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Overcoming barriers to supply chain decarbonization: Case studies of first movers

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ABSTRACT

Excess greenhouse gas emissions from human and industrial activities are believed to be the key cause of catastrophic climate change. According to the United Nations, carbon neutrality by 2050 is the world's most urgent mission. Many countries recently made commitments to this mission; however, at a supply chain level, little is known about barriers to carbon neutrality, circumventing strategies, and their performance implications. This pioneering study addresses the knowledge gap by case studies of six first movers. We find four common barriers: "major upfront investment costs," "lack of awareness," "lack of expertise," and "resistant mindset." Small and medium-sized enterprises face additional barriers relating to "lack of support from supply chain partners" and "uncertainty in return on investment." We find that most first movers achieved positive economic performance associated with their carbon neutrality initiatives. Based on the findings and the literature, we develop a framework and discuss practical implications for governments and businesses to jointly overcome barriers to supply chain decarbonization.

1. Introduction

The world has witnessed an accelerating trend of sea level rise and more extreme weather events in recent decades due to global warming (IPCC, 2021). It's widely believed that climate change is mainly caused by the increasing greenhouse gas (GHG) emissions from human and industrial activities since the industrial revolution. "Stabilizing the climate will require strong, rapid, and sustained reductions in greenhouse gas emissions, and reaching net zero CO₂ emissions" (IPCC, 2021, p. 3). Due to the severity and urgency of the climate issue, the United Nations considers carbon neutrality by 2050 the world's most urgent mission (Guterres, 2020).

Carbon neutrality, often used interchangeably with net zero, means accomplishing net zero CO₂ emissions to prevent global warming (Chen, 2021). Globally, the average atmospheric concentration of CO₂ has increased from 285 ppm to 415 ppm since 1850, resulting in an average surface temperature increase of 1.2 °C. The goal of reaching carbon neutrality by 2050 was set as a means of limiting global temperature increases to between 1.5 and 2.0 °C over pre-industrial levels by 2100. Countries around the world are joining forces to help achieve this.

Carbon neutrality provides accountability for nations and

organizations. No country has achieved carbon neutrality yet, but many have pledged to carbon neutrality by 2050. In 2019, the United Kingdom (U.K.) became the first major economy that made a commitment to net zero by 2050 (U.K. Government, 2019). Later in the same year, the European Commission (2019) announced the European Green Deal, which included a road map for the European Union to lead the way to carbon neutrality by 2050. With the new Biden administration, the United States re-entered the Paris Agreement and pledged to reach net zero by no later than 2050 (U.S. Department of State, 2021). China, the largest GHG emitter, recently pledged to achieve carbon neutrality, albeit by 2060 (United Nations, 2020).

Following the trend, many leading global organizations have started to plan how to achieve carbon neutrality in their operations and supply chains. The engagement of publicly listed firms is mainly driven by credibility and leverage in climate policy development, fiduciary responsibility, risk avoidance, and ethical considerations (Okereke, 2007). The process to carbon neutrality is accelerating; as of November 2021, 60 of the U.K.'s FTSE100 companies have signed up to the United Nations' Race to Zero campaign (U.K. Government, 2021). Until March 2022, 313 leading companies have joined the Climate Pledge (Climate Pledge, 2021). They committed to working towards net zero carbon in

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their worldwide businesses and to meeting the Paris Agreement 10 years early.

The Greenhouse Gas (GHG) Protocol, a widely-used GHG accounting tool, categorizes GHG emissions into three scopes. Scopes 1 and 2 cover the direct (i.e., from internal operations) and indirect (i.e., from generating purchased energies) emissions of organizations. Scope 3 includes all other indirect emissions from supply chain activities, including the extraction and production of purchased materials, transportation of purchased materials and products, and consumption of products and services (Olatunji et al., 2019).

Very often, the organizations that have attempted to minimize GHG emissions have discovered that their direct emissions are overshadowed by those generated by their supply chain networks (Plambeck, 2012). With supply chain emissions 5.5 times higher than operational emissions, it has become obvious that firms must work with their suppliers to take meaningful actions (CDP, 2019). To determine the most lucrative ways to reduce overall emissions, organizations must take a supply chain approach to engage multiple tiers' suppliers and customers (Gong et al., 2018). Such organizations should play a leadership role (Jia et al., 2019) by considering not only their direct emissions but also those of their suppliers (both direct suppliers and lower-tier suppliers) and customers, attempting to mitigate them by providing incentives and information or even direct assistance (Plambeck, 2012).

Existing research has explored barriers to carbon neutrality to a certain extent. For example, RTPI (2021) explored barriers to net zero transport from a macro (national/regional) perspective. De Haas et al. (2021) analyzed barriers to net zero on financial management aspects. Melville (2019) briefly mentioned four common barriers at the industry level, including commitment and communication, understanding Scopes of emissions, uncertainty, and credibility of carbon offsetting. From a regional perspective, Sankaran (2021) proposed that financial hurdles could be the biggest barrier to net zero. The above research tends to focus on macro factors, policies with no empirical evidence, and limited discussion on supply chains.

On the other hand, grey literature shows that practices are leading research. Consulting firms have explored carbon neutrality at a supply chain level, perhaps driven by their commercial interest in offering solutions to their clients. Burchardt et al. (2021), Boston Consulting Group consultants, identified a barrier in the lack of understanding of the extent or the nature of the problem, which is more challenging for organizations with a large supplier base or many tiers of suppliers. The authors suggested that organizations need to have a thorough understanding of their value chains, commit to long-term and more intensive engagement with suppliers, greater education, and launch joint projects. McKinsey Sustainability (2011) summarized five challenges for value chains to become net zero: the lack of carbon-accounting foundations, overreliance on secondary data for Scope 3 emissions, uncertainty in cost and technical feasibility, the requirement of industry-wide collaboration, and the need for sustained long-term engagement with multiple stakeholders.

Overall, academic research lags behind practices and grey literature on supply chain decarbonization. There is a lack of scholarly research on barriers to supply chain decarbonization and performance implications, even though a supply chain perspective is crucial for organizations to achieve carbon neutrality. Thus, this research aims to answer the following research questions:

- 1 What are the barriers to supply chain decarbonization?
- 2 How can the barriers be overcome?
- 3 What are the performance implications of moving towards carbon neutrality?

In order to answer these research questions, we study six cases of first mover organizations. Using primary and secondary data from multiple sources, an in-depth case-study analysis was conducted to understand the barriers, the strategies to overcome such barriers, and the

performance implications from supply chain decarbonization.

Our research makes the following contributions: (1) to the best of our knowledge, it is the first empirical research that systematically investigates barriers to carbon neutrality from a supply chain perspective; (2) this research identifies four common barriers: "major upfront investment costs," "lack of awareness," "lack of expertise," and "resistant mindset." We also find that small and medium-sized enterprises (SMEs) and firms in a developing country context face additional barriers; (3) we identify a variety of effective strategies for overcoming the barriers; (4) we find all the first movers gained a good reputation and most of them benefited economically from their carbon neutrality initiatives; (5) this study develops a framework for guiding governments and businesses to overcome barriers to supply chain decarbonization.

The remainder of this paper is organized as follows. The following section conducts a literature review on the relevant academic research. Section 3 describes the research methodology and data. Section 4 presents case study analysis results and findings. Section 5 presents a framework for overcoming barriers to supply chain decarbonization and discusses managerial and policy implications. Finally, Section 6 concludes the research.

