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The fallacy of profitable green supply chains: The role of green information systems (GIS) in attenuating the sustainability trade-offs

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ABSTRACT

While green supply chain management (GSCM) has been studied extensively, a lack of a clear view on performance improvements arising from the adoption of GSCM practices obstructs a full understanding of resultant consequences. Moreover, there are still limited efforts to understand the contingent nature of how performance is improved in this context. This study aims to ascertain whether the GSCM implementation yields sustainability–profitability trade-offs and examine the moderating effects of green information systems (GIS) on performance improvements. Survey data were collected from 189 firms operating in the UK automotive industry and analyzed using moderated hierarchical regression. The results suggest that pursuing GSCM can bring trade-offs into play, demonstrating a paradoxical view of enhanced sustainability versus less profitability. The authors call this phenomenon the fallacy of profitable GSCM. Interestingly, high levels of GIS were found to positively moderate the relationships between GSCM practices and economic performance. This study contributes to the knowledge bank of GSCM by elucidating the mixed views about the GSCM adoption and its economic effects and refutes the fallacy that "low-hanging fruits" of GSCM are readily available. Second, this study offers new directions to balance the trade-offs between sustainability and profitability, contributing to the development of a more robust GSCM theory. Two important managerial contributions can be drawn from this study: (1) managers need to prioritize GSCM practices on the basis of having the most significant performance improvement; (2) they are encouraged to develop more robust GIS and exploit the capabilities of information sharing, supply chain traceability, and monitoring as a new pathway to attenuate sustainability trade-offs. Future studies are recommended to explore wider sectors and employ longitudinal or quasi-experimental designs to capture the effects of GSCM practices on performance over time.

1. Introduction

A key insight in the operations and supply chain management (OSCM) literature is that greening the supply chain can deliver both environmental values and economic benefits (Montabon et al., 2016). In recent years, many firms have shown an increased interest in undertaking green supply chain management (GSCM) initiatives in the hope of better environmental mitigation while achieving performance improvements (Meinlschmidt et al., 2018). The vast majority of existing research suggests that the adoption of GSCM practices has a positive effect on both environmental and economic performance (Rao and Holt, 2005; Zhu et al., 2012; Zailani et al., 2012b; Ortas et al., 2014; Vanalle et al., 2017; Geng et al., 2017; Cousins et al., 2019), providing "win-win" opportunities for environmental protection together with economic advantages.

Conversely, a recent branch of research casts doubt on profitable green supply chains by revealing another side to the story and exhibited limited positive effects of GSCM on financial outcomes, advocating that the GSCM implementation does not truly yield economic performance improvement despite its environmental benefits (Montabon et al., 2016; Esfahbodi et al., 2017; Esfahbodi and Zhang, 2020b; Matos et al., 2020). It has also been noted that the extent of GSCM practices contributing to organizational performance improvements is unclear (Golicic and Smith, 2013; Miroshnychenko et al., 2017; Agarwal et al., 2018). Accordingly, the question "does it pay to be green?" still remains debatable (Ambec and Lanoie, 2008, p. 45). The lack of a clear view on

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the effects between the GSCM practices and better financial firm performance and conflicting findings around the resultant unanticipated consequences of the GSCM adoption necessitates the need for this study.

Moreover, one line of inquiry the extant literature has given relatively little consideration is the ways to balance the trade-off between sustainability and profitability. Although there is a nascent stream of studies pointing out unintended sustainability trade-offs that adopting green practices leads to environmental improvements but may constrain the firm's financial resources (Matos et al., 2020; Carter et al., 2020), they seldom offer some remedy for firms to remain commercially viable while implementing GSCM practices. Capturing the value from the supply chain (SC) sustainability initiatives is crucial for most firms as the impetus to embark upon GSCM adoption is often on the economic motive (Hsu et al., 2013). This research thus seeks to determine if the GSCM adoption can truly contribute to economic improvements, and to identify the ways to manage the trade-off between enhanced sustainability and improved profitability.

