Supply Chain Resilience and Carbon-Neutral Supply Chain Performance: Examining the Mediating and Moderating Role of Information Sharing Capability

This study investigates the impact of supply chain resilience (SCR) on carbon-neutral supply chain performance (SCP), focusing on the mediating and moderating roles of information-sharing capabilities. Conducted within the food manufacturing and retail sectors, the research highlights how SCR, characterised by preparedness, alertness, and agility, is crucial for sustaining operations and achieving carbon neutrality amidst disruptions. The findings underscore that robust information-sharing capabilities enhance the effectiveness of SCR, enabling organisations to better manage disruptions, reduce inefficiencies, and lower carbon emissions. By fostering collaboration and communication among supply chain partners, firms can optimise logistics, engage suppliers in sustainable practices, and enhance overall environmental performance. This study provides empirical evidence supporting the integration of SCR and information-sharing capabilities as strategic tools to achieve carbon-neutral goals. The insights gained offer valuable implications for policymakers and business leaders aiming to balance economic growth with environmental sustainability. The research contributes to the existing literature by providing a comprehensive framework that underscores the importance of SCR and information sharing in achieving sustainable supply chain practices. It also suggests that adopting a holistic approach that includes these factors is critical for businesses transitioning to a low-carbon economy.

Keywords: Supply Chain Resilience, Carbon-Neutral Supply Chain Performance, Information Sharing Capability, Sustainability, Environmental Management

I. INTRODUCTION

The global economy has become increasingly interconnected in recent years, making supply chains more complex and vulnerable to disruptions caused by various factors, such as natural disasters, pandemics, geopolitical tensions, and technological failures. The recent past has witnessed several disruptions, including the wildfires in Australia in 2019 [1], the Japanese earthquake of March 2011, the outbreak of COVID-19 in 2019, and the Russian-Ukraine war in 2022. These disruptions have derailed sustainability efforts by causing inefficiencies, resource wastage, and increased emissions. Numerous authors have previously highlighted the impact of global supply chains on the carbon footprint [2], [3], emphasising that firms cannot achieve carbon neutrality without effectively focusing on their supply chains. There is a pressing need to mitigate these impacts by

restoring operations and minimising disruptions, thus supporting consistent carbon-neutral goals [4]. As a result of these disruptions, global supply chains have shown their fragility [5], which has further contributed to environmental degradation and highlighted the need to transform traditional supply chains. Despite the significant potential of supply chain resilience (SCR) techniques, developing efficient supply chain processes that support sustainable development remains a challenge [6], [7]. Given the high probability of future disruptions [8], [9], creating resilient supply chains that can achieve carbon-neutral supply chain performance is imperative.

Carbon neutrality, a state of net-zero carbon emissions, can be achieved by balancing the total carbon dioxide emissions produced directly or indirectly throughout the supply chain over a certain period through carbon offset or removal initiatives [6]. Supply chains are responsible for a significant proportion of greenhouse gas (GHG) emissions, as they involve the transportation of goods and materials, the use of energy in manufacturing and distribution, and the disposal of waste [10], [11]. Organisations can reduce their carbon footprint by implementing sustainable supply chain practices and contributing to a more sustainable future. Global temperatures will continue to rise without targeted improvements, leading to more catastrophic floods, bushfires, extreme weather, and species destruction. As a result, achieving carbon neutrality in supply chains has become a major topic in academic research in recent years. While Miroudot (2020) [12] proposed future policies to support businesses in building more robust and resilient supply chains, the question remains: how does supply chain resilience impact carbon-neutral supply chain performance? Supply chains must make joint efforts to mitigate global climate threats by reducing carbon emissions [3].

As goods move through the supply chain, carbon dioxide produced during transportation due to the use of fossil fuels significantly contributes to environmental damage. Determining how frequently supply deliveries are made could be as important in mitigating carbon emissions as the energy efficiency of the vehicles used to make these deliveries. Similarly, a firm's decisions regarding where to locate facilities, from which suppliers to source, and what mode of transportation to use can significantly affect its carbon footprint. In addition to carbon dioxide (CO_2), other GHGs such as methane, nitrous oxide, ozone, and fluorinated gases also significantly contribute to climate change [13]. Therefore, firms must take a supply chain approach to engage their suppliers and customers across multiple tiers if carbon neutrality targets are to be met [11].

Understanding these processes can help reduce food shortages, price spikes, and reductions in food quality. Although frameworks for supply chain resilience (SCR) have been proposed in the literature, they do not provide comprehensive information on the linkage between SCR and carbon-neutral supply chain performance (CNSCP) [14].

While there are efforts to shift from traditional supply chain practices to net-zero carbon emissions, this infrastructural shift is not as straightforward as envisioned by policymakers. Challenges in achieving this shift in supply chain operations range from policymaking to financial constraints. These challenges can be broadly classified into transparency, supplier engagement, execution, and support [15]. Emphasis should be placed on removing these challenges, as supply chain organisations are major contributors to global carbon emissions. Furthermore, individual nodes in the supply chain may operate on outdated data, leading to increased emissions and uncertain analysis of carbon dioxide emissions [16]. A lack of transparency creates a knowledge gap among suppliers across the supply chain regarding emission data, which needs to be addressed [17].

Reducing oil use would require electrifying the transportation sector by at least 85% [18]. However, the electrification of energy-intensive industries such as steelmaking and chemicals is still in its infancy. Reducing natural gas use requires transitioning cooking and heating mechanisms from gas to electricity. Moreover, the stability of coal will still be critical in the near to medium future. Additionally, government policy has been uncertain in coal development, inconsistent with the decisive actions needed for carbon-neutral goals. These challenges show that businesses have a significant and urgent role in the world's mission to achieve decarbonisation [15]. However, there is growing awareness of environmental issues among individuals and societies, leading to greater demand for businesses of all sizes to show a strong commitment to sustainability. This includes a push to reduce greenhouse gas emissions and achieve carbon neutrality. Green innovation is a critical approach that aligns closely with the goal of carbon neutrality. To create sustainable business environments, supply chain management must ensure that global supply chains work towards meeting net-zero targets. Those at the forefront of green innovation and who have mastered key innovative technologies will be crucial in bridging the gap.

Supply chain resilience is the capacity of a supply chain to persist, adapt, or transform in the face of change [19]. It is imperative to understand how supply chains persist, adapt, and respond to disruptions while maintaining operational performance and sustaining carbon-neutral initiatives

[20]. Being resilient is associated with stability and the speed of returning to equilibrium [21]. However, modern, resilient supply chains should demonstrate a strong commitment to environmental preservation and sustainability. A resilient supply chain can better absorb shocks and continue to operate efficiently, thus supporting the achievement of long-term carbon reduction targets [22]. While the significance of resilience is acknowledged, there is limited research on how resilience specifically impacts carbon-neutral performance in supply chains. As a social-ecological system, supply chain resilience must evolve to remain meaningful, requiring managers to strive for adaptability and transformability, foreseeing and influencing developments within and outside the supply chain [19].

To sustain operational performance, a supply chain must be able to anticipate, adapt to, and recover from disruptions [23]. Supply chains must be resilient to withstand shocks and bounce back and transform when faced with new challenges [24] while simultaneously influencing carbon-neutral supply chain performance. Despite the widespread recognition of the importance of supply chain resilience, little is known about its direct impact on carbon-neutral supply chain performance. Understanding the relationship between supply chain resilience and carbon-neutral supply chain performance and the role of information-sharing capability as both a mediator and moderator in this context is of utmost importance for achieving zero carbon-neutral supply chain performance. Information sharing capability among supply chain partners can be a potential mechanism for improving supply chain resilience. It fosters stronger relationships, enhances decision-making, and facilitates the efficient flow of goods and information [25]. Information sharing capability among supply chain partners helps supply chain managers know when to deliver, how to deliver, what time to deliver, and the mode of transportation to reduce the carbon footprint. A lack of coordination among multiple firms within the supply chain can increase the overall carbon footprint [26]. Information sharing can amplify supply chain resilience, enabling better coordination and response strategies across the supply chain network to enhance carbon-neutral supply chain performance.

