strategy rather than a wiser and more long-term strategy. The more effort they can put into climate-related issues, independently from their actual efficacy, the more legitimacy they gain (DiMaggio and Powell, 1983), and the more they are facilitated to strengthen their SC linkages.

Political-Economic Level Linkages have been observed to be a robust and effective driver of *Supply Chain Within-Level Linkages*, independently of the direction of the within-level linkage. Our results align with those presented by Rebs *et al.* (2018), who allege that stakeholders, claiming their interest towards non-economic goals, pressure firms into a higher orientation towards sustainability. Nevertheless, the SC position does determine a difference between the linkages that affect the structuration of the *Supply Chain Within-Level Linkages*. Indeed, while at the focal firm position we observe the relevance only of the linkage through the *Cumulative Policymaker Engagement*, at the T1 suppliers position, we observe that every linkage through each single engagement channel with the policymaker and the cumulative engagement are effective in transforming the *Supply Chain Within-Level Linkages*. In our case, it is observed that this behaviour seems more influential on T1 suppliers rather than focal firms. This result confirms the difference in capabilities between the two tiers. Focal firms, considered early adopters, started approaching climate change issues decades ago. Now, they can communicate with policymakers and endure their pressures (Delmas and Toffel, 2004; Schmidt *et al.*, 2017). Instead, T1 suppliers have recently been acknowledged as crucial in the diffusion of sustainability in the SC and, therefore, are experiencing scrutiny and pressure from policymakers. T1 suppliers could be interested in capitalising on policymakers' resources and knowledge and exploiting it to their advantage to gain legitimacy and further develop valuable SC linkages (Wassmer *et al.*, 2014). An important matter to be further investigated is the nature of mechanisms generating the extreme sensitivity of T1 suppliers to policymakers. Is it related to suffering from power mechanisms or a sign of resources and knowledge exploitation?

The study achieved its theory elaboration purposes and supports the relevance of panarchy theory in the SSCM field. The results contribute to the identification of relevant cross-level linkages that impact the SC system's capability of augmenting its connectedness by accumulating capital and building its internal controllability (Holling, 2001; Mirzabeiki and Aitken, 2023; Wieland, 2021). Particularly, we conceptualise that such capability is acquired through the extension of *Within-Level Linkages*, extending to the panarchy theory the concept of SC linkages (Rungtusanatham *et al.*, 2003).

Moreover, this study confirms how SC position is a non-negligible contextual factor in explaining why firms perceive the cross-level linkages differently, and extends the SSCM literature by proving its relevance also in the context of inter-organisational SC linkages (Kim *et al.*, 2022; Matos *et al.*, 2020; Mena and Schoenherr, 2020; Schmidt *et al.*, 2017; Stekelorum *et al.*, 2023). We further highlight that the directionality of the linkages is another contextual variable that has been overlooked. Indeed, we empirically show that linkages directed upstream and downstream have different antecedents and should therefore be differentiated.

Figure 4 summarises the final conceptual framework resulting from our empirical study, which conceptualises the view of the SC actors of the panarchy cross-level linkages effects.

6. Conclusion

This study investigates the application of the panarchy theory to the study of SC linkages for sustainability management. In a context characterised by multi-tier and highly fragmented supply chains, understanding what cross-level linkages affect the SC within-level linkages, operationalised as the engagement concerning climate management issues among different upstream and downstream actors, is relevant to implementing effective practices and

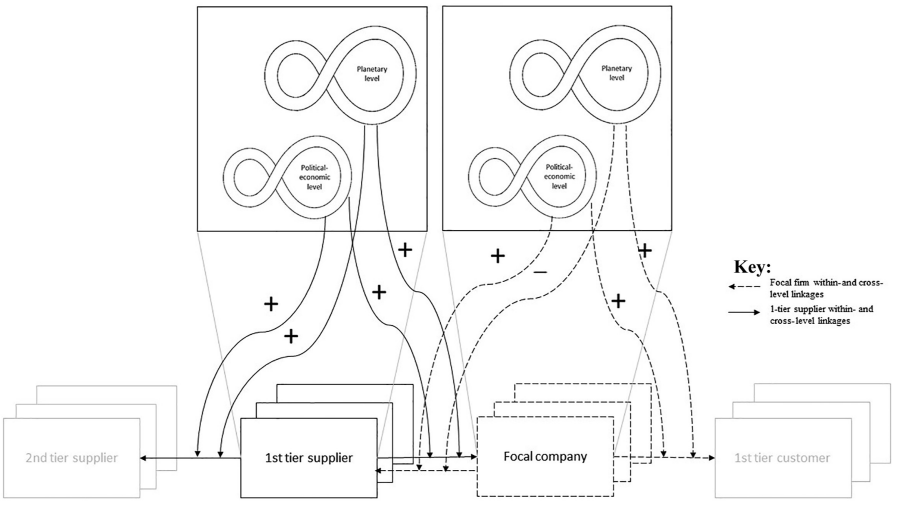


Figure 4.
Final conceptual framework – a supply chain view on the panarchy theory

Source(s): Authors own creation

initiatives directed towards higher sustainability and climate change reduction. The study adopted data gathered from the CDP within its SCP, in which large buyers, namely focal firms, invite their suppliers, namely T1 suppliers, to respond to a questionnaire as part of their supplier selection procedure. The data provide rich information regarding the engagement and collaboration activities put in place with both suppliers and customers, as well as data on CO_2 emissions, climate change risk exposure, climate change initiatives and engagement with policymakers.