Our study is also motivated by calls for research on theory building surrounding GSCM, which remains scarce (Markman and Krause, 2016; Pagell and Shevchenko, 2014), to explore the broader moderating effects on GSCM adoption and performance outcomes. In this vein, our paper theorizes green information systems (GIS) as a predicted moderator that influences the effectiveness of GSCM initiatives on performance outcomes. We observed a growing trend of establishing GIS among firms in recent years (Tseng et al., 2019). However, whether GIS can positively influence the firms' profitability when undertaking GSCM practices remains uncertain and insufficiently understood (Gholami et al., 2013; Yang et al., 2018).

Drawing on the information theory, we argue that information asymmetry creates problems for firms and their suppliers when communicating environmental sustainability requirements and standards as suppliers often hold more environmental information about materials and products flowing across the supply chain (Sarkis et al., 2011). Using the tenets of the information theory, we contend that managing under such information asymmetry situations requires effective information sharing capability. More robust information systems allow firms to monitor and track environmental activities of various supply chain actors from source to customers. Intuitively, this reinforces a firm's ability to identify and tackle environmental issues across its supply chains, influencing the effectiveness of the GSCM implementation on performance improvement. We conceptualize the contingent role of GIS on the GSCM practices-performance links that is unique to the green supply chains context. Despite the prominence of information systems in the supply chain sustainability literature (Fiorini and Jabbour, 2017; Malhotra et al., 2013; Green et al., 2007), they have not previously integrated into the GSCM practices-performance relationships and little is known about their moderating effects on performance improvements (Micheli et al., 2020; Yang et al., 2018; Brandenburg et al., 2014). Our study addresses this gap by offering directions to realize the full benefits of the GSCM adoption in the presence of robust GIS. In doing so, our study answers the following questions with empirical evidence from 189 respondent firms operating in the UK automotive industry = (a) does the implementation of GSCM practices yield improvements in both environmental sustainability and economic performance? (b) What effect do the green information systems (GIS) have on the GSCM practices-performances relationships?

This paper makes several contributions to the literature on GSCM. First, we explicate how the core GSCM practices are associated with organizational performance outcomes, elucidating the mixed views about the GSCM adoption and its economic effects. We challenge the conventional proposition that "green and profitable is sustainable" (Figge and Hahn, 2012, p. 92) and showcase that not all the SC sustainability initiatives pay off. We highlight the contradicting view of greater environmental protection versus less economic efficiency and label this phenomenon the fallacy of profitable green supply chains, which could bring significant theoretical advancement to the GSCM research theme. Second, we explore the contingent effect of GIS on GSCM practice-performance relationships that is absent in the extant literature to reveal the crucial role of effective information sharing and traceability capabilities in influencing the effectiveness of GSCM initiatives on performance improvements, offering useful insights into the ways to attenuate the GSCM resultant unintended consequences.

The paper proceeds as follows. Section 2 reviews the theoretical foundations on GSCM practices, their associated performance outcomes and the moderating role of GIS. Section 3 presents our research method, followed by a set of critical analyses in Section 4, where our results are presented. We then channel our findings into discussions on theoretical and managerial implications in Section 5. Lastly, we discuss the limitations and offer directions for future research.

2. Theoretical foundation and hypotheses development

2.1. Green supply chain management (GSCM)

The GSCM approach integrates environmental management strategies into inter- and intra-organizational processes of the individual firm and its supply chains, driving value creation for environmental and economic performance (Golicic and Smith, 2013). Today, firms are increasingly becoming more conscious of environmental sustainability and immensely expected to demonstrate a sound stance for greening the supply chain, as customers often hold a focal firm accountable for adverse environmental effects of its multiple tiers suppliers (Sarkis et al., 2010; Fang and Zhang, 2018). Therefore, it is imperative for firms to address the sustainability-related issues directed at their supply chains.

In line with arguments made in the GSCM literature (Zhu et al., 2013; Geng et al., 2017), we focus on four distinguished GSCM practices, including green purchasing (Carter and Jennings, 2004), eco-design (Zhu et al., 2005), green logistics (Lai and Wong, 2012), and investment recovery (Green et al., 2012a) to capture the scope of GSCM implementation. These core dimensions constitute the backbone of the GSCM approach, encompassing internal and external environmental management practices across the downstream and upstream supply network (Esfahbodi et al., 2016; Agarwal et al., 2018).