2. Literature review

Production and logistics activities in supply chain networks are the major contributors to GHG emissions. Some early studies explored low carbon practices at a supply chain level, although the term "carbon neutrality" has not been applied. Zhu and Geng (2013) studied the drivers and barriers of Chinese manufacturers to implementing emission reduction practices along the extended supply chains. As most manufacturing companies focus on financial gains and do not have the resources and capabilities, internal factors are seen as a major impediment to implementing low-carbon initiatives. Similarly, Subramanian and Abdulrahman (2017) further verified that the implementation of low carbon practices could lead to considerable performance improvement for manufacturing companies, such as product redesign capabilities. However, the main barriers are related to financial and policy aspects. From a macro perspective, Liu (2014) summarized four categories of barriers to adopting low carbon production, i.e., structural, regulatory, cultural, and contextual barriers, while "lack of financial incentives" and "lack of a common definition" were identified as the most prominent.

Some studies focus on more detailed functions of the supply chain network. For example, Goh (2019) explored the barriers to low-carbon warehousing from a single multinational company. It found that technical deficiencies and lack of supporting policy guidance as barriers to decarbonization efforts in warehousing. Liu et al. (2017) studied consumers' purchasing intention for low-carbon products. Through simulations, it found that people's awareness or income were not the main factors influencing their intentions. Instead, delivery time and satisfaction with low-carbon products had more significant impacts.

Accompanied by urgent national actions of "carbon neutrality," research on decarbonization-related practices is emerging. Olatunji et al. (2019) believed that consumers were the crucial stakeholder to maintain a carbon-efficient supply chain because the ultimate purpose of manufacturing products was to satisfy them. Lopes de Sousa Jabbour et al. (2020) proposed a conceptual framework of low-carbon production and logistics and emphasized that stakeholder pressure will affect decarbonization operation management practices. However, companies often face difficulty of understanding stakeholder pressures due to awareness gaps. To enhance the performance of the decarbonization supply chain, digital technology could play a significant role. For example, Sharma et al. (2022) concluded that low carbon practices partially mediate the sustainable performance of digital supply chains among manufacturing firms. As an emerging Industry 4.0 technology, blockchain technology can help enterprises record carbon emission data with its characteristics of tamperproof and transparent traceability

(Sadawi et al., 2021).

The decarbonization operations vary in specific contexts since heterogeneity exists in different regions or industrial contexts. For example, Tingley et al. (2017) studied carbon emission reduction in the U.K. construction industry, especially in the reuse of structural steel. They identified the two most essential practical barriers are cost and the difficulty of supply chain integration. In developing countries, the progress to “carbon neutrality” appears even tougher and is likely to take longer. In China, for example, the carbon peak has not been reached, and it would be challenging to decouple economic growth with increasing CO₂ emissions as China remains reliant on high-carbon fossil energy (Liu et al., 2022; Zhao et al., 2022). From a study of low-carbon operations in the Brazilian market, Wanke et al. (2021) believed that emerging markets lack the necessary knowledge and skills for low-carbon logistics. Also, manufacturing companies pay more attention to logistics aspects than to decarbonization management of manufacturing processes or products. Table 1 summarizes these major studies on the barriers to supply chain decarbonization.

To conclude, the research on carbon neutrality from a supply chain perspective is scattered. Early research tends to focus on a macro level, or low carbon practices of focal firms or specific functions (e.g., logistics, warehousing, marketing) with the research trends shifting towards carbon neutrality at a supply chain level. Firm size, industry, and development status of host countries present significant distinctions in implementing low carbon practices. With the recent consensus on moving to carbon neutrality, the supply chain plays a critical role in decarbonization, especially in addressing the Scope 3 emissions. Our research questions remain to be explored on this “giant untapped opportunity” (Burchardt et al., 2021, p. 6).

3. Methodology and data

This study uses a multiple case study method for several reasons. Firstly, a case study method is a good fit for descriptive (*what* happened?) and explanatory (*how* or *why* did something happen?) research questions (Yin, 2013). Secondly, a strength of the case study method is the ability to conduct in-depth examinations of a research phenomenon within real-life contexts (Yin, 2013), which is necessary for this exploratory study. Last but not least, we select multiple cases to gain insights into the effect of contexts, including industry sectors, the economic development stage of the host country, etc. In line with the chosen case study method, this study employs an inductive approach to theory development to generalize findings from limited case data (Eisenhardt and Graebner, 2007).

The research employed a purposive sampling approach in case selection (Yin, 2013). An essential inclusion criterion is that a business must have already made a commitment to carbon neutrality and have implemented multiple carbon neutrality initiatives. The researchers selected case companies in the U.K., Bulgaria, and Pakistan to compare the situations in a developing vs. developed country context. In addition, a variety of business sectors were investigated on the effects of contextual factors.

To recruit research firms, a researcher first searched online to identify firms that have made a public commitment to carbon neutrality and have done multiple related projects. An invitation to participate in research was sent to senior managers who had a broad understanding of environmental sustainability and supply chain management. These senior managers were contacted mainly through LinkedIn. A total of 25 firms were approached, of which nine agreed to participate in this study. However, two of these firms postponed interview meetings multiple times due to their busyness. We decided to drop them from the study

Table 1
Literature review on supply chain decarbonization barriers.

Research	Journal	Research focus	Barriers
Zhu and Geng (2013)	<i>Journal of Cleaner Production</i>	Extended supply chain practices for energy saving and emission reduction among Chinese manufacturers	<ul style="list-style-type: none"> • Insignificant financial gains • Lack of resources and capabilities • Lack of information
Liu (2014)	<i>Energy policy</i>	Low carbon production of industrial firms	<ul style="list-style-type: none"> • Lack of financial incentives to stimulate low carbon innovation • Lack of common definition of low carbon production
Liu et al. (2017)	<i>Business Strategy and the Environment</i>	Consumer willingness to pay for low carbon products	<ul style="list-style-type: none"> • Delivery speed, consumer's patience, and satisfaction will impact the willingness to buy low-carbon products
Subramanian and Abdulrahman (2017)	<i>International Journal of Logistics Management</i>	Carbon efficient practices of manufacturing firms	<ul style="list-style-type: none"> • Management • Financial • Policy • Infrastructure • Cost
Tingley et al. (2017)	<i>Journal of Cleaner Production</i>	Low carbon operation of structural steel reuse	<ul style="list-style-type: none"> • Availability storage • No client demands • Traceability • Lack of supply chain integration
Goh (2019)	<i>International Journal of Physical Distribution & Logistics Management</i>	Low carbon warehousing	<ul style="list-style-type: none"> • Technology • Government / regulatory-related
Liu et al. (2019)	<i>Management Decision</i>	Market integration on carbon emissions	<ul style="list-style-type: none"> • Regional barrier • The coordination role of government
Olatunji et al. (2019)	<i>Journal of Cleaner Production</i>	Carbon efficient supply chain in the manufacturing industry	<ul style="list-style-type: none"> • The awareness of consumers • Different regulations • The complexity of supply chain tracking
Lopes de Sousa Jabbour et al. (2021)	<i>International Journal of Production Research</i>	Low carbon production and logistics	<ul style="list-style-type: none"> • Stakeholder pressures • Difficulties in understanding stakeholder pressures
Wanke et al. (2021)	<i>International Journal of Production Economics</i>	Low carbon operations in the Brazilian market	<ul style="list-style-type: none"> • Lack of hard resources (equipment and assets) • Lack of soft resources (knowledge)
Liu et al. (2022)	<i>Nature Reviews Earth & Environment</i>	Carbon neutrality in China	<ul style="list-style-type: none"> • Decouple economic growth and CO₂ emission • Data report challenges • Difficulties in reducing emissions from the demand side
Zhao et al. (2022)	<i>Resources, Conservation & Recycling</i>	Carbon neutrality in China	<ul style="list-style-type: none"> • Lags in terms of technological research and innovation • Carbon peak has not reached (Reliant on high-carbon fossil energy) • Immature low-carbon technologies

after collecting and analyzing data from seven other firms. This is not only because of the difficulty to secure a meeting, but also because the sixth case provided limited new insight and the seventh case no new insight. Thus, we believe our findings have achieved theoretical saturation. We retain the first six cases in this study. Table 2 presents the profile of these six companies and case data sources.