While the significant impact of supply chain disruptions, including the recent pandemic, has nurtured important literature over the last few years, little is being said about the relationship between supply chain resilience and net-zero carbon supply. There has been an extensive theoretical acknowledgement of supply chain resilience (SCR) as a critical factor in maintaining

supply chain performance (SCP) during disruptions [27], [28], with little being said about how it influences carbon neutrality, even though the supply chain is a major contributor to environmental degradation [2], [29]. Limited studies have explored carbon neutrality from the global supply chain perspective [15]. The pandemic exposed vulnerabilities in global supply chains, revealing critical shortfalls in their ability to sustain operational continuity and meet performance expectations [30], [31]. Although SCR strategies are theoretically robust and designed to withstand, adapt, and recover from disruptions, empirical research has been limited in examining their impact on net-zero carbon supply [32], [8]. Furthermore, the role of information-sharing capability as a potential mediator and moderator of the relationship has not been sufficiently explored [33], [34]. To fill this gap, the current study examines the role of information-sharing capability in mediating and moderating the relationship between supply chain resilience and carbon-neutral supply chain performance.

Given the growing importance of environmental sustainability, supply chain organisations are under increasing pressure to reduce their carbon footprints and achieve carbon neutrality. Supply chain resilience has been identified as a key strategy in achieving these goals, helping supply chains maintain environmental sustainability while ensuring continuity during disruptions. The relationship between resilience and carbon-neutral performance is critical, as disruptions can lead to waste, inefficiencies, and increased carbon emissions, undermining sustainability efforts [8], [3]. This study aims to understand how supply chain resilience affects carbon-neutral supply chain performance, particularly its impact on sustainability. It also explores the role of information-sharing capability in shaping this relationship, considering both its mediating and moderating effects. By focusing on these aspects, the study seeks to provide insights into how supply chains can be structured to be both resilient and sustainable, effectively aligning business practices with environmental goals.

2. LITERATURE REVIEW AND HYPOTHESES

2.1 Supply Chain Resilience

Global businesses heavily rely on supply chain management to ensure the smooth flow of goods, services, and information from source to destination. As these supply chains become increasingly interconnected, they also become more vulnerable to disruptions, highlighting the critical importance of supply chain resilience (SCR) [24], [28], [35]. While some disruptions are

manageable, others can have far-reaching impacts beyond reduced profits, including damaging brand reputation, reducing customer satisfaction, causing compliance breaches, and hindering overall corporate efforts [36]. Consequently, the importance of SCR has grown significantly over the past few decades, evolving from a peripheral concern to a central aspect of supply chain management. Disruptions, whether predictable (like seasonal fluctuations) or unpredictable (such as pandemics and geopolitical issues), pose significant threats to carbon-neutral supply chain performance (SCP) [37], [38].

Supply chain resilience is defined as the ability of a supply chain to persist, adapt, or transform in the face of change [19]. It involves more than merely reducing the likelihood of failure; it also emphasises the need to prepare for, respond to, and recover from unforeseen turbulence in the operational environment [39], [40]. Viewing SCR as a social-ecological system [19] acknowledges that supply chains must evolve to stay relevant, requiring managers to focus on adaptability and transformability to promote carbon-neutral SCP. This definition underscores the importance of preparing for unexpected events, responding to disruptions, and maintaining continuity of operations to achieve SCR. Therefore, SCR is defined as a holistic and proactive capability that builds the capacity to handle disruptions, thereby mitigating the impact of unexpected risks and enhancing carbon-neutral SCP. Resilience should be seen as an inherent, active, and value-creating component of operations management rather than a passive defence against rare, severe disruptions [28].

The consequences of a non-resilient supply chain can include financial losses, operational interruptions, reduced product quality, damage to property and equipment, loss of goodwill with customers, and delays in supplies and deliveries. These outcomes highlight the need to prioritise SCR to support carbon-neutral SCP. Traditional risk management approaches often fail to adequately address unpredictable events [41], and SCR offers a promising approach to overcoming the limitations of traditional methods and addressing the complexities of global supply chains [42], [43]. Global events like the 2011 Tōhoku earthquake and the COVID-19 pandemic have underscored the critical importance of resilient supply chains. However, some critics argue that an excessive focus on resilience could lead to inefficiencies, adding costs without immediate apparent benefits [44]. Therefore, balancing resilience with effective carbon-neutral SCP is essential, yet

not always straightforward. Managers must carefully navigate the trade-offs between SCR and carbon-neutral SCP.

Research indicates that supply chains with high resilience are better equipped to handle disruptions without significant performance setbacks, leading to improved efficiency and sustainability [45]. However, the direct impact of supply chain resilience on achieving carbon-neutral performance has not been extensively explored. In theory, resilience could help reduce inefficiencies and waste during disruptions, thereby lowering carbon emissions and promoting sustainability. Liu et al. [46] identified three critical dimensions of SCR: supply chain preparedness, alertness, and agility. By assessing these dimensions, SCR can prepare for disruptions, thereby supporting improved carbon-neutral SCP.

2.1.1 Preparedness

Achieving resilience requires careful planning to prepare for potential disruptions. Businesses can maximise efficiency and cost-effectiveness by organising supply chain resources. By thoroughly preparing and implementing strategies such as assessing carbon footprints to identify key emission sources, investing in renewable energy and green technologies, and redesigning logistics and transportation to reduce emissions associated with goods movement, supply chains can become resilient and effective in working toward carbon neutrality. Developing contingency plans [24] and aligning interests across supply chain members are crucial for building readiness for disruptions. Selecting supply chain partners based on reliability, expertise, and alignment with organisational values, such as a commitment to carbon neutrality, further enhances network stability [47]. Reliable channel partners are more likely to collaborate effectively, increasing the overall resilience of the supply chain [48]. As a proactive resilience capability, supply chain preparedness significantly influences a firm's performance more than alertness and agility, indicating the importance of proactive strategies for building SCR that support the transition to net-zero carbon emissions [49].

Timely preparation and risk assessment in supply chains can lead to the adoption of practices that reduce supply chain risk and enhance recovery during catastrophic events [50]. Supply chain preparedness is directly linked to financial performance [51]. However, the effectiveness of preparedness depends on the resources allocated [52]. Insufficient resources can limit a firm's ability to invest in robust communication channels and maintain adequate safety stock, potentially

leaving them vulnerable to disruptions and negatively impacting their resilience and carbon-neutral performance.

2.1.2 Alertness

Supply chain alertness refers to a firm's ability to quickly recognise threats or changes in the environment [53]. Maintaining supply chain alertness is critical for preventing severe disruptions. Alert managers monitor the carbon footprint, track how channel members meet low-carbon initiatives, and implement carbon offsetting strategies to achieve resilient carbon-neutrality. Quick information processing enhances carbon-neutral SCP, making alertness a key component of supply chain agility. Regular supply chain alert reviews ensure up-to-date alert levels, enhancing resilience by identifying and addressing vulnerabilities. An alert supply chain can detect changes in the external environment and respond promptly, thereby improving visibility and producing better responses [54], [49]. Severe disruptions can trigger a ripple effect, impacting the organisation, the broader environment, the economy, and society [55].