The supply chain sustainability mandate plays a determinant role in the manufacturing context, particularly for automakers that often have complex and geographically dispersed supply chain networks (Jasiński et al., 2016). The automotive sector has traditionally been a major polluter and above-average resource consumer within the manufacturing industry (Jasiński et al., 2016), which offers compelling insights into the study's objectives.

2.2. GSCM practices and performance

The relationships between GSCM practices and organizational performance outcomes have been well-documented in the literature, reflecting a consistent growth in the evaluation of the GSCM practice-performance links (Feng et al., 2022; Golicic and Smith, 2013; Tseng et al., 2019). While the positive association between GSCM initiatives and environmental performance is well-established (Zhu and Sarkis, 2004; Zailani et al., 2012a; Tachizawa et al., 2015), it has been observed that empirical research about the effects of GSCM practices on improved economic performance is still mixed (de Burgos-Jiménez et al., 2013; Esfahbodi et al., 2017; Tamayo-Torres et al., 2019; Esfahbodi and Zhang, 2020a; Miroshnychenko et al., 2017).

Consistent with arguments made in the current literature (Zhu et al., 2005; Zailani et al., 2012a; Lai and Wong, 2012; Agarwal et al., 2018), the implementation of GSCM practices is predominantly geared toward improving environmental performance as they are often indicated by the firm's ability to reduce pollution, emissions, waste, energy and material consumption, and the use of harmful materials. For example, Zailani et al. (2012b) and Vanalle et al. (2017) found a positive relationship between adoption of the green purchasing practice and environmental performance, suggesting that sourcing green inputs and environmentally friendly materials and products brings improvement in environmental performance. In the same vein, Hsu et al. (2016) reported that green logistics management, which often involves green packaging using recycled contents, and greening outbound logistics using biofuels in transportation (Lai and Wong, 2012), mitigates environmental impacts of manufacturing firms and enhances their environmental performance.

Agarwal et al. (2018) demonstrated a positive link between eco-design and environmental performance improvement, arguing that undertaking eco-design practices reduces the environmental footprint of products life-cycle and facilitates the reuse and recycling of materials from used items or end-of-life products. Similarly, Zailani et al. (2012a) noted that eco-design implementation yields improved process efficiency, contributing towards cleaner production. Green et al. (2012a) maintained that undertaking investment recovery, which focuses on recuperating the value of previous investments through reusing and remanufacturing by-products, end-of-life or re-useable items, and recyclable materials (Vanalle et al., 2017), leads to better environmental performance. Thus, we hypothesize that core GSCM practices, including green purchasing, green logistics, eco-design, and investment recovery, are associated with environmental performance improvements:

H1a–H1dGSCM practices, (a) green purchasing, (b) green logistics, (c) eco-design, and (d) investment recovery are positively associated with environmental performance.

The preponderance of existing research suggests that GSCM implementation delivers positive economic values (Rao and Holt, 2005; de Burgos-Jiménez et al., 2013; Vanalle et al., 2017; Fang and Zhang, 2018; Cousins et al., 2019; StekelorumLaguir et al., 2021). In line with this literature, Zailani et al. (2012b) identified a significant linkage between green purchasing and improved economic performance due to long-term savings incurred from enhancing the firm's brand image and reputation, leading to customer satisfaction and enhanced market performance. Similarly, Mitra and Datta (2014) and StekelorumLaguir et al. (2021) maintained that green logistics yields economic performance improvement because of cost savings incurred from green packaging and eco-friendly transportation characteristics such as material usage reduction in packaging, rearranged loading patterns and route optimization. In the same vein, Zhu et al. (2012) and Miroshnychenko et al. (2017) found that undertaking eco-design practices positively affect economic performance as eco-design aims at using fewer materials and less energy when designing products during the product development stage. Such energy and material recovery cost savings are expected to deliver economic performance improvement. Moreover, Agarwal et al. (2018) reported that implementing investment recovery brings economic advantages to manufacturing companies because this practice fosters value recovery from previous investments through the sale of scraps, by-products, used materials and surplus inventories. Thus, we hypothesize:

H2a - H2dGSCM practices, (a) green purchasing, (b) green logistics, (c) eco-design, and (d) investment recovery are positively associated with economic performance.