To ensure data validity, a request was made to the participating firms that we must interview senior managers who oversaw sustainability projects and who were familiar with supply chain operations. This was to ensure that we correctly understood a participating firm's carbon neutrality program and its impact on supply chain performance. We requested to have multiple interviewees in each participating firm. However, the request was granted only by company D. We also interviewed an external consultant who advised company A on their carbon neutrality initiatives. For both companies A and D, we found that the interview data were consistent between different interviewees, which suggests that recruiting multiple interviewees for this project may not be necessary. Table 3 lists the profile of participants and the number of interviews. The participants had an average of eight years of experience in sustainability initiatives, demonstrating a broad knowledge base and practical expertise relevant to the research topic.

A semi-structured interview approach was followed as it enables an interviewer to focus on key questions while allowing flexibility to accommodate unexpected developments in interview conversations (Eisenhardt, 1989). Face-to-face interviews were not possible due to the ongoing COVID-19 pandemic; therefore, all the interviews were conducted online via Zoom.

We sent a copy of the interview questions (in Appendix A) to the research participants well in advance so that they could think through and prepare their answers. Each interview lasted between 45 and 90 min, and the average length of interviews was about 60 min. All interviews were recorded. The same researcher transcribed the recordings, and the transcripts were checked by another researcher. To safeguard data validity and reliability, we triangulated interview data with multiple secondary data sources (Pfeffer and Salancik, 1978; Tracy, 2010), as listed in Table 2. Some interviewees provided internal company documents on their carbon neutrality projects. We also examined data on the websites of the companies and relevant government agencies. We followed up with some of the interviewees where there appeared to be inconsistencies across the data sources.

Following Miles and Huberman (1994), we performed the within-case analysis to reduce the complexity in data by extracting the most relevant information for answering each research question. The researchers went through the data multiple times to ensure a holistic understanding of the data before finalizing the analysis results. We then conducted the cross-case analysis to compare and contrast the commonalities and differences in barriers and performance implications across firms. It brought to the surface the effects of contextual factors in a firm's transition to carbon neutrality. We also identified the strategies that have been proven effective in the case companies for overcoming

Table 3
Profile of the interviewees.

Company	Number of interviews	Interviewee designation	Years of experience	Interview date
A	2	U.K. International freight manager	15	2/08/2021
		Managing director of a consultancy firm	10	1/07/2021
B	1	Sales and marketing manager	4	27/07/2021
C	1	Managing Director	5	30/07/2021
D	4	Manager Project and Compliance	8	15/07/2021
		Senior Deputy Manager Utility	8	15/07/2021
		Sustainable	4	15/07/2021
		Technical Manager	4	15/07/2021
		Administrative MTO in waste management	2	15/07/2021
E	1	General Manager Supply chain and Operations	8	26/07/2021
F	1	Director of Projects and Sustainability	10	17/07/2021

the barriers and the degree of difficulty in overcoming the barriers. Two researchers coded all the case data separately and discussed their differences in within-case and cross-case analysis results until they reached a consensus. In the data analysis process, the researchers consulted several interviewees for clarification when they were not sure. This process ensured no misinterpretation of data.

4. Results and findings

We first provide the results of the within-case analysis, describing and explaining the collected data. We then report the findings from the cross-case analysis, including the major barriers, circumventing strategies, and performance implications.

4.1. Within-case analysis

4.1.1. Case company A

Company A in the U.K. is part of a multinational logistics company headquartered in the United Arab Emirates (UAE). The corporate follows an asset-light business model by partnering with local logistics firms that have well-established networks for last-mile deliveries. On its pathway to carbon neutrality, the company wanted to purchase electric vehicles and other technologies for its operations. The main barrier was major upfront investment costs because electric vehicles were quite expensive. However, they were very positive about upgrading diesel-

Table 2
Case company profile and data sources.

Company	Country	Industry sector	Business scope	Size (number of employees)	Data Sources
A	U.K.	Logistics and Transport	Multinational logistics, courier, and package delivery	12,000–13,000	Interviews and company website
B	U.K.	Logistics and Transport	The U.K.'s largest freight exchange serving shippers and transport providers.	50–100	Interview and company website
C	Bulgaria	Food Packaging	Imports and distributes sustainable and compostable packaging for the food and beverage market	50–100	Interview and archive files
D	Pakistan	Textile	Manufacture and export textile and garments to multinational brands	5000–6000	Interviews, company website and archive files
E	Pakistan	Food and Beverages	Franchisee manufacturer of a multinational beverage brand	4000–5000	Interview and company website
F	Pakistan	Textile	Manufacture and export textile and garments to multinational brands	20,000+	Interview, archive files and company website

powered vans and gas-powered forklifts as their electric counterparts had lower running costs. They tried to overcome the financial challenges by budgeting for vehicle replacements wisely over time. They required their local partners to make the same commitment to carbon neutrality; otherwise, they would be excluded from future business relationships.

A commitment to carbon neutrality has been essential for the business to retain some customers, which are environmentally conscious. It has enabled them to gain new customers and helped them become a more attractive prospect to customers. The company actively uses social media platforms, including Facebook and LinkedIn, to promote and publicize its green initiatives within its organization and to the public. Such platforms have been very helpful in creating awareness on the concept of carbon neutrality, so the awareness issue is no longer a main barrier after the initial stage.

4.1.2. Case company B

Company B runs the largest online freight exchange platform in the U.K., serving shippers and transport providers to maximize vehicle utilization on the roads. The most critical barrier that it faced was a resistant mindset of some of its customers and supply chain partners that disregarded the urgency of transitioning to carbon neutrality. A second barrier was a lack of awareness and knowledge among individuals in the organization as well as among the public on the concept of carbon neutrality. For example, many people didn't think a logistics business could become carbon neutral because they knew nothing about carbon offsetting. The company emphasized the important role of education in overcoming the barrier. A lack of expertise was another barrier, and it was overcome by hiring people with the right expertise in sustainability.

The company did not face any financial barrier and claimed that there were a lot of incentives, for example, good long-term return on investment (ROI), for companies pursuing carbon neutrality. The firm now runs more efficiently by optimizing routes through different telematics to reduce fuel costs which indirectly helps their customers reduce their logistics costs and attract more customers. Note that the firm only used rental vehicles and was very asset-light. However, for its carbon neutrality aspiration, it had difficulty getting support from supply chain partners, most of which owned transport vehicles. A lack of supply chain transparency on the status of cargo and vehicles has been another barrier, and the firm plans to use technologies to improve transparency.