2.1.3 Agility

Supply chain agility is crucial for achieving better SCP [56]. Agility involves the ability to respond quickly to environmental changes by adapting to these changes [57] to ensure carbon-neutral SCP. Quick responses, rapid decision-making, and the ability to reconfigure resources enable firms to perform better during disruptions, as seen during the pandemic [58]. Agility positively correlates with overall business performance [59] and can reduce operational costs [60], leading to more efficient processes.

2.2 Carbon-Neutral Supply Chain Performance

Climate change, driven by anthropogenic greenhouse gas (GHG) emissions, is a significant global challenge. Rising CO2 concentrations have increased the planet's temperature, leading to severe environmental impacts such as sea-level rise, flooding, droughts, and extreme weather events [61]. Organisations must commit to carbon neutrality, balancing the amount of GHG emissions produced with the amount removed from the atmosphere [15], [10]. Carbon neutrality is rooted in the principle that reducing GHG emissions is essential to mitigate climate change impacts. However, many GHG emissions (or reductions) result from joint efforts by multiple parties,

highlighting the importance of collaboration across supply chain networks to achieve carbon neutrality.

Challenges in measuring carbon-neutral supply chain performance include determining key performance indicators such as total GHG emissions per product unit, year-over-year carbon emissions reduction, the percentage of energy consumption from renewable sources, the number of carbon offset projects supported, and the carbon footprint per transportation kilometre. Achieving certifications such as ISO14001 (Environmental Management Systems) can also indicate strong carbon-neutral supply chain performance. Organisations and supply chains must work together to mitigate global climate threats by reducing carbon emissions [11]. A commitment to carbon neutrality enhances accountability and legitimacy in sustainable business practices, fostering positive relationships with the environment and society. However, organisations often find that their direct emissions are overshadowed by those generated by their supply chain networks [62], making it imperative for all supply chain partners to cooperate.

Supply chains bear a significant responsibility to reduce their network's carbon footprint. To achieve carbon neutrality goals, decision-makers need accurate information and intelligent technologies to create efficient, smart supply chains [3]. Zhang et al. [63] suggest that digitalising the supply chain is crucial for a firm's sustainability mission, with green transportation being a key area to support carbon neutrality goals. Strategies to reduce carbon emissions include promoting awareness among suppliers, green transportation, supply chain digitalisation, stakeholder readiness, monitoring sustainable practices, and integrating supply chain systems [3]. Sustainable SCR practices can reduce carbon footprints, lead to cost savings, and increase efficiency, helping organisations comply with environmental regulations and standards [11].

However, achieving carbon neutrality through SCR is complex, involving multiple stakeholders across the supply chain. Many companies struggle to achieve carbon neutrality due to limited visibility and control over their supply chain [10]. A lack of standardisation in emission reporting and accounting practices adds further complexity [64]. Information sharing capability among supply chain members can mitigate these challenges by facilitating emission tracking and compliance with carbon reduction goals. Firms can reduce emissions without significantly increasing costs by adopting resilience strategies [11]. Emission regulations increase the value of preparedness, alertness, and agility in achieving net-zero carbon emissions. Resilient supply chains

can maintain or achieve carbon-neutral performance by minimising inefficiencies and optimising resource use. The study proposed the following hypotheses:

H1a: Supply Chain Preparedness has a direct positive effect on carbon-neutral SCP.

H1b: Supply Chain Alertness has a direct positive effect on carbon-neutral SCP.

H1c: Supply Chain Agility has a direct positive effect on carbon-neutral SCP.

2.3 Information Sharing Capability

Organisations must rethink their approach to sharing up-to-date information in today's global economy to ensure survival. Achieving supply chain resilience (SCR) heavily relies on accurate and timely information sharing [65], [66]. Close relationships between customers and suppliers facilitate higher levels of information sharing, enabling faster response times to market changes and disruptions. A significant reason for weaknesses in supply chain functionality is the lack of collaboration among supply chain members [67]. Consequently, organisations have recognised the importance of building strong relationships and fostering collaboration within their supply chain networks. Collaborative partnerships facilitate information sharing, joint problem-solving, and risk mitigation [68]. Such strong relationships allow organisations to navigate disruptions by sharing information on alternative sourcing strategies, managing demand fluctuations, and addressing supply chain challenges collaboratively. Organisations must extend their information-sharing capabilities beyond immediate supply chain interactions to address large-scale disruptions effectively [69].

Information sharing among supply chain partners enhances agility and improves the carbon-neutral performance of the entire supply chain [70]. By nurturing information-sharing relationships, organisations can leverage collective intelligence and resources, thereby enhancing resilience and agility [71]. However, reluctance to share information can hinder collaboration, underscoring that an organisation's efficiency and success depend significantly on the health of its collaboration with supply chain partners [72]. Literature suggests that mutual dependency among supply chain partners fosters a greater willingness to share information, engage in joint problem-solving, and make dedicated investments, indirectly boosting resilience and carbon-neutral performance. While the importance of information-sharing capability in enhancing business success is well-acknowledged, more empirical insights are needed into how it mediates the relationship between

SCR and carbon-neutral performance. High internal and external collaboration levels through information sharing are crucial for maximising carbon-neutral SCP [48]. Effective information sharing positively impacts supply chain performance, creating win-win scenarios for firms involved in joint supply chain practices [70].

Despite the clear benefits of information sharing, such as providing advanced warnings of events [43], offering a platform for learning [73], and enabling knowledge creation and transfer [74], there are associated costs. These costs arise from information-sharing vulnerabilities, including corruption risks, inadequate policies, poor planning, and undue influence from powerful political and business interests. Effective information sharing should be based on mutual trust, which fosters agility, preparedness, and alertness, all crucial for achieving carbon-neutral SCP [43]. Information-sharing structures must be thoughtfully designed to realise substantial improvements in carbon-neutral performance. Enhancing an organisation's capabilities through information sharing promotes supply chain integration and agile practices, such as responsiveness and alertness [75]. Additionally, greater collaboration among firms in the supply chain increases resilience [76]. Improving transparency, integrating management information systems, and enhancing large-data processing capabilities can further boost carbon-neutral SCP [77].

Modern supply chains rely on information-sharing capabilities that allow partners to understand each other's capabilities and work together to reduce carbon emissions. In this way, information-sharing capability becomes a critical factor in mitigating the impacts of disruptions on carbon-neutral SCP. Effective information-sharing capabilities in disrupted supply chains are characterised by rapid communication channels, collaborative problem-solving efforts, and resource-sharing strategies, which foster more agile and coordinated responses. Information-sharing capability enhances adaptability and fosters an environment conducive to learning, innovation, and continuous improvement beyond its role as a protective buffer. This approach also prepares supply chains to respond effectively to emerging challenges [78], [79]). The ability to make pre-emptive adjustments to processes relies on the timely acquisition and exchange of pertinent information, highlighting the importance of swift decision-making [69]. Considering these factors, it is suggested that the positive impact of supply chain resilience on carbon-neutral performance is partly due to enhanced coordination and decision-making enabled by information sharing among supply chain partners. Thus, we propose the following hypotheses:

H2a: Information-sharing capability mediates the relationship between supply chain preparedness and carbon-neutral SCP.

H2b: Information-sharing capability mediates the relationship between supply chain alertness and carbon-neutral SCP.

H2c: Information-sharing capability mediates the relationship between supply chain agility and carbon-neutral SCP.