2.3. Green information systems (GIS) and information theory

Firms often seek to communicate their environmental standards and requirements to their suppliers as much of the focal firm's ability to support environmental sustainability resides outside of its boundary and within external stakeholders (Sarkis et al., 2010). Yet they may not always find this easy due to unequal environmental information that exists between various SC partners (Simpson et al., 2007). The information theory defines this situation as an information asymmetry and calls for a focus on environmental information collection and sharing to manage a sound green supply chain under such an information asymmetry environment. Whether or not reduced information asymmetry leads to better GSCM performance is still an open question mainly due to lack of empirical evidence (Erlandsson and Tillman, 2009; Gholami et al., 2013).

A focal firm often has partial knowledge about the materials, products, and processes flowing through its supply chains, whereas sub-tier suppliers may hold more information related to environmentally-focused supply requirements (Wong et al., 2012). Drawing on the information theory (Sarkis et al., 2011), we contend that information asymmetry creates problems for the firm and its suppliers when communicating one another's environmental requirements and sustainability standards. In effect, this information asymmetry situation poses a challenge to both environmental and economic performance. The information asymmetry is more likely to increase in geographically dispersed supply networks given SC partners' physical and cultural distance, which further constrain performance improvements (Ortas et al., 2014).

Intuitively, sharing information related to environmentally-focused supply requirements can reduce such information asymmetry among SC partners. Information sharing supports the coordination and integration of environmental practices throughout the supply chain that facilitate opportunities for performance gains through operational efficiency. Effective information sharing is also associated with greater interaction and close collaboration among SC partners, further mitigating information asymmetry and facilitating GSCM implementation (Green et al., 2012b). Thus, effective information sharing, greater coordination and collaboration capabilities that lessen the likelihood of high information asymmetry are likely to assist firms in capitalizing on environmental and operating cost improvements.

2.3.1. The moderating role of GIS

GIS is referred to as information systems that have been modified to monitor environmental practices and outcomes of supply chain activities (Green et al., 2012a). GIS is particularly relevant under the premise of information theory (Sarkis et al., 2011), as it fosters tools for the transfer of information to another SC member with the target to mitigate information asymmetries. Two particular characteristics of GIS are information sharing and traceability along the supply chain (Yang et al., 2018; Cousins et al., 2019). Most broadly, the role of information sharing is essential for the management and survival of supply chains as it enables the coordination of business processes throughout the entire supply network (Sarkis et al., 2011). Effective information sharing plays a critical role in greening the supply chain as it can provide various SC members with the operational and environmental information necessary for undertaking sustainability initiatives (Green et al., 2007). In the same vein, Green et al. (2012a) maintained that successful GSCM undertakings depend on the ability of the firm's information systems to capture environmentally-related data of their SC activities, including sourcing, production, logistics and selling. In effect, firms may analyze the data to generate and share the information necessary for better coordination and integration across the supply chain that yields performance improvement. Information sharing catalyzed by GIS facilitates environmental collaboration with suppliers, a key enabler for adopting green purchasing (Carter and Jennings, 2004). Collaborative relationships with suppliers can create opportunities for cleaner production and green purchasing cost savings (Vachon and Klassen, 2008), positively moderating the GSCM consequences.