4.1.3. Case company C

Company C is a small and medium-sized enterprise (SME) that imports and distributes plant-based packaging for the food and beverage market in Bulgaria. A main barrier faced by this organization was cost - It had to bear the cost of marketing its greener products by providing free samples to its distributors and clients. Investment risk, i.e., being uncertain about ROI, was another barrier that prevented it from a technology upgrade to further reduce carbon footprints. The firm did not have economies of scale, so it was risky for them to invest. The third barrier is creating awareness among their customers by educating them on the importance of using low-carbon packaging. The fourth barrier was higher product prices. Its products were 70% more expensive than plastic packaging partly due to its carbon neutrality initiatives. A tiny part of the market was passionate about its products, but most consumers were not willing to pay more for greener packaging. The last barrier was the bureaucracy in the government because it was difficult to get new things approved in the food sector. The company's carbon neutrality program focused on Scope 3 as its main activities were importing products and selling to its customers.

4.1.4. Case company D

Company D in Pakistan manufactures and exports textiles and garments to multinational brands. While moving towards carbon neutrality, it faced two major barriers: the high cost of upgrading equipment and a lack of awareness among the suppliers and within the organization regarding the carbon neutrality concept. It tried to overcome the second

barrier by creating awareness among the supply chain partners. Its overseas clients helped in the process by providing guidance from their sustainability departments. A lack of government policies on carbon neutrality was another main barrier, which made it difficult to convince its suppliers to go carbon neutral. The firm had been mainly dealing with Scope 1&2 carbon emissions. However, it recently started to look into Scope 3 emissions. It planned to track its logistics providers which transport their products to clients and urge them to reduce carbon emissions. Because of going green, the firm had won more business contracts by following the standards appreciated by overseas customers. It saved water and electricity, and its new projects had good ROI.

4.1.5. Case company E

Company E in Pakistan is a franchisee of a multinational beverage brand. In moving towards carbon neutrality, a major barrier was a lack of awareness among its employees and supply chain partners in the country, so it had to make great efforts to create more awareness. It also faced a financial barrier in investing in advanced technologies. Another barrier was a lack of knowledge and expertise in how to achieve carbon neutrality. There were no validated examples yet in many areas of implementation. The company was in a mode of learning by doing, but it was convinced of a first mover advantage. The company was very active in learning from research publications and from people in the same and different environments that did similar projects.

The company achieved a great ROI from its carbon neutrality projects. It reduced its expenses and resources consumptions, and at the same time, eliminated some long-term risks associated with its resource dependency. It gained a better reputation than its local competitors. The firm had been working on all three emissions scopes. For example, it installed a waste burning boiler to replace a gas burning boiler to reduce its Scope 1 emissions. To control Scope 3 emissions, it reduced plastic use in product packaging, which helped make loads of containers weigh less. This initiative reduced carbon emissions in its supply chain. It plans to initiate more projects which can help further reduce Scope 3 emissions, for example, route optimization of vehicles from their distribution centers to distributors.

4.1.6. Case company F

Company F manufactures and exports textiles and garments to multinational brands. It is one of the largest exporters in Pakistan, employing about 20,000 workers. This firm had been reducing carbon emissions in all three scopes. A resistant mindset was one of the major hurdles in the organization. Many disregarded the importance and urgency of carbon neutrality, and they did not believe in its economic benefits as well. The company pressed on with some demonstrative carbon neutrality projects. After 18 months, some employees and suppliers started to gain confidence in the company's slogan for carbon neutrality after seeing the economic benefit. The firm acknowledged that education and communication had its limitation in changing people's mindsets. Seeing no further benefit in doing more education, the firm decided to change people if they hadn't changed their mindset yet. It shuffled people from one department to another within the organization to reduce resistance. Similar resistance was observed in its upstream supply chain. However, the firm had seen a lot of behavioral changes among the supply chain entities after educating the suppliers, partly due to its large business scale and bargaining power.

The other barrier was the high cost which was required for purchasing new machinery that is energy efficient and environmentally friendly. The firm had a plan to move forward progressively. Over the years, it had invested a lot in machines in innovation. Such investments had accrued economic benefits of reducing operating costs. By moving towards carbon neutrality, the firm succeeded in getting more business from major brands, including H&M, Zara and Levis, which were eager to work with environmentally sustainable manufacturers. The other barrier was a lack of government policies. The firm complained that the government only talked about planting some trees, but nothing was

clear for the businesses.

4.2. Cross-case analysis

4.2.1. Barriers to carbon neutrality

Table 4 summarizes each firm's progress, barriers, and unique contextual factors. The results show several common barriers to carbon

Table 4
Cross-case analysis results.

Case	Scopes of emissions being dealt with	Main barriers	Contextual factors
A	Scopes 1, 2 & 3	<ul style="list-style-type: none"> Major upfront investment costs 	The logistics provider in the U.K. engages a business partner for local deliveries but operates its own trucks and warehouses for other logistics activities. Upgrading to electric vehicles is costly.
B	Scopes 1, 2 & 3	<ul style="list-style-type: none"> Resistant mindset Lack of awareness Lack of expertise Lack of support from supply chain partners Lack of supply chain transparency 	This UK SME is an intermediate between a diverse range of shippers and logistics providers. It was difficult to get all supply chain partners on board due to a resistant mindset toward carbon neutrality because some don't think it is urgent and important. Many lack awareness of the concept and its benefits. The firm only uses rental vehicles.
C	Scopes 1, 2 & 3	<ul style="list-style-type: none"> Marketing cost Uncertainty in RIO Lack of awareness among customers Consumers are not willing to pay more for greener products Lack of expertise Bureaucracy in the food sector 	This Bulgarian SME imports and sells plant-based packaging products, which are 70% more expensive than plastic ones. It has limited financial resources. Due to uncertainty in RIO, it is reluctant to invest in new technologies that would help further reduce carbon footprints. The firm has difficulty hiring qualified or skilled people as many talented people choose to work in more developed European countries. Bureaucracy in the government causes difficulty in getting new things approved in the food sector.
D	Scopes 1 & 2	<ul style="list-style-type: none"> Major upfront investment costs Lack of awareness among the suppliers and within the organization Lack of government policies 	These manufacturers in Pakistan started their carbon neutrality journey because of a push from their overseas customers. Some of their equipment is expensive to upgrade.
E	Scopes 1, 2 & 3	<ul style="list-style-type: none"> Major upfront investment costs Lack of awareness among supply chain partners Lack of expertise 	There is a lack of awareness on the concept of carbon neutrality in the country, and some people do not consider the matter as important or urgent. The Pakistan government has not formulated policies and implementation strategies for achieving carbon neutrality.
F	Mainly in Scopes 1 & 2; Moving onto Scope 3	<ul style="list-style-type: none"> Major upfront investment costs Resistant mindset Lack of government policies 	

neutrality: "major upfront investment costs," "lack of awareness," "lack of expertise," and "resistant mindset." We also find context-specific barriers relating to small and medium-sized enterprises (SME), where the data from companies B and C show "lack of support from supply chain partners" and "uncertainty in return on investment (ROI)." Two companies (D and F) in a developing country, Pakistan, complained about a "lack of government policies" on carbon neutrality.

We observe three financial barriers: "major upfront investment costs," "marketing cost," and "uncertainty in ROI." All case companies except B and C consider "major upfront investment costs" as their major hindrance toward carbon neutrality. This financial barrier is understandable because most firms need to make large investments to upgrade machines and vehicles to reduce emissions. Generating renewable energies also requires a substantial amount of investment. However, most firms are positive about the potential ROI if they have funds to invest. When asked about barriers, an interviewee from Company A stated:

"Mainly the finances I would say. As we know, right now, electric vehicles are quite expensive. But you must change the way you think about that and look at the overall cost saving over 5 to 10 years - it's not you know it's going to hurt initially. These can be quite costly to begin with, but then you look at the advantages of less maintenance and all those kinds of good stuff that comes with making the switch."