The study is one of the first in SSCM to propose a different perspective by looking at what fosters or hinders the *Supply Chain Within-Level Linkages* for sustainability at the different levels of the SC. The findings highlight the relevance of *Planetary Level Linkages*, particularly *Financial Exposure to Climate-Change-Related Risks*, which have been assessed as fundamental in downstream collaboration for focal firms and T1 suppliers. Instead, *Environmental Investments*, measured in terms of reductions of CO_2 emissions achieved, seem trivial for focal firms and randomly approached by T1 suppliers. Finally, *Political-Economic Level Linkages*, measured as *Policymaker Engagement,* are exploited by T1 suppliers to reduce the pressure to comply with sustainability requirements and extract knowledge and capabilities not yet developed from them.

This work contributes to the literature on SSCM by providing empirical support to the panarchy theory and expanding it by adding the conceptualisation of the SC within-level linkages, well acknowledged in the SCM field. Moreover, the study observes why firms should develop SC linkages more, not limiting the considerations to why focal firms should develop SC linkages with T1 suppliers but also observing why the reverse should happen, along with why T1 suppliers should develop SC linkages with lower-tier suppliers and focal firms with the end customers. In addition, the study demonstrates the suitability of the panarchy theory as a lens to frame the relevant factors influencing SC within-level linkages, regardless of the position in the SC. On the other hand, we demonstrate how the SCM perspective could enrich the conceptualisation derived from applying the panarchy theory.

The study also provides practical contributions to managers of both focal firms and T1 suppliers by showing them what stimulates the efforts of the respective partners in fostering

the linkages. T1 suppliers' managers are now aware that the focal firms they are linked with are mainly pushed by the increase in CO_2 emissions (worst environmental performance) and the rise in the channels through which external stakeholders are engaged to drive policymaking for climate change. Moreover, focal firms are now aware that besides the pressure of even a single channel used to engage with external stakeholders, a higher awareness of the climate change risk exposure will push their T1 suppliers to engage more in sustainability-oriented within-level linkages. Finally, through our results, policymakers can understand the power they can exert on the different SC actors to stimulate their collaborative efforts towards sustainability. While a simultaneous action through multiple channels would be requested to stimulate focal firms, T1 suppliers would be sensitive to the pressures exerted by a single channel activated with policymakers through direct engagement, trade associations or funding research associations.

The research presents some limitations, starting from the inability to establish whose firm the suppliers are and linking every one of them to its focal firm(s). In this research, we considered the specific firm, a focal firm or a T1 supplier, as the focus of the analysis and the extent to which it is linked with the pool of suppliers and customers. Future research could dig deeper into the linkages in place with specific suppliers and customers along the SC, although this was out of the scope of this research. Given the premises on the CDP-SCP, the values of *Supply Chain Within-Level Linkages With Buyers* could have been inflated as several non-member respondents specified that engagement meant solely answering the questionnaire. Despite this, we believe that even filling in the CDP questionnaire is the first mean of information sharing with the focal firm. Moreover, the questionnaire requires the respondent to collect multiple data and start considering its initiatives and actions towards climate change adaptation and mitigation. We believe that the sample selection performed at the beginning of the study and the support that the CDP provides while answering limited the biases potentially generated by ill-answered questionnaires. Though the firms that respond to the questionnaire have various behaviours concerning sustainability, those in the sample appear to be relatively advanced, at least in terms of environmental disclosure. The motivation could be found in the governance section of the CDP questionnaire, where 431 of 444 firms disclosed having a person responsible for sustainability on their board, and 425 out of 444 firms reported having implemented incentive plans to reward the achievement of sustainable goals. Future developments could corroborate this appearance by retrieving the scores that the CDP attributes to each respondent, understanding how more and less sustainable firms operate, and extending the sample to comprise firms that are not so advanced in sustainability management.

Another limitation lies in the variables chosen as proxies for the cross-level and within-level linkages; the choice was somehow limited by the data available through the CDP questionnaire, which was not designed specifically for our research. Particularly, we had to restrict our study to consider the linkages directed towards the management of climate issues to limit the scope of the work and avoid potential confounding effects. Despite this limitation, the results still provide exploratory evidence of the suitability of panarchy theory as a lens through which to observe the SC and its embeddedness into the socio-ecological system. Of course, while the panarchy theory would assume bidirectional linkages among the planetary, political-economic and SC levels, in our study, we were only able to conceptualise and test the mono-directional connection going from the planetary and political-economic levels toward the supply chain level. SSCM scholars will have the opportunity to consider this bidirectionality in future endeavours. Finally, as cross-sectional data were used, we could not formally test causality even if the relationships found were theoretically sound. Further research endeavours relying on longitudinal data will have the opportunity to confirm the causal relationship and test additional nuances concerning the time period needed to transfer the evolutionary dynamics of the planetary and political-economic level to the SC level and vice versa.