Another key characteristic of GIS that facilitates monitoring the SC environmental actions and outcomes is traceability. Traceability refers to the ability to track the origin of materials and products and trace their displacement history across the supply chain (Alfaro and Rábade, 2009). Traceability often entails identifying the source of raw materials, determining if harmful materials are used in purchased items, tracking processes involved in production, tracing the return of recyclable products, and tracking the environmental performance throughout the supply chain (Wowak et al., 2016; Bai and Sarkis, 2020). In addition, traceability shares real-time information required for coordinating with suppliers and customers on eco-friendly packaging and green transportation (Yang et al., 2018). The ability of tracking and trace supply chain processes can mitigate environmental information asymmetry amongst SC partners, which may in turn positively moderate the impacts of GSCM practices on environmental performance. In this vein, Alfaro and Rábade (2009) reported that improved levels of monitoring enabled by traceability lead to enhanced operational efficiency through reduced lead-times, stock-outs, and spoiled inventory, all of which can contribute to environmental performance improvement.

With respect to cost savings effects, traceability provides the information needed to recover the firm's previous investments in surplus inventories, capital equipment and by-products that contribute to cost performance improvement (Agarwal et al., 2018). In addition, traceability reduces the costs of reporting to external stakeholders and minimizes environmentally-related legal fees, penalties and fines for potential environmental accidents (Cousins et al., 2019). SC traceability is then expected to reduce the additional costs related to the GSCM implementation, which positively moderates the effect of GSCM practices on economic performance. Thus, we argue that firms which have high levels of GIS capabilities such as effective information sharing and SC traceability may be more likely to gain performance improvement when undertaking GSCM practices and posit the following hypotheses:

H3a - H3dThe relationship between GSCM practices, (a) green purchasing, (b) green logistics, (c) eco-design, and (d) investment recovery and environmental performance is stronger when a firm has high levels of green information systems (GIS).

H4a - H4dThe relationship between GSCM practices, (a) green purchasing, (b) green logistics, (c) eco-design, and (d) investment recovery and economic performance is stronger when a firm has high levels of green information systems (GIS).

2.4. *An integrating model*

The conceptual model displayed in Fig. 1 theorizes the direct and positive effects of GSCM practices on performance outcomes, and integrates the interaction effects of green information systems (GIS) on the relationships between each GSCM practice and environmental and economic performance.

3. Research method

3.1. *Survey development*

The hypotheses were empirically tested using quantitative data gathered by means of a cross-sectional survey. First, the draft questionnaire was developed by employing established pre-existing measures. A survey pre-test was then performed on six academics with expertise in supply chain and environmental management and eight experienced professionals with relevant expertise in this area to evaluate the questionnaire clarity, usability, and relevancy. Based on their feedback, two items with overlapping content were dropped, some rewording were made in the questionnaire to make it clearer and easier to understand, along with some minor changes in the Likert scales. Table 1 presents all the measurement items in the final questionnaire.

For the independent variables, i.e., GSCM practices, we drew largely on the measures developed by Zhu et al. (2008) and utilized additional items found in Lai and Wong (2012) and Agarwal et al. (2018) works. A five-point reflective Likert scale was applied to each GSCM practices measure, ranging from 'not considering' (1) to 'implementing fully' (5). For the dependent variables, i.e., environmental and economic performance, we adopted the established scales developed by Zhu et al. (2008). A five-point Likert scale was also employed for assessing the significance level of environmental and economic improvement, ranging from 'not at all' (1) to 'significant' (5). With respect to the moderating variable (GIS), the survey contained nine items adapted from Green et al. (2012a) and Gholami et al. (2013). Respondents were asked to indicate the extent to which their organization's information system is used concerning environmental practices and outcomes, ranging from 'not used at all' (1) to 'used to a great extent' (5). These measures were operationalized in our survey instrument to assess the GSCM practices-performance links and to understand the moderating effect of GIS in this context. Further explanation was provided for each measure in the survey to mitigate respondents' different understandings of the questions and options (Fowler, 2013). We also included two additional control variables, i.e., firm size and supply chain position, in the analysis. First, we control for firm size, which was measured based on the number of full-time employees, as larger firms may have more resources to engage in GSCM initiatives and the ability to influence performance improvements (Gimenez et al., 2012). We then control for supply chain tier positions using two dummy variables, Tier 1 and OEM with Tier 2 as the baseline, which were measured based on a company's major product in the supply network. This is because tier position within the supply chain may produce confounding effects on the hypothesized relationships.