Company B is an exception because it does not own any vehicle – it only uses rental vehicles, so does not have to bear the capital cost of upgrading vehicles. Besides "major upfront investment costs," company C faces the other two financial barriers, which are "marketing cost" and "uncertainty in ROI". As an SME, the firm has very limited financial capacity. Lacking economies of scale, its breakeven time is much longer than large firms, therefore higher investment risk.

Table 4 shows three knowledge related barriers: "lack of awareness" (*about general knowledge*), "lack of expertise" (*about specialist knowledge and technical know-how knowledge*), and "resistant mindset" (*about disbelief or disregard of knowledge*). "Lack of awareness" is a significant barrier that emerged in all the three countries involved in the study due to the newness of the carbon neutrality concept. The issue is widespread among all the stakeholder groups, including consumers, customers, suppliers, and employees. However, the issue is more prominent in developing countries such as Pakistan and Bulgaria than in developed countries like the U.K. In fact, all three Pakistani firms (D, E, F) were introduced to the carbon neutrality concept by their overseas customers. For example, Company D has been supplying brands including Zara and H&M, which impose stringent environmental standards on their suppliers and sub-suppliers (Venkatesh et al., 2020). Due to such standards, the firm had to require its suppliers to tackle emissions. However, its local suppliers were not much aware of emissions-related concerns. They did not want to take the risk by jumping into carbon neutrality initiatives because they were not confident about how they would benefit from it. One participant from company D stated:

"The second barrier was to create awareness among every entity in the supply chain and to make them understand the long-term benefit because of the adoption of carbon neutrality. We had to teach our suppliers as well about the importance of this concept because our clients were not allowing us to work with such entities which were not following their standards."

"Lack of expertise" is a common challenge faced by both governments and businesses because the whole world is on uncharted water. A transition to carbon neutrality requires a lot of technical expertise. Some research participants in Pakistan raised concerns about the lack of government policies because of the lack of expertise in the government. Businesses have also been set back by the skill shortage. The managing director of a consultancy firm stated:

"Companies are not fully educated how to adopt this concept because they're not that an expert or they need expertise people they're

working with like our company. They need the expertise, because the people who are trying to do this, get consumed by the job that is in hand.”

“Resistant mindset” exists as a barrier because some firms do not think it is urgent or important to move toward carbon neutrality. This barrier can be partly attributed to a lack of awareness of emissions-related environmental issues but can also be due to a mindset of disbelief or disregard for climate change. All the large firms in our sample except one (Company F) do not consider this barrier a major challenge to them because of their power in the supply chain – if their suppliers do not want to get on board, they will lose their business. However, this barrier is a main challenge to Company B, which is an SME that deals with a diverse range of shippers and logistics providers. It does not have the power to push its supply chain partners for a mindset change. On the contrary, for the same reasons, it faces another barrier: “lack of support from supply chain partners.” “Lack of supply chain transparency” is also voiced out because its business model highly depends on information exchanges to match cargo with freight capacities. The interviewee from Company B stated:

“I don’t think the financial side of it is so much of an issue as the whole mindset and the urgency and the education side, I think, (the latter) is more important...”

Company C faces two other barriers: “Consumers are not willing to pay more for greener products” and “Bureaucracy in the food sector.” The company not only serves corporate clients but also runs retail operations to serve consumers. Its plant-based packaging has a fine reputation but has not gained a mass market due to higher prices than plastic packaging. Due to regulations on food safety, it has to deal with the bureaucracy in the government to get new food packaging approved.

4.2.2. Overcoming barriers to carbon neutrality

Our cross-case analysis reveals strategies as outlined in Table 5 for overcoming the four common barriers. We also compare the degrees of difficulty in overcoming the common barriers across two groups of case firms: Logistics firms in an industrialized economy (A, B) and manufacturers in an emerging economy (D, E, F).

When being confronted with “major upfront investment costs,” companies A, D, and F budgeted carefully to spread out large capital expenditures over multiple years. Our case data suggest that it may be relatively straightforward for logistics firms to get around this barrier. Companies A and B benefited from an asset-light business model, which greatly helped relieve financial pressure. For example, company A partnered with DPD, a carbon-neutral logistics provider, to manage its local deliveries in the U.K. Consequently, there was no need for company A to own or upgrade local delivery vehicles. However, manufacturers D, E, and F had to make their own investments in energy-efficient machinery, so they faced a greater difficulty in overcoming this barrier. To maintain their economic viability, companies D and F picked low-hanging fruit first by giving priority to less capital-intensive carbon neutrality projects and those that have a higher ROI. An interviewee from company D said:

“In case of finances we are modeling our new projects in such a way that they will be giving us a good ROI in less than 3–4 years, so that we are able to overcome the expenses used initially for such projects.”

To deal with a “lack of awareness” among consumers, customers, suppliers, and employees, all companies resorted to educate and communicate with the concerned stakeholders. They used a variety of means, including meetings, social media, and marketing leaflets. Company A specially commended the effectiveness of using Facebook and LinkedIn. They kept publishing information on their sustainability projects and the resulting benefits, which quickly created awareness on carbon neutrality among all their stakeholders. Companies D and F also

Table 5

Strategies for overcoming the common barriers and degrees of difficulty.

Barrier	Circumventing strategies	Degree of difficulty to be overcome Logistics firms in an industrialized economy (A, B)	Manufacturers in an emerging economy (D, E, F)
• Major upfront investment costs	<ul style="list-style-type: none"> • Budget wisely – to budget investments in carbon neutrality projects progressively over the years (A, D, F) • Follow an asset-light business model (A, B) • Start with low-hanging fruit projects (D, F) 	Low	High
• Lack of awareness (among consumers, customers, suppliers, and employees)	<ul style="list-style-type: none"> • Educate and communicate with the concerned stakeholders using a variety of means, including meetings, social media, and marketing leaflets (A, B, C, D, E, F) • Start with low-hanging fruit projects (D, F) 	Low	Low
• Lack of expertise	<ul style="list-style-type: none"> • Engage external expert consultants (A) • Hire people with the right expertise in sustainability (B) • Get assistance from experienced clients (D, E, F) • Learning from research publications (E) • Learning from those who have done similar projects (E) • Learning by doing (E) 	Low	High
• Resistant mindset	<ul style="list-style-type: none"> • Select like-minded business partners (A) • Educate and communicate with the concerned stakeholders using a variety of means, including meetings, social media, and marketing leaflets (A, B, C, D, E, F) • Carrot and stick approach (A, D, E, F) • Change people and shuffle people internally (F) 	Generally high, but depends on the power position	Generally high, but depends on the power position

(continued on next page)

Table 5 (continued)

Barrier	Circumventing strategies	Degree of difficulty to be overcome	
		Logistics firms in an industrialized economy (A, B)	Manufacturers in an emerging economy (D, E, F)
	<ul style="list-style-type: none"> Start with low-hanging fruit projects (D, F) 		

purposefully started with low-hanging fruit projects to create awareness. The barrier of “lack of awareness” is not costly to overcome, but it requires persistent efforts in education and communication over an extended period of time. While those case firms who were manufacturers in Pakistan claimed the lack of awareness at a country level, the awareness at the supply chain level was initiated by overseas buying firms and then transferred to the upstream supply chains. As an intermediate echelon in the supply chains, a logistics provider has the advantage of educating and communicating the carbon neutrality concept in their distribution networks.