Research shows a direct association between information-sharing activities and supply chain performance [70], [80]. Studies by Chowdhury and Quaddus [81] and Wieland and Wallenburg [82] also found that SCR is linked to trust, cooperation, and commitment. Scholten and Schilder [83] also demonstrated that sharing information could enhance SCR readiness, alertness, and agility. Therefore, it is reasonable to assert that the level of information-sharing capability influences the strength of the relationship between SCR and carbon-neutral performance. High levels of information sharing can amplify the positive effects of resilience on carbon-neutral performance. Consequently, we propose the following hypotheses:

H2a: Information-sharing capability moderates the relationship between supply chain preparedness and carbon-neutral SCP.

H2b: Information-sharing capability moderates the relationship between supply chain alertness and carbon-neutral SCP.

H2c: Information-sharing capability moderates the relationship between supply chain agility and carbon-neutral SCP.

2.4 Conceptual Framework

It is increasingly evident that the robustness and adaptability of supply chains are fundamental to sustained organisational success in today's rapidly evolving global business environment. Understanding how SCR influences carbon-neutral SCP has become critical. Using boundary-spanning theory as a lens, this study provides a framework for analysis. Figure 1 illustrates a conceptual framework highlighting the relationships between supply chain resilience, information-sharing capability, and carbon-neutral supply chain performance.

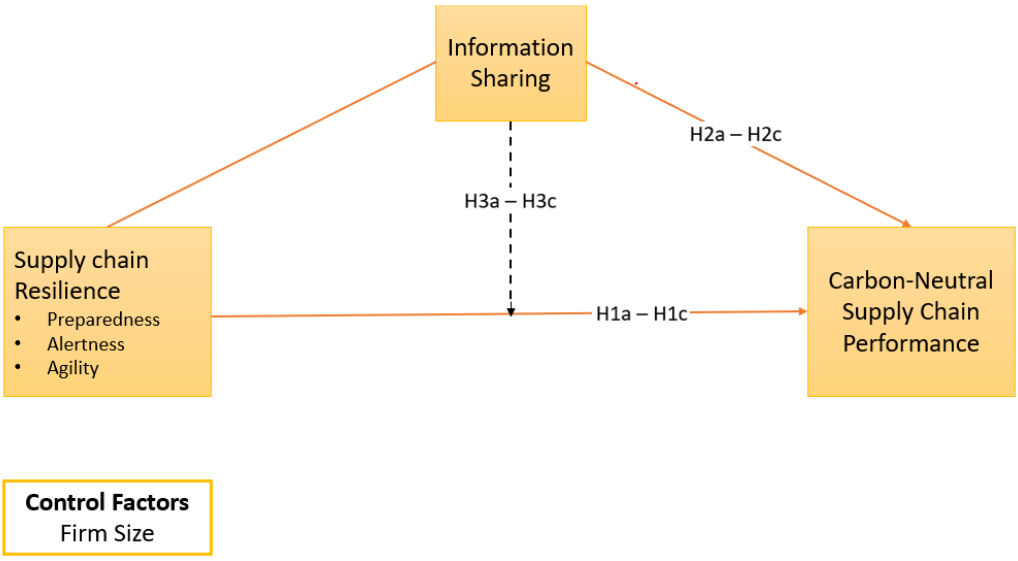

Figure 1: Conceptual framework for the study

Source: Authors' construct (2024)

Figure 1 illustrates the proposed hypothesis in this study. SCR and carbon-neutral SCP (H1a – Ha1c) were analysed. The mediating effect of (H2a – H2c) and the moderating effect of (H3a – H3c) were examined. Firm size was the control variable.

3. METHODOLOGY

3.1 Data Collection

The study population consisted of registered food manufacturing (86) and retail (230) organisations in Qatar, totalling 316 establishments. The targeted respondents were general managers and supply chain managers within these sectors. Two respondents—general and supply chain managers—were identified and contacted for each selected firm. A census approach offered more accurate and reliable results and reduced the possibility of personal biases [84] and sampling errors [85]. The use of an online questionnaire facilitated the management of this census. To enhance the response rate, follow-up reminders were sent to participants who had not completed the survey two weeks after the initial invitation, with subsequent weekly reminders to optimise response rates [86].

A total of 632 questionnaires were distributed, and 341 were returned, representing a 54% response rate. However, 32 returned questionnaires were deemed incomplete and excluded from the analysis.

Thus, 309 responses were considered usable for the data analysis, reflecting a 49% effective response rate. This response rate is adequate for generalising results and accurately represents the population [87]. Table 1 presents the demographic profile of the 309 respondents.

Table 1: Respondents' Profile

Respondent variable	Category	Frequency	Per cent	Cumulative Per cent
Respondents' duration at the firm	Less than 2 years	48	15.50%	15.50%
	3 - 5 years	111	35.90%	51.40%
	6 - 8 years	92	29.80%	81.20%
	More than 9 years	58	18.80%	100.00%
	Total	**309**	**100.00%**	
Level of Education	Secondary school or related certificate	9	2.90%	2.90%
	First degree	147	47.60%	50.50%
	Second-degree or more	153	49.50%	100.00%
	Total	**309**	**100.00%**	
Managerial Level	First line	42	13.60%	13.60%
	Middle management	237	76.70%	90.30%
	Top management	28	9.10%	99.40%
	Other	2	0.60%	100.00%
	Total	**309**	**100.00%**	
Department	Accounts /Finance	19	6.10%	6.10%
	Marketing	18	5.80%	11.90%
	Operations	73	23.70%	35.60%
	Supply chain logistics	185	59.90%	95.50%
	Other	14	4.50%	100.00%
	Total	**309**	**100%**	
Industry type	Food retailing	171	55.30%	55.30%
	Food manufacturing	138	44.70%	100.00%
	Total	**309**	**100.00%**	
Firm type	Public sector	44	14.20%	14.20%
	Private sector	265	85.80%	100.00%
	Total	**309**	**100.00%**	

Eighty-five percent of respondents had been with their firm for at least three years (35.9% between 3 and 5 years, 29.8% between 6 and 8 years, and 18.8% for over 9 years), indicating that most employees were experienced and understood their company and the subject matter well. This distribution suggests respondents had enough time and industry knowledge to provide accurate and reliable responses.

Regarding the education level of respondents, 91.5% held a tertiary degree, with 47.6% holding a first degree and 49.5% holding a second degree. This reflects a well-educated workforce, indicating that respondents could understand and accurately complete the survey, which was written in English. The majority of respondents (77%) were in middle management, with 9% in top management, indicating that they possessed a good understanding of supply chain management and carbon-neutral performance, thereby enhancing the reliability of the results. The relatively low response rate from top management might be attributed to "Qatarisation" and the difficulty of top management in securing time for the survey.

About 59.9% of the study's respondents worked in supply chain logistics, followed by 23.7% in operations. Regarding industry type, 55.3% of respondents were in the food retailing sector, and 44.7% were in food manufacturing. A large majority (85.8%) were from the private sector, indicating that the food sector in Qatar is predominantly privately owned. Additionally, 82.8% of the organisations had been established for at least six years, likely reflecting the business opportunities that emerged when Qatar won the bid for the World Cup. The data in Table 1 shows that the survey captured a diverse sample of firms in terms of industry type and employee numbers, which supports the representativeness and reliability of the survey findings.