3.2. *Data collection*

The automotive sector was selected because automakers are at the forefront of environmental management strategies with a track record of undertaking SC sustainability initiatives (Simpson et al., 2007). A sample of 1000 UK firms operating in the automotive industry was randomly surveyed from the Automotive Industry Portal obtained through the "MarketLine" database that comprised approximately 13,000 OEMs and

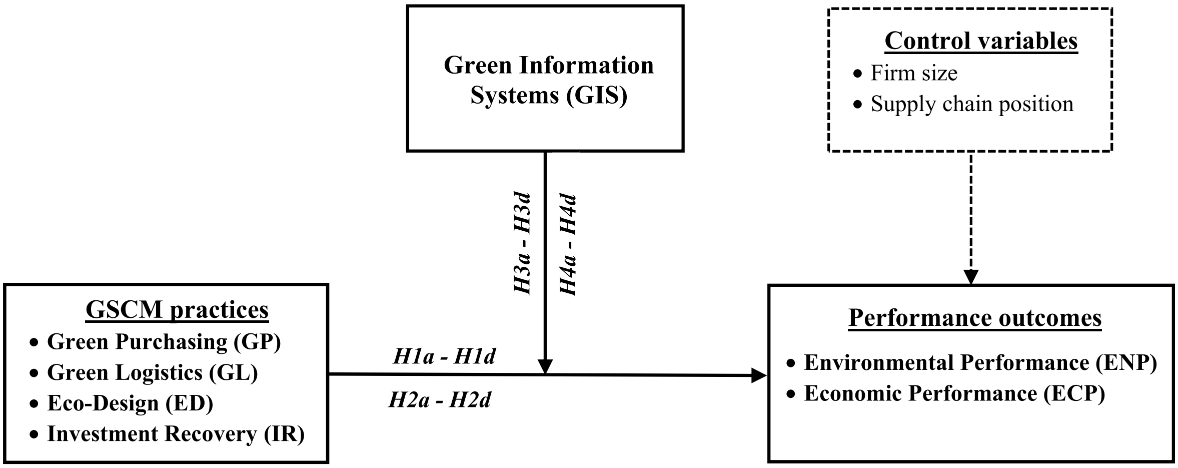

Fig. 1. Conceptual model.

Table 1
Measurement items, reliability and validity test.