The barrier of “lack of expertise” was tackled by a variety of strategies. Company A engaged external expert consultants which helped them a great deal. Company B recommended hiring people with the right expertise in sustainability, for example, an experienced sustainability manager, to lead carbon neutrality projects. Companies D, E, and F got assistance from the sustainability departments of their overseas clients to help with their own projects and those of their suppliers (i.e., the sub-suppliers of their overseas clients). Company E has been very active in learning from research publications and from those who have done similar projects on their journey of learning by doing. With the rapid development of electricity- and hydrogen-powered vehicles in the transport sectors, logistics companies may increasingly find it feasible to overcome the barrier of lack of expertise. Contrarily, manufacturers, especially those in the emerging economies, may still face great difficulty in overcoming the expertise barrier. They can benefit from technology transfer and organizational learning from supply chain partners in industrialized economies.

“Resistant mindset” can be very challenging to overcome, especially for firms with a weak power position in the supply chain. Companies A and F deliberately select like-minded business partners that are committed to environmental protection. All the companies tried to educate and communicate with the concerned stakeholders, and they had a varying degree of success in overcoming the barrier. Companies A, D, E, and F, all of which are large enterprises, used a carrot and stick approach. They gave business opportunities to compliant suppliers and threatened to terminate business relationships with non-compliant suppliers. Company F frankly stated that they would change people if people didn’t change after enough education and communication. They also shuffled people internally to reduce resistance to change. Companies D and F also started with low-hanging fruit projects to induce a mindset change by showing the economic benefits of going carbon neutral. An interviewee from Company F stated:

“Fundamentally, I would say the mindset change. Making people realize that this is important, and number two this has economic benefits as well because people don’t take this as an economic benefit. Yeah, and you know with the 18 months of data, people (employees and suppliers) have started sort of gaining confidence in our slogan for carbon neutral.”

In addition to the strategies mentioned in Table 5, all the case companies emphasized the critical role of technologies in their carbon neutrality initiatives. They believe that it will continue to be so, and further progress to carbon neutrality will be increasingly dependent on technological advancements. For example, company B plans to deploy new technologies to overcome the barrier of “lack of supply chain transparency.” There is a consensus among all the firms that

sustainability drives innovation which requires investments in technologies. The research participant from case company E stated:

“I think it’s all about technology. I cannot think of any initiative which is independent or isolated from technology.”

4.2.3. Performance implications

All the firms in the sample improved their environmental performance by going towards carbon neutrality. They reduced the consumption of resources, including gas, electricity, diesel, petrol, and water. Besides the obvious benefit of reducing emissions, Firm C reduced waste generation and reused waste creatively to recover value. As first movers to carbon neutrality, they also gained a good reputation in the market. The implications for economic performance, as summarized in Table 6, however, are less homogeneous.

Five first movers (A, B, D, E, F) involved in the study improved customer retention and increased sales as a direct result of their commitment to carbon neutrality. This shows that an early commitment to carbon neutrality has created a substantial first mover advantage in marketing. Some of these firms also reported lower operating costs and good ROI from their carbon neutrality projects. The other first mover (C), being an SME, however, suffered a product price disadvantage due to the higher cost associated with producing greener packaging. It has a very small market share in the sector because most consumers and customers in the country do not want to pay more for greener alternatives.

5. Discussion

5.1. A framework for overcoming barriers

The findings presented above provide empirical evidence for some of the barriers discussed in the grey literature. “Major upfront investment costs” are indeed the biggest hurdle, as suggested by the accounting firm EY (). “Lack of knowledge and expertise” is a key constraint, as voiced out by the leading consulting firms Boston Consulting Group (Burchard et al., 2021) and McKinsey & Company (Spiller, 2021). Apparently, these two barriers are related to the business interests of EY, BCG, and McKinsey, respectively. This study finds two other common barriers:

Table 6

Implications for economic performance.

Case	Implications for economic performance	Key outcomes
A	It would have lost some customers if it hadn’t made a commitment to carbon neutrality. The transition has given the firm a good reputation, which has helped the firm to attract more customers.	<ul style="list-style-type: none"> Customer retention Increased sales
B	The firm now runs more efficiently by route optimization to reduce fuel costs which indirectly helps their customers reduce their logistics cost and attract more customers through this business model.	<ul style="list-style-type: none"> Customer retention Increased sales Lower operating cost
C	Moving towards carbon neutrality has made its products more expensive. However, it wins a niche market of customers who are passionate about environmental protection.	<ul style="list-style-type: none"> Product price disadvantage
D	Going green has benefitted the firm to win new customers. Carbon neutrality projects have helped them save energy and get good ROI.	<ul style="list-style-type: none"> Customer retention Increased sales Lower operating cost Good ROI
E	A great ROI and a very good reputation in contrast to competitors can be achieved, due to environmental legitimacy.	<ul style="list-style-type: none"> Customer retention Increased sales Good ROI
G	Its customers have started to trust them in better ways compared to competitors, which indirectly gives them more business. Carbon neutrality projects have led to reduced operating costs.	<ul style="list-style-type: none"> Customer retention Increased sales Lower operating cost

“lack of awareness” and “resistant mindset.” Our results identify two additional barriers faced by SMEs: “uncertainty in ROI” and “lack of support from supply chain partners.” The results also suggest that firms in developing countries are likely to face more barriers because their governments are lagging in developing policies related to carbon neutrality, which is identified as a barrier in Pakistan.

Our study finds a wide range of effective strategies for overcoming the common barriers, which adds valuable knowledge to the scant literature on the topic. However, the case studies also reveal that some other barriers have not been circumvented by the firms. The SMEs simply don't have economies of scale and supply chain power to overcome the barriers of “uncertainty in RIO” and “lack of support from supply chain partners.” There is a niche market in which some consumers are willing, but most “consumers are not willing to pay more for greener products.” Such a barrier is generally beyond the control of firms, although they can make efforts to promote sustainable purchasing behaviors. Businesses also have limited influence over the barriers in the governments, for example, “bureaucracy in the food sector” and “lack of government policies.”

Based on the study findings and the literature, we propose a framework, as presented in Fig. 1, to guide governments and businesses to jointly overcome barriers to carbon neutrality in the supply chain. The framework integrates business actions in the center, three governmental pushes on the left, two pulling forces on the right, and four enablers at the bottom. Sustainable purchasing behaviors of consumers can drive businesses to design and produce zero-carbon products. Performance improvements, as observed in most case companies, motivate businesses to work toward carbon neutrality. Four enablers are green infrastructure (RTPI, 2021), knowledge and expertise, technologies and information, and supply chain collaboration (McKinsey Sustainability, 2011). These enablers will play a crucial role to support businesses to tackle their emissions at all three scopes, preferably by emissions abatement, but also possibly by emissions offsetting if it is technically infeasible to further reduce emissions. The recommended actions for businesses, supply chains, governments, and other stakeholders are discussed in the following subsections.

To ensure the framework was valid and relevant to practice, we separately sought feedback from four senior managers who were our research interviewees. They unanimously affirmed the validity of the framework and commended its merits. Just as an example, one of them

gave the following comment:

“Having read through the framework, I think this approached a lot of the difficulties the worldwide supply chain will face, in a methodical and logical manner. It is refreshing to see a report that recognizes the solutions to enable sustainability and puts pressure on governments and business leaders to both educate and fund the introduction of policies and technology across the sector.”