3.2 Measurements and Controls

Several steps were taken to ensure the accuracy and reliability of the findings, including analysing variance inflation and common method bias. Careful consideration was given to the questionnaire design to ensure respondents' ease of completion and comprehension, thereby establishing content validity and reliability. The supply chain performance measure was adapted from Abeysekara et al. [88], Juan et al. [74], and Kumar et al. [89], focusing on assessing supply chain preparedness, alertness, and agility for sustainable performance. The measure for information-sharing capability was adapted from Cao and Zhang [25] and Kumar [90], while the carbon-neutral supply chain performance measure was adapted from Chen et al. [6] and Mofokeng and Chinomona [80]. Performance was evaluated using indicators such as carbon emissions, energy efficiency, and adopting renewable energy sources based on established sustainability performance metrics. Supply chain resilience, information sharing, and carbon-neutral supply chain performance were measured using a 7-point Likert reflective scale. Guided by Slattery et al. [91], the questionnaire items (see Table 2) were pilot-tested to identify any flaws, and no issues were found. Firm size

was included as a control variable, given its impact on both supply chain resilience and sustainability outcomes [92]. Larger firms in different manufacturing industries might be more inclined to develop robust information processing capabilities and implement new technologies for SCR than smaller firms.

3.3 Reliability and Validity Analyses

To assess the psychometric properties of the measurement model, both Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were conducted following Anderson and Gerbing's [93] two-stage approach. As shown in Table 2, the factor loadings ranged from 0.674 to 0.866, indicating strong correlations between the items and their respective constructs. This suggests a robust factor structure, with each set of items reliably measuring the intended constructs. The overall fit of the factor model was robust, with most items displaying high loadings, supporting the validity of the constructs identified through EFA.

Table 2: Exploratory Factor Analysis Solution

Indicators	Constructs with scale items	Loadings
	Preparedness	
SCRP01	Our company selects firms that are easy to work with (i.e., willing to accommodate the focal firm's business objectives) as supply chain partners.	0.759
SCRP02	Our company chooses reliable firms to establish a supply chain partnership.	0.745
SCRP05	Our company develops contingency plans to increase supply chain stability.	0.845
	Alertness	
SCRA01	We identify technologies for supply chain management that increase supply chain visibility.	0.732
SCRA02	We track structural changes (i.e., structural shifts in the market caused by economic progress, political and social changes, demographic trends and technological advances).	0.800
SCRA03	We detect threats to supply networks.	0.733
SCRA04	We detect sudden changes in demand.	0.825
SCRA05	We detect unexpected changes in the physical flows throughout the supply chain	0.759
	Agility	
SCA01	The company is fairly sensitive to the opportunities and threats in the business environment.	0.674
SCA02	We reconfigure supply chain resources to respond to sudden changes in supply/demand.	0.771
SCA03	The company reserves extra service capacity in response to the rapidly changing market.	0.719
SCA04	One of the company's important criteria for finding collaborative partners is its agility and ability to react.	0.778
SCA05	Our supply chain can change delivery modes	0.693
	Information Sharing	
CAIS1	Our firm and supply chain partners jointly search for and acquire new and relevant knowledge.	0.834
CAIS2	Our firm and supply chain partners jointly assimilate and apply relevant knowledge	0.846
CAIS3	Our firm and supply chain partners jointly identify customer needs.	0.866

CAIS4	Our firm and supply chain partners jointly discover new or emerging markets.	0.847
CAIS5	Our firm and supply chain partners jointly search for and acquire new and relevant knowledge.	0.838
	Caborn-Neutral Supply chain performance	
SCP01	Our company can quickly modify products to meet our major customer's requirements.	0.738
SCP02	Our company can quickly introduce new products into the market.	0.694
SCP03	Our company can quickly respond to changes in the market demand.	0.735
SCP04	Our company has an outstanding on-time delivery record for our major customers.	0.694
SCP05	Our company provides a high level of customer service to our major customers.	0.742
SCP06	Our firm has a reliable delivery track record with our customers.	0.764
SCP07	Our firm has a reliable delivery track record with our customers	0.726
SCP08	As a Firm, our products are highly reliable and meet customer needs.	0.697

The Cronbach Alpha coefficient and composite reliability were used to validate the research instrument's internal consistency [94]. Cronbach alpha (CA) and composite reliability (CR) are the two most used methods for determining reliability [95]. The Cronbach alpha and composite reliability results are provided in Table 3. Cronbach's alpha values range from 0.722 to 0.861, while composite reliability ratings range from 0.827 to 0.927. Both reliability metrics exhibit reliability statistics greater than the recommended level of 0.7 [95]. As a result, construct reliability is established.

Table 3: Reliability Test Results

Constructs	**Cronbach's alpha (CA)**	**Composite reliability (CR)**	**Average variance extracted (AVE)**
Agility	0.778	0.849	0.530
Alertness	0.829	0.880	0.594
Information Sharing Capability	0.901	0.927	0.716
Carbon-Neutral Performance	0.861	0.892	0.508
Preparedness	0.722	0.827	0.615

Source: Authors' computations (2024)

The reliability of a measurement scale is critical but not sufficient on its own. According to Hair et al. [96], a measurement scale should be reliable and valid, meaning it must accurately measure what it is intended to measure. Therefore, reliability and validity are essential characteristics of a robust measurement scale. Construct validity is achieved when both convergent and discriminant validity are present [97]. This study assessed convergent validity using Average Variance Extracted (AVE) statistics. The results indicated no issues with convergent validity, as all constructs in the

study had AVE values exceeding the recommended cutoff of 0.5. The AVE values for each construct are shown in Table 4.

4. RESULTS AND DISCUSSION

4.1 Direct path relationships

In this analysis, the Independent Variable (IV) is Supply Chain Resilience (SCR), which includes the dimensions of Preparedness, Alertness, and Agility, while the Dependent Variable (DV) is Carbon-Neutral Supply Chain Performance (SCP). The findings for Hypothesis 1a (H1a) show a positive relationship between Supply Chain Preparedness and Carbon-Neutral SCP ($\beta = 0.125$, $t = 2.074$, $p < 0.038$). Similarly, for Hypothesis 1b (H1b), there is a positive relationship between Supply Chain Alertness and Carbon-Neutral SCP ($\beta = 0.132$, $t = 2.037$, $p < 0.043$). For Hypothesis 1c (H1c), the results also reveal a positive relationship between Supply Chain Agility and Carbon-Neutral SCP ($\beta = 0.210$, $t = 3.148$, $p < 0.002$). These results indicate that all three hypotheses (H1a, H1b, and H1c) are supported. The detailed results are presented in Table 4.

Table 4: Hypothesis Testing: Main Results

Hypotheses	**Direct Path**	**Beta**	**T-stats**	**P-values**	**Supported**		**Hypotheses Testing**
H1a	Preparedness -> Supply Chain Performance	0.116	2.071	0.038	Yes		Accepted
H1b	Alertness -> Supply Chain Performance	0.126	2.377	0.043	Yes		Accepted
H1c	Agility -> Supply Chain Performance	0.253	3.776	0.002	Yes		Accepted
Hypotheses	**Indirect Path**	**Beta**	**T-stats**	**P values**	**2.50%**	**97.50%**	
H2a	Preparedness -> Information Sharing -> Supply Chain Performance	0.029	2.068	0.039	0.018	0.048	Accepted
H2b	Alertness -> Information Sharing -> Supply Chain Performance	0.046	3.441	0.001	0.016	0.039	Accepted
H2c	Agility -> Information Sharing -> Supply Chain Performance	0.084	2.244	0.026	0.029	0.184	Accepted
Hypotheses	**Interaction Effect**	**Beta**	**T-stats**	**P values**	**2.50%**	**97.50%**	
H6a	Information Sharing x Preparedness -> Performance	0.047	2.301	0.022	0.156	0.242	Accepted
H6b	Information Sharing x Alertness -> Performance	0.087	2.465	0.014	0.207	0.413	Accepted
H6c	Information Sharing x Agility -> Performance	0.119	2.397	0.017	0.092	0.299	Accepted