Measurement items		Std. Loading
Green Purchasing (Cronbach's α = 0.78, CR = 0.79, AVE = 0.62)		
GP1	Eco labelling of products.	0.81
GP2	Cooperation with suppliers for environmental objectives.	0.80
GP3	Environmental audit for suppliers' internal management.	0.77
GP4	Suppliers' ISO 14000 certification.	0.87
GP5	Second-tier supplier environmentally friendly practice evaluation.	0.85
GP6	Providing design specification to suppliers that include environmental requirements for purchased item.	0.82
Green Logistic (Cronbach's α = 0.73, CR = 0.76, AVE = 0.59)		
GL1	Cooperation with customers for using less energy during product transportation.	0.77
GL2	*Cooperation with customers for green packaging.*	–
GL3	Use of green- and bio-fuels such as fuels with low sulphur content in transportation.	0.81
GL4	Use of biodegradable, reused, returnable and recyclable materials in the process of products packaging.	0.78
GL5	Upgrade freight logistics systems and distribution strategies (e.g. minimising empty miles, reducing container weight, improving refrigeration systems, route optimization, and rearranged loading patterns).	0.78
GL6	Developing green logistics management database for capturing and reporting logistics performance periodically.	0.82
Eco-Design (Cronbach's α = 0.81, CR = 0.82, AVE = 0.68)		
ED1	Design of products for reduced consumption of material.	0.87
ED2	Design of products for reduced consumption of energy.	0.88
ED3	Design of products for reuse, recycle, recovery of used materials, component parts, and by-products.	0.87
ED4	Design of products to avoid or reduce use of hazardous materials in their manufacturing process.	0.92
ED5	Design of product or service to reduce negative effects on the environment during its entire life cycle.	0.91
ED6	Design of products to be manufactured using clean production technologies and best practices.	0.85
Investment Recovery (Cronbach's α = 0.71, CR = 0.75, AVE = 0.56)		
IR1	Sale of excess inventories or materials.	0.78
IR2	Sale of scrap and used materials or by-products.	0.74
IR3	Sale of excess capital equipment.	0.80
IR4	Recycling system for used and defective products	0.77
Green Information Systems (Cronbach's α = 0.84, CR = 0.84, AVE = 0.70)		
GIS1	Reducing transportation costs.	0.90
GIS2	Tracking environmental information (such as toxicity, energy used, water used, air pollution).	0.89
GIS3	Monitoring emissions, waste production, and carbon footprint.	0.87
GIS4	*Identifying the role of IS in energy policy.*	–
GIS5	Providing information to encourage green choices by consumers.	0.85
GIS6	Improving decision making by executives by highlighting sustainability issues.	0.90
GIS7	Reducing energy consumption.	0.92
GIS8	Supporting the generation and distribution of renewable energy.	0.88
GIS9	Limiting carbon and other emissions.	0.85
Environmental Performance (Cronbach's α = 0.81, CR = 0.82, AVE = 0.67)		
ENP1	Reduction of air and carbon emissions.	0.82
ENP2	Reduction of solid wastes.	0.89
ENP3	Reduction of effluent wastes.	0.81
ENP4	*Reduction of waste emission.*	–
ENP5	Decrease of consumption for hazardous/harmful/toxic materials.	0.79
ENP6	Decrease of frequency for environmental accidents.	0.84
ENP7	Improvement of a firm's environmental situation.	0.88
Economic Performance (Cronbach's α = 0.79, CR = 0.80, AVE = 0.63)		
Green Purchasing (Cronbach's α = 0.78, CR = 0.79, AVE = 0.62)		
ECP1	Decrease in cost for purchased materials.	0.81
ECP2	Decrease in cost for energy consumption.	0.83
ECP3	Decrease in fee for waste treatment.	0.85
ECP4	Decrease in fee for waste discharge.	0.89
ECP5	Decrease in fine for environmental accidents.	0.82

Notes: CR = composite reliability; AVE = average variance extracted; Items in italics were dropped after CFA.

suppliers entries. Each sample firm was selected based on two key criteria: the company should have certain environmental management systems and standards such as ISO 14000/14,001 certifications; and the company's main product serves the automotive sector (which determines the company's tier position in the supply network). Individual managers who are knowledgeable about the GSCM issues served as key informants in this research. Before distributing the questionnaire, anonymity was guaranteed for the respondents and their companies; the incentive of an executive summary of the study findings was offered to maximize the response rate (Malhotra and Grover, 1998).

The survey invitation email was sent out to our entire sample, followed by two further email reminders to non-respondents that were placed two weeks apart. Whilst 28 surveys could not be delivered, we received 251 responses, 32 of which were removed due to missing data. Further 30 responses were screened out (19 "non-managers" and 11 "other managers") to ensure that our respondents were knowledgeable about their firm's GSCM efforts. This resulted in 189 useable responses, which gives an acceptable response rate of 19.4% (189/972) (Frohlich, 2002). Table 2 displays the characteristics of the organizations in the final sample. All our respondents hold management roles with an average of 7.88 years in their current positions, indicating they were experienced and knowledgeable about the issues under investigation.

3.3. *Data assessment*

A *t*-test of difference was first performed between respondents and non-respondents in terms of supply chain position and firm size (turnover and employees). The results showed insignificant differences ($p >$

Table 2
Sample characteristics.

	Number
Position	
Logistics Manager	28
Supply Chain Manager	42
Operations Manager	31
Purchasing Manager	19
Engineering Manager	16
Industrial Waste Manager	18
Plant Manager	15
Information Systems Manager	20
Tenure in current position	7.88
Supply chain position	
OEM	39
Tier 1 supplier	102
Tier 2 supplier	48
Firm size (employees)	
<50	8
50–250	75
251–1000	69
>1000	37
Total	189

0.05), suggesting that our responses represent the original sample. Non-response bias was then assessed by comparing early respondents (initial invite respondents 42%) and later respondents (reminders invite respondents 58%) (Armstrong and Overton, 1977). To this end, we performed a comparison of the means of all variables for the two groups using one-way ANOVA (Lambert and Harrington, 1990). No significant differences were detected ($p > 0.05$), indicating that non-response bias was not an issue.