5.2. Managerial implications

Top management should make it a strategic priority to kick off a transition to carbon neutrality. Our study results show a substantial first mover advantage in business reputation among all the case companies, and consequently, most of them achieved sales growth because of their carbon neutrality initiatives. Any procrastination in starting the transition is likely to disadvantage a business, risking losing environmentally conscious customers. Furthermore, in the next few years, many national governments are expected, if they haven't already done so, to introduce industry-specific laws and regulations related to emissions after making commitments to carbon neutrality. A transition to carbon neutrality will soon be compulsory for most, if not all, industry sectors. Therefore, we call for strong leadership to take concrete actions within a firm and across its supply chain (Jia et al., 2019).

In strategic planning, businesses should build synergy in the dual goals of carbon neutrality and circularity (Ivanova and Sanders, 2021). Due to increasing resource scarcity, supply chains need a transformation from linear to circular (Zhang et al., 2021). Circular supply chain management aspires a zero-waste vision by reducing waste generation and value recovery from waste (Farooque et al., 2019). According to the Circularity Gap Report 2021 (Circle Economy, 2021), the circular economy model has the potential to cut global emissions by 39%. In a circular supply chain, reuse and recycling can help save emissions that are embedded in the end-of-use products and materials. We recommend businesses to consider not only end-of-use product and waste management, but, more importantly, the product design stage. By integrating end-of-life thinking into the product design stage, there is a greater potential to reduce supply chain emissions and waste (Burke et al., 2021).

Wise budgeting is required for overcoming financial constraints. It is

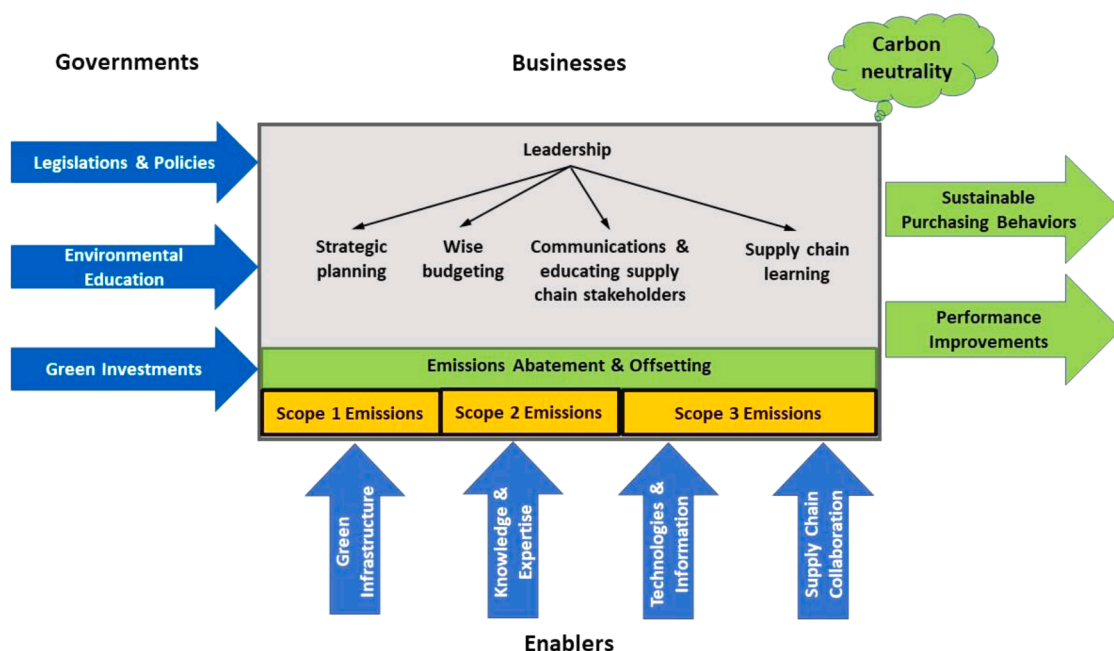


Fig. 1. A framework for overcoming barriers to supply chain decarbonization.

necessary to budget large investments in carbon neutrality projects over multiple years, as some of our case companies did, to make them financially viable. Our study results identify “resistant mindset” as a main barrier, which is in line with the findings of Zhang et al. (2016) that resistance to change is a major challenge in business improvement initiatives. We recommend firms to start with quick-win projects, which can be very beneficial to help supply chain stakeholders to understand the importance and benefits of carbon neutrality, therefore, support overcoming the barriers in awareness and mindset.

Communications and educating supply chain stakeholders should be ongoing in a firm's transition to carbon neutrality, especially in the initial stage, which will be much more challenging due to a “lack of awareness” and “resistant mindset.” Our study suggests the use of a variety of means, including meetings, social media, marketing leaflets, and demonstrative quick-win projects. Social media may be very helpful as it can effectively reach a large audience, especially younger generations, at a low cost. While educating business partners may become less demanding after they are on the same transition, there will be a continuous need to communicate with and educate consumers. Businesses will need to keep promoting the environmental benefits of their greener products to induce sustainable purchasing behaviors.

Furthermore, businesses need to be prepared to manage supply chain learning in transitioning to carbon neutrality. This research reveals a shortage of specialist knowledge and expertise to support the transition. Consulting firms should be considered when required, but they can be costly. Still, businesses need to develop in-house expertise. Supply chain stakeholders need to learn from a variety of knowledge sources, including consultants, academics, research publications, and those who have done similar projects. Because of a need for supply chain collaboration, organizational learning in the transition needs to move beyond the traditional firm boundaries. Firms will need to orchestrate internal and external resources to support supply chain learning of knowledge related to reducing and offsetting emissions (Gong et al., 2018).

5.3. Policy implications

There is an urgent need for many national governments to develop emissions-related legislations and industry-specific policies for achieving carbon neutrality. This study identifies “lack of government policies” as a barrier because businesses need policy guidance. In addition, regulatory pressure reduces resistance in getting supply chain partners on board carbon neutrality initiatives. The need is specially pressing in many developing countries which are lagging in the transition. The European Green Deal provides a roadmap for its member countries (European Commission, 2019), which can serve as a reference for other countries. However, the pathways to carbon neutrality are likely to be unique for each country because of the differences in the availability of renewable energy sources, emissions intensity, industrial structure, infrastructure, etc. Therefore, each country will need to adopt a scientific approach to tailor carbon neutrality related legislation and policies. Given that most consumers are not willing to pay more for greener products, as found in the research, governments should consider using carbon taxes, and/or credits to level the ground for greener products to compete.

Governments should make strategic green investments in multiple areas to support the transition to carbon neutrality (Chang et al., 2021). First, cities worldwide face tremendous challenges to provide new infrastructure for a carbon-neutral and sustainable future (Chen et al., 2021). For example, there is a pressing need to fund infrastructure for charging electric vehicles in order to take conventional petrol and diesel cars and vans off roads. Second, it is necessary to invest in hydrogen, carbon capture, utilization and storage, and renewable energies, including solar and wind energy (IEA, 2021). Third, resolving the skill shortage issue would require investments in carbon neutrality related research, education, and training activities. Last but not least, many businesses, especially SMEs and those in the energy-intensive sectors,

may need financial assistance to achieve carbon neutrality. Governments should allocate funds to support a just and equitable transition to carbon neutrality.