4.2 Mediation Analysis

In this analysis, the Independent Variable (IV) is Supply Chain Resilience (SCR), which includes the dimensions of Preparedness, Alertness, and Agility. The Dependent Variable (DV) is Carbon-Neutral Supply Chain Performance (SCP), and the Mediating Variable (MV) is Information Sharing Capability. Using Smart-PLS version 4 and the bootstrapping method, the results demonstrated a significant indirect effect of SCR (Preparedness, Alertness, Agility) on Carbon-Neutral SCP through Information Sharing Capability. The specific results were as follows: for Preparedness ($B = 0.029$, $p < 0.039$), for Alertness ($B = 0.046$, $p < 0.001$), and for Agility ($B = 0.084$, $p < 0.026$). Additionally, the bias-corrected 95% confidence intervals (CI) for these relationships did not include zero, indicating mediation for Preparedness (CI: 0.018 to 0.048), for Alertness (CI: 0.016 to 0.039), and for Agility (CI: 0.029 to 0.184). These findings confirm that Information Sharing Capability mediates SCR and Carbon-Neutral SCP, thus supporting Hypotheses H2a, H2b, and H2c. The detailed results are shown in Table 4.

4.3 Moderation Analysis

A moderation analysis was conducted using regression techniques to examine the moderating effect of Information Sharing Capability on the relationship between SCR (Preparedness, Alertness, Agility) and Carbon-Neutral SCP. SCR components (Preparedness, Alertness, Agility) served as the predictors, Carbon-Neutral SCP as the dependent variable, and Information Sharing Capability as the moderator. Statistical methods were applied to assess the interaction effects among the variables, including calculating regression coefficients (β), standard deviations (SD), T-statistics, P-values, and confidence intervals to evaluate the strength and significance of these interactions. The summary of the moderation effect of Information Sharing Capability on the relationship between supply chain resilience and carbon-neutral supply chain performance is presented in Table 5.

Table 5: Moderation effect of Information Sharing Capability on Supply Chain Resilience (Preparedness, Alertness and Agility) and Carbon-neutral Supply Chain Performance

Hypotheses	Interaction Effect	Beta	SD	T-stats	P values	2.5%	97.5%
H6a	Information Sharing x Preparedness -> Performance	0.047	0.021	2.301	0.022	0.156	0.242
H6b	Information Sharing x Alertness -> Performance	0.087	0.035	2.465	0.014	0.207	0.413
H6c	Information Sharing x Agility -> Performance	0.119	0.050	2.397	0.017	0.092	0.299

4.3.1 Moderating effect of Information Sharing Capability on Supply Chain Preparedness and Carbon-Neutral Supply Chain Performance

The analysis revealed a significant interaction effect of Information Sharing Capability on the relationship between Supply Chain Resilience (Preparedness) and Carbon-Neutral Supply Chain Performance, with β = 0.047, BCa CI [0.156, 0.242], T-statistics = 2.301, p = 0.022. It was found that firms with higher-than-average levels of Information Sharing Capability experienced a stronger effect of SCR (Preparedness) on Carbon-Neutral SCP than those with average or lower levels of Information Sharing Capability. These results indicate that the effect of SCR (Preparedness) on Carbon-Neutral SCP is indeed moderated by Information Sharing Capability, thereby supporting Hypothesis H3a. Further analysis using simple slopes (see Figure 2) shows that when Information Sharing Capability is high, the impact of Supply Chain Preparedness on achieving better Carbon-Neutral SCP is enhanced.

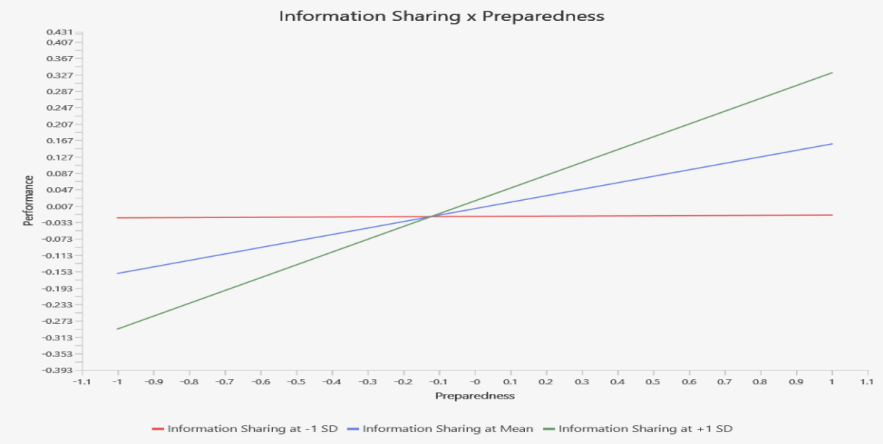

Figure 2: Simple slope analysis of the interaction between SCR Preparedness and Information Sharing Capability

4.3.2 Moderating Effect of Information Sharing Capability on Supply Chain Alertness and Carbon-Neutral Supply Chain Performance

A significant interaction effect was also found for Information Sharing Capability on the relationship between Supply Chain Resilience (Alertness) and Carbon-Neutral SCP, with $\beta = 0.087$, BCa CI [0.207, 0.413], T-statistics = 2.456, $p = 0.014$. Firms with higher-than-average Information Sharing Capability demonstrated a greater effect of SCR (Alertness) on Carbon-Neutral SCP than those with average or lower levels of Information Sharing. These results support Hypothesis H3b, confirming that information-sharing capability moderates the effect of SCR (Alertness) on Carbon-Neutral SCP. Simple slope analysis (see Figure 3) further indicates that improvements in Information Sharing Capability enhance SCR Alertness, leading to better Carbon-Neutral SCP.

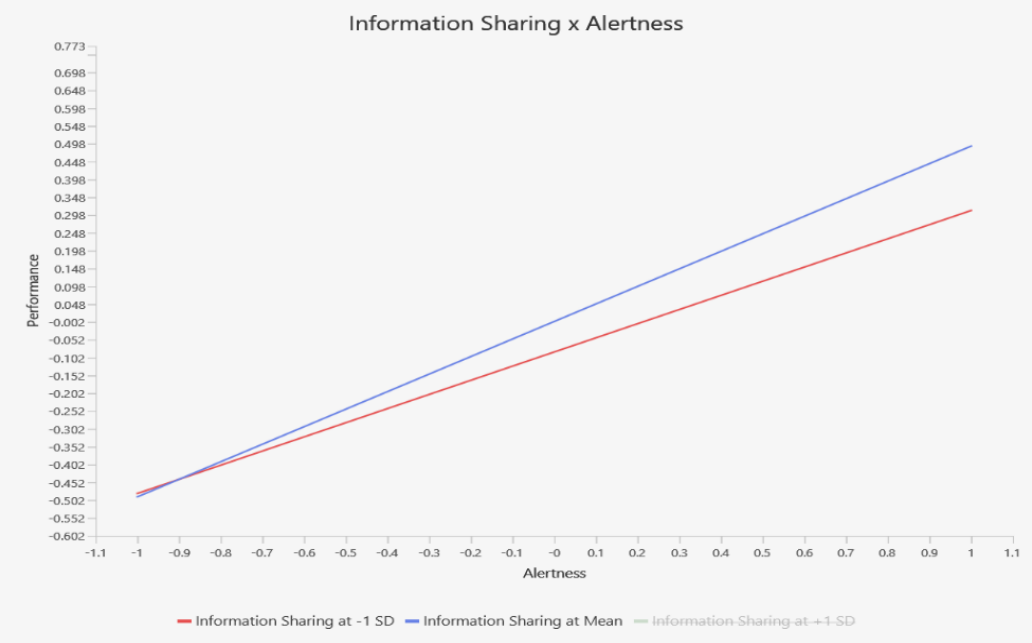

Figure 3: Simple slope analysis of the interaction between SCR Alertness and Information Sharing Capability