In future research, the exact definition of the supply network will be crucial, which would facilitate the comparison of the observed behaviour by the multi-tier SC structure classified by Mena *et al.* (2013). Furthermore, by mapping the SCs and establishing the links between the different firms, the conceptual framework suggested by Rezaei Vandchali *et al.* (2020) could be precisely applied, thereby defining the collaboration strategies not only by the objective thereof but also on the parameters that characterise a supply network, namely dependency, distance, power and transparency (Kim *et al.*, 2011). Another attractive future research opportunity regards the different reactions to disruptive environmental or political-economic events and/or changes of SCs displaying within-level linkages characterised by different strengths and/or either balanced or unbalanced SC linkages strength upstream and downstream. Finally, it would be interesting to analyse the interaction and/or mediation effects between the planetary and political-economic levels and test them through a multi-level regression analysis.

This work finally challenges the usual perspective taken in SSCM research and suggests that researchers currently approaching sustainability ask themselves the following question: "When studying sustainability, is the usual performance-oriented perspective the right approach?". In this study, we inverted the perspective and considered performance as an explicative factor to explain the tendency to build linkages to address sustainability-related issues in the SC. We believe that this reverted approach might prove valuable in many future studies regarding sustainability, which still does not represent the priority of most companies.

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Appendix

Questions extracted from the CDP questionnaire

(C2.3a) Have you identified any inherent climate-related risks with the potential to have a substantive financial or strategic impact on your business? Provide details of risks identified with the potential to have a substantive financial or strategic impact on your business:

(1) C9: Potential financial impact

(C4.3b) Did you have emissions reduction initiatives that were active within the reporting year? Provide details on the initiatives implemented in the reporting year in the table below:

(1) C1: Activity type

(2) C3: Estimated annual CO2e savings (metric tons CO2e)

(C12.1) Do you engage with your value chain on climate-related issues?
Response options (Select all that apply from the following options):

(1) Yes, our suppliers

(C12.1a) Provide details of your climate-related supplier engagement strategy:
C1: Type of engagement:

(1) Compliance and onboarding

(2) Information collection (understanding supplier behaviour)

(3) Engagement and incentivisation (changing supplier behaviour)

(4) Innovation and collaboration (changing markets)

(5) Other, please specify

(2) Yes, our customers

(C12.1b) Give details of your climate-related engagement strategy with your customers:
C1: Engagement category:

(1) Education/information sharing

(2) Collaboration and innovation

(3) Other, please specify

(4) Yes, other partners in the value chain

(5) No, we do not engage

(C12.3) Do you engage in activities that could either directly or indirectly influence public policy on climate-related issues through any of the following?
Response options (Select all that apply from the following options):

(1) Direct engagement with policymakers

(2) Trade associations

(3) Funding research organisations

(4) Other

(5) No

About the authors

Alice Madonna is a Ph.D. student at the Department of Management, Information and Production Engineering of the University of Bergamo. She has been a visiting Ph.D. student at the Ivey Business School of Western University (Canada). Her research focuses on sustainable supply chain management, focusing on environmental collaboration along the chain, environmental and carbon disclosure programs. Other topics of interest are related to the circular economy in the textile and agri-food industries. Her research has been presented at national and international. She is member of several national and international associations, such as Italian Management Engineering association, Decision Science Institute, European Operations Management Association and Academy of Management. Alice Madonna is the corresponding author and can be contacted at: alice.madonna@unibg.it

Albachiara Boffelli is assistant professor at the University of Bergamo. She has been a visiting researcher at the Department of Industrial Management and Logistics of Lund University (Sweden). Her research focuses on the topic of manufacturing relocation, with a focus on the reshoring phenomenon. She is also interested in topics related to sustainability and the impact of new technologies on organization and supply chains. Her research has been presented at national and international conferences and published in international journals. She is member of several national and international associations, such as Italian Association of Management Engineering, Decision Science Institute, European Operations Management Association. Since 2022 she has been serving as a board member of EurOMA.

Matteo Kalchschmidt is full professor at the University of Bergamo. Since 2021, he has been Head of the Department of Management, Information and Production Engineering. Since 2018 he has been Editor-in-Chief of the international journal Operations Management Research: Advancing Practice Through Theory. Since 2017 he is a member of the Editorial Review Board of the International Journal of Operations and Production Management. His research has been published in international journals and he is member of several national and international associations, such as Italian Association of Management Engineering, International Society for Inventory Research, European Operations Management Association, Production and Operations Management Society, International Purchasing and Supply Education and Research Association.