Governments must gear up environmental education to increase awareness of the importance of going carbon neutral, and cultivate a more environmentally sustainable culture. Behavioral change is a key pillar of decarbonization, but there are great uncertainties in the behaviors of the public (IEA, 2021). Earlier studies on the circular economy advocated school curriculum reform and public education campaigns for overcoming the barriers in the culture and public behaviors (Farooque et al., 2019; Zhang et al., 2019). Yin and Shi (2021) recommended the use of social interaction channels to promote low-carbon consumption behaviors in China. We believe similar policy measures would help with the transition to a carbon-neutral future.

5.4. Multi-stakeholder engagement for framework implementation

Carbon neutrality requires fundamental modifications in firms' internal and supply chain operations and the wider business environment. Thus, a system-wide change involving multiple stakeholders is necessary for overcoming the barriers found in this study. The actions encapsulated in Fig. 1 should be viewed as the synchronized responses by multiple stakeholders (e.g., businesses, supply chains, and governments). Disproportionate stakeholder engagement may result in failures in implementing circumventing strategies and performance uncertainty. Therefore, we discuss multi-stakeholder engagement for implementing the framework at two levels, namely, within the supply chain and in the wider business environment.

The supply chain has a significant influence on a firm's decisions and economic performance. Modern business models require close and collaborative configuration, planning, and coordination at the supply chain level. More often than not, Scope 1 and 2 emissions from internal operations may be affected by supply chain partners' decisions which have a directly impact on Scope 3 emissions. A downstream buying firm's carbon neutrality efforts are unlikely to succeed if an upstream Original Equipment Manufacturer or a component supplier has a resistant mindset. A focal company is in a natural position to exercise supply chain leadership on carbon neutrality initiatives. A focal company usually has greater power than its supply chain partners. So, it can use its power strategically to facilitate the implementation of a consistent carbon neutrality strategy across the supply chain. A coercive mechanism (e.g., only selecting like-minded business partners) can be effectively employed by a focal company to overcome a “resistant mindset” of suppliers. Furthermore, with a focal company coordinating carbon neutrality initiatives across the supply chain, all business partners are more likely to develop organizational learning and exploit low-hanging fruit projects effectively.

The transition to carbon neutrality also requires stakeholder engagement in the wider business environment. The concerned stakeholders include industry associations, non-government organizations (NGOs), the public, and governments; their engagement must be orchestrated. Industry associations are increasingly instrumental in supporting information and resource exchanges beyond the supply chains. They can facilitate the development of emissions reduction capabilities, carbon capture and storage technologies, and their applications across industries. Also, industry associations can promote the utilization of carbon by-products. For example, the captured carbon can be used in fertilizer production or can be converted to purified gas for the beverage industry. NGOs play an important role in educating and communicating with the public. They monitor green washing and false disclosures of carbon emissions to hold businesses accountable. They can also propagate best practices and technological solutions for carbon neutrality in collaboration with industry leaders and consumer groups. Besides regulatory and policy mechanisms, governments can use public procurement to support a transition to carbon neutrality. By incorporating emissions measures into supplier selection criteria, substantial

public procurement values provide businesses with a strong economic incentive to decarbonize their supply chain operations.

In summary, we advocate an orchestrated multi-stakeholder engagement to implement the framework as outlined in Fig. 1. While businesses can start with their supply chains and by the leadership of focal companies, industry associations, NGOs, the public, and governments must establish a supportive business environment. There must be synchronized technological and financial support on emissions reduction, carbon capture, storage, and utilization, and regular communication and education on carbon neutrality. The effectiveness of the identified circumventing strategies relies on such an orchestrated multi-stakeholder engagement, contributing to firms' strong economic performance and long-term commitment to carbon neutrality.

6. Conclusions

The human race is on a critical mission to fight climate change by transitioning to carbon neutrality. Many economies, including the U.K., the European Union, the U.S., and China, have pledged to achieve carbon neutrality in the next three or four decades. The required transition faces many hurdles at regional, industry, supply chain, and firm levels. This pioneering study explores the barriers to carbon neutrality at firm and supply chain levels, strategies to overcome the barriers, and performance implications. We employ a supply chain perspective because a corporate's supply chain emissions are about 5.5 times of its direct emissions on average.

This paper makes several original contributions. First, this pioneering work is believed to be the very first research that systematically investigates barriers to supply chain decarbonization and their circumventing strategies. The research topic is of strategic importance and warrants further studies. Second, based on case studies of six first movers, we identify four common barriers: "major upfront investment costs," "lack of awareness," "lack of expertise," and "resistant mindset". We also uncover two additional barriers faced by small and medium-sized enterprises in the sample: "lack of support from supply chain partners" and "uncertainty in ROI." The results also suggest that firms in a developing country context are likely to face more barriers due to lacking government policies. Third, we find many effective strategies that have been used by the first movers for overcoming common barriers. For example, the barrier of "resistant mindset" may be tackled by starting with low-hanging fruit projects and by a carrot and stick approach with suppliers. Overall, most first movers benefited from positive economic performance. Last but not least, we develop a framework to guide governments and businesses to jointly overcome barriers to carbon neutrality and make practical recommendations for accelerating the transition to carbon neutrality.

This research has its limitations. We used English in data collection. Therefore, our interview invitations were only sent to businesses in the U.S., Europe, Australia, New Zealand, and Pakistan, where business managers are expected to be proficient in English. We focused on first movers to carbon neutrality, so not many firms met the eligibility criteria. We only secured participation from seven firms in the U.K., Pakistan, and Bulgaria. Nevertheless, we observed theoretical saturation in the case data. Future research may widen the scope of data collection to cover non-English speaking countries, and consider other research methods other than the case study approach. In addition, our study collected data from businesses only. Given the importance of other stakeholders, it would be worthwhile to cover other stakeholders, including the governments, non-governmental organizations, and consumers, to acquire a more holistic understanding of the research phenomenon in further studies.

Credit author statement

Abraham Zhang: Conceptualization, Methodology, Analysis, Writing. **Muhammad Faizan Alvi:** Investigation, Analysis, Data

Curation **Yu Gong:** Writing, Analysis **Jason X Wang:** Writing, Analysis

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A: Interview questions

- Q1: Which scope of emissions has your organization been working on for transitioning to carbon neutrality? (First, explain that there are three scopes of emissions. Scope 1 emissions are direct emissions from company-owned and controlled resources. In other words, emissions released to the atmosphere as a direct result of a set of activities, at a firm level. Scope 2 emissions are indirect emissions from the generation of purchased energy, from a utility provider. Scope 3 emissions are all the other indirect emissions – those not included in scope 2 – that occur in the value chain of the reporting company, including both upstream and downstream emissions. In other words, emissions that are linked to the company's operations.)
- Q2: What barriers do your firm and your supply chain partners face when moving toward carbon neutrality?
- Q3: How did you and your supply chain partners overcome the barriers to carbon neutrality, or how do you plan to overcome the barriers if you haven't achieved carbon neutrality yet?
- Q4: What business opportunities does your firm believe in, or have already benefited from, by going carbon neutral?
- Q5: How has your journey to carbon neutrality impacted on your firm and supply chain performance considering all three dimensions, including economic, environmental and social sustainability? What changes did you make or plan to make in your internal operations as well in your supply chain operations for achieving carbon neutrality?
- Q6: What is the role or potential role of technologies in your journey to carbon neutrality?

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