4.3.3 Moderating Effect of Information Sharing Capability on Supply Chain Agility and Carbon-Neutral Supply Chain Performance

The analysis identified a significant interaction effect of Information Sharing Capability on the relationship between Supply Chain Resilience (Agility) and Carbon-Neutral SCP, with $\beta = 0.119$, BCa CI [0.092, 0.299], T-statistics = 2.397, $p = 0.017$. It was observed that higher-than-average

Information Sharing Capability resulted in a greater effect of SCR (Agility) on Carbon-Neutral SCP compared to average or lower levels of Information Sharing. These findings support Hypothesis H3c, indicating that Information Sharing Capability moderates the effect of SCR (Agility) on Carbon-Neutral SCP. Simple slope analysis (see Figure 4) demonstrates that the positive impact of Supply Chain Agility on Carbon-Neutral SCP is more pronounced when Information Sharing Capability is high.

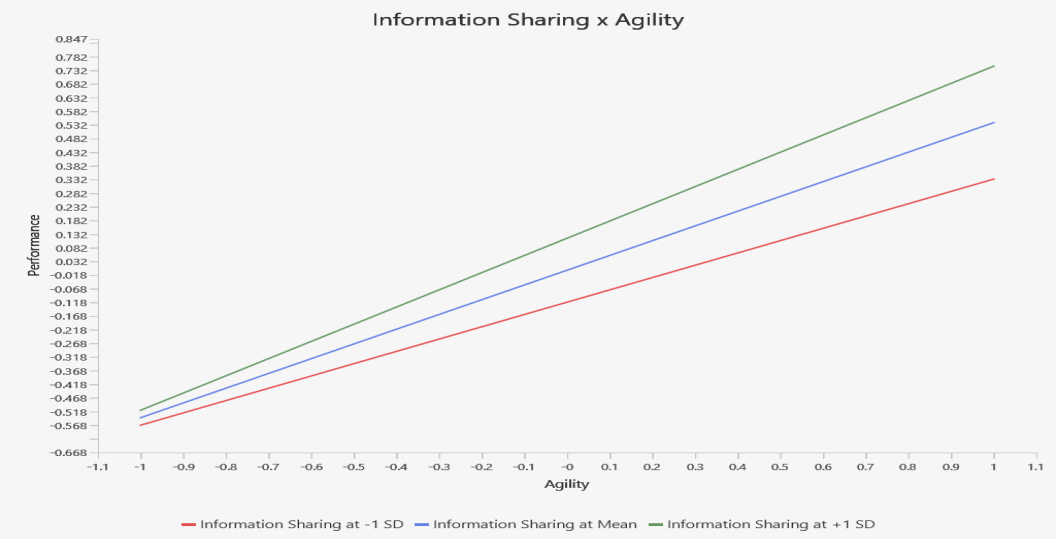

Figure 4: Simple slope analysis of the interaction between SCR Agility and Information Sharing Capability

5. CONTRIBUTION TO THEORY

This study establishes an empirical basis for the relationship between supply chain resilience (SCR) and carbon-neutral supply chain performance (SCP), offering several theoretical contributions to the literature on carbon-neutral supply chains and SCR.

First, the study highlights the role of SCR in volatile environments and its influence on carbon-neutral SCP. Predictable and unpredictable disruptions threaten achieving carbon-neutral SCP [37], [38]. The findings confirm a positive correlation between carbon-neutral SCP and the dimensions of preparedness, alertness, and agility. By empirically validating these correlations, the research supports and extends existing theoretical frameworks by illustrating how these specific resilience dimensions enhance carbon-neutral SCP. This novel perspective is supported by evidence showing that resilience can help reduce inefficiencies and waste during disruptions, thus decreasing carbon emissions and promoting sustainability, aiming for net-zero carbon emissions. Effective

preparation and risk assessment allow SCR to manage disruptions, ensuring improved carbon-neutral SCP. Timely preparation and risk assessment can facilitate the adoption of practices that mitigate supply chain risks and enhance recovery during catastrophic events [50]. Additionally, alertness strengthens organisational resilience by identifying and addressing vulnerabilities, ensuring continuous operations during challenging periods.

Second, this study extends SCR literature by demonstrating the significant mediating role of information-sharing capability in the relationship between SCR and carbon-neutral SCP. Timely and accurate information sharing is crucial for resilience [65]. This study highlights the importance of information sharing from three resilience perspectives: Preparedness, Alertness, and Agility, which are foundational to achieving carbon-neutral SCP. High internal and external collaboration levels through information sharing among supply chain members are essential for maximising carbon-neutral SCP [48]. Such collaboration enables supply chain partners to better understand each other's capabilities, leading to reduced carbon emissions.

Consequently, information-sharing capability is a decisive factor in mitigating the impact of disruptions on carbon-neutral SCP. Organisations that have attempted to minimise GHG emissions often find that their direct emissions are overshadowed by those generated throughout their supply chain networks [62]. Therefore, robust information-sharing capability is crucial to ensuring full cooperation among all supply chain partners in achieving net-zero carbon neutrality.

Third, by examining the moderating effects of information-sharing capability, this study provides deeper insights into the complexity of supply chains. The findings reveal that firms with higher-than-average information-sharing capability experience a stronger effect of SCR (Preparedness, Alertness, and Agility) on carbon-neutral SCP compared to those with average or lower levels of information-sharing capability. Thus, the strength of the relationship between SCR and carbon-neutral performance is influenced by the level of information-sharing capability. This study addresses a gap in both conceptual understanding and empirical evidence regarding how SCR can influence carbon-neutral SCP. The results suggest a strong information-sharing capability is critical for strengthening the resilience-performance linkage. This research offers a new perspective on the dynamics influencing SCR and carbon-neutral performance by highlighting the complex interplay between resilience, information-sharing capability, and carbon-neutral performance.

A significant contribution of this study is presented in Figure 5, which provides a comprehensive framework for understanding how to build and sustain high-performing, resilient supply chains. This framework challenges existing models to consider additional layers of interaction, providing a more holistic approach to managing supply chains in pursuit of carbon neutrality.

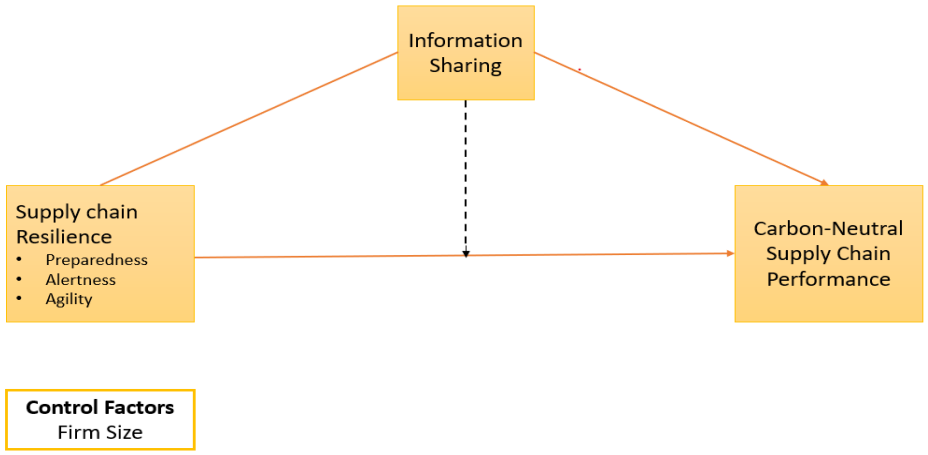

Figure 5: Conceptual framework for the study

Source: Authors' construct (2024)

6. POLICY IMPLICATIONS

This study underscores the importance of Supply Chain Resilience (SCR) and Carbon-Neutral Supply Chain Performance (SCP) in maintaining economic stability and growth by developing resilient supply chains capable of withstanding disruptions. These findings align with Qatar's National Vision 2030, which aims to transform Qatar into a modern society capable of sustaining its development and providing a high quality of life. The study's insights are particularly relevant to this policy vision. By identifying information sharing as a critical capability that enhances SCR in Qatar, the study informs policymakers about the need to strengthen policies that encourage collaboration among supply chain stakeholders. Enhanced collaboration will equip managers with better knowledge and innovative solutions, enabling more effective supply chain decision-making, especially during disruption.

To achieve these goals, there may be a need to establish more collaborative platforms, promote public-private partnerships, and provide incentives for information sharing. Such measures can enhance the international competitiveness of Qatar's food manufacturing and retail industries and contribute to achieving net-zero carbon neutrality.

Considering Qatar's policy focus on rapid economic growth and diversification, the study highlights the complex interplay between SCR and carbon-neutral SCP. It suggests that rapid growth without sufficient resilience and consideration of environmental sustainability can create vulnerabilities. Policymakers should ensure that the pursuit of economic growth and diversification is balanced with the development of resilient and well-managed supply chains. By doing so, they can mitigate risks that might lead to disruptions and losses while supporting sustainable economic growth and diversification.

These insights have broader implications beyond Qatar. Globally, economies aiming for rapid growth and diversification face similar challenges in balancing economic objectives with sustainability goals. The study emphasises that rapid economic expansion can expose nations to significant vulnerabilities, including supply chain disruptions, resource scarcity, and increased carbon emissions without a resilient supply chain infrastructure. Internationally, policymakers must also consider the need for robust SCR frameworks that incorporate environmental sustainability as a core component. Creating resilient, carbon-neutral supply chains is crucial for sustaining economic growth and addressing global challenges such as climate change, resource depletion, and social inequality.

Therefore, countries around the world can benefit from adopting similar strategies to those recommended for Qatar:

- *Promoting Collaboration*: Encouraging collaboration across sectors and borders to enhance information sharing and knowledge transfer can lead to more resilient and sustainable supply chains.
- *Incentivizing Green Practices:* Offering incentives for businesses to adopt sustainable practices, including the use of renewable energy, reduction of waste, and minimisation of carbon footprints, can drive the transition towards carbon neutrality.
- *Building Resilient Infrastructure:* Investing in resilient infrastructure and technologies that can withstand disruptions will ensure supply chains remain operational and sustainable, even during unforeseen events.
- *Integrating Sustainability into Economic Planning:* Policymakers should integrate sustainability considerations into economic planning and development strategies to ensure that growth is not achieved at the expense of the environment or future generations.

By adopting these strategies, nations can achieve a balanced approach to economic development, ensuring that growth is resilient, sustainable, and aligned with global environmental goals. This holistic approach will benefit individual countries and contribute to the broader global effort to combat climate change and promote sustainable development.

7. LIMITATIONS AND FUTURE RESEARCH

While this study offers valuable insights into the relationship between SCR and carbon-neutral SCP, it has some limitations. The findings are based on data from a specific sector and geographical location, which may limit their applicability to other contexts. The study focused on food manufacturing and retail companies in Qatar and examined three dimensions of SCR—preparedness, alertness, and agility—as drivers of SCR, viewed from the perspective of an emerging economy.

Although multiple factors can influence carbon-neutral SCP, this study concentrated on information-sharing capabilities' mediating and moderating effects. While financial performance measures are important for strategic planning and external reporting, this study focused on non-financial measures of carbon-neutral SCP, which are more effective for managing daily operations in manufacturing, distribution, and retail [98]. However, relying on self-reported measures can introduce bias, as respondents' perceptions may not accurately reflect actual practices or outcomes. Future research could consider using objective measures or independent observations to validate self-reported data, such as conducting audits or assessments, analysing operational records or performance metrics, or seeking input from various stakeholders within the supply chain to ensure a more comprehensive and reliable assessment.

Several recommendations for future research are proposed based on these limitations and the study's findings. Future studies could expand beyond Qatar's food manufacturing and retail sectors to include other industries and countries, providing a broader understanding of SCR across diverse contexts [99]. Furthermore, comparing SCR and performance across different countries and regions, particularly between emerging and developed economies, as suggested by Tukamuhabwa et al. [100], would be valuable for enhancing the generalizability of the findings.

In terms of methodology, future studies could adopt a mixed-methods approach, combining qualitative and quantitative research to analyse carbon-neutral SCP. This approach could include

examining operational records, financial reports, and other reliable data sources. Independent observations, audits, or assessments can be employed to validate self-reported data, ensuring the reliability and validity of the findings. Additionally, engaging a wide range of stakeholders—including suppliers, customers, policymakers, and industry experts—through participatory research methods can enhance the relevance and applicability of the findings by addressing practical challenges and incorporating diverse perspectives.

Despite its limitations, this study offers valuable insights for practitioners and provides a robust theoretical framework for scholars to deepen their understanding of SCR and carbon-neutral supply chain performance. By examining the mediating and moderating roles of information-sharing capability, the study contributes to the discourse on supply chain management, emphasising the challenges of achieving resilience and net-zero carbon emissions in today's interconnected and rapidly changing supply chains.

8. CONCLUSIONS

This study examines the impact of supply chain resilience (SCR) on carbon-neutral supply chain performance (SCP), emphasising the critical roles of information-sharing capabilities as mediating and moderating factors. Through research conducted in Qatar's food manufacturing and retail sectors, the study highlights that SCR is essential for sustaining operations and achieving carbon-neutral performance during disruptions. Achieving carbon neutrality through supply chains requires significant stakeholder coordination and dedicated efforts. This is necessary for operational efficiency and a crucial step in the global fight against climate change and the pursuit of a sustainable future.

A comprehensive strategy is needed to achieve carbon neutrality, leveraging the power of information-sharing capabilities across supply chain partners. Organisations can become more alert, prepared, and agile in response to disruptions by fostering an environment where information is shared openly and efficiently. This will reduce waste and emissions, optimise transportation and logistics, and greater engagement with suppliers to improve their environmental practices. The path to net-zero carbon emissions lies in the commitment to robust information sharing among all stakeholders.

While achieving carbon neutrality through supply chain management presents challenges, it also offers immense opportunities for innovation, cost reduction, and value creation. By taking proactive steps, businesses can take charge of combating climate change, positioning themselves as leaders in the transition to a low-carbon economy. This requires not only resilience but also a steadfast commitment to sustainability. Carbon neutrality should not be viewed as a distant goal but rather as a fundamental attribute of the supply chain system [101]. By embracing this mindset, organisations can turn the challenge of carbon neutrality into a strategic advantage, ensuring long-term success and resilience in a rapidly changing world. Now is the time for businesses to take decisive action, demonstrate leadership, and drive the transformation towards a sustainable, low-carbon future.

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