Moreover, we examined common method bias by applying two methods. First, we conducted Harman's single-factor test, in which all variables were analyzed together using un-rotated exploratory factor analysis. The factor analysis revealed no sign of a single-factor accounting for most of the variance (<24.66%), suggesting that common method bias is not a substantial concern (Podsakoff et al., 2003). Second, we performed the marker-variable analysis, using the lowest bivariate correlation between all variables as the marker-variable (Lindell and Whitney, 2001). We employed "the number of years in the current position" as the marker-variable as it is theoretically unassociated with at least one variable (Craighead et al., 2011). A comparison of the adjusted and original correlations showed that most of the correlations remained significant after adjustment (41 out of 43 originally significant correlations), providing additional support that common method bias was insignificant in our data (Malhotra et al., 2006).

3.4. Measurement assessment

We carried out several tests to assess the measurement validity. First, exploratory factor analysis (EFA) was conducted using principal components and Varimax rotation to extract factors with eigenvalues (≥1). As a result, three items were removed from the analysis, i.e., GL2, GIS4, and ENP4, suggesting an eight-factor solution. The factor loading of each remaining item was greater than the recommended 0.70 level, all loadings were significant ($p < 0.01$), and the AVE values exceeded 0.50 benchmark (Hair et al., 2010), indicating sufficient convergent validity. The Cronbach's α and composite reliability (CR) values exceeded the minimum threshold of 0.70, suggesting the indicators' internal consistency. Table 1 presents factor loadings, Cronbach's α, composite reliabilities (CR), and average variance extracted (AVE).

Second, discriminant validity was assessed in two ways. A chi-square difference test was performed in the first approach to examine each pair of variables amongst the seven constructs. The $\chi2$-difference tests for all pairs of variables returned significant at $p < 0.01$, providing support that discriminant validity was acceptable (Farrell, 2010). The procedure proposed by Fornell and Larcker (1981) was employed in the second approach and the square-roots of AVEs were found to be greater than the corresponding correlations between each pair of constructs, exhibiting adequate discriminant validity.

Finally, confirmatory factor analysis (CFA) was performed with LISREL 8.80 to estimate the measurement models and examine unidimensionality. The CFA results exhibit Chi-square ($\chi2$) of 627.35 ($p = 0.00$), a degree of freedom (df) of 416, and the relative chi-square value ($\chi2/df$) of 1.51, which is below the recommended threshold of 3.00 (Kline, 2016). The RMSEA value is 0.072, which is lower than the 0.08 benchmark (Hair et al., 2010). Results for the other fit indices, including normed fit index (0.93), non-normed fit index (0.94), comparative fit index (0.97), and incremental fit index (0.97), indicate a good fit between the data and measurement model. Moreover, the standardized residuals were lower than the 4.00 threshold, suggesting an acceptable degree of error (Hair et al., 2010).

4. Data analysis and results

In the first step, the data normality was evaluated using the Shapiro-Wilks test to determine if the data violated the normality assumption. The results revealed insignificant p-values for all variables, suggesting that the data is normally distributed (Curran et al., 1996). Table 3 presents descriptive statistics and correlations.

A moderated hierarchical regression was conducted with ordinary least squares in SPSS 24 to assess each hypothesis. The control variables were first introduced, the main effects of the independent variables (IVs) were then tested, and the interaction effects between the IVs and the moderator were subsequently analyzed. To this end, four regression models were built and assessed (see Table 4). As recommended by Carte and Russell (2003), the *F* hierarchical values and incremental explained variance can be obtained by comparing the models to validate the level of significance. Moreover, we mean-centred all interaction variables before the analysis to control for potential multi-collinearity.

The effect of the control variables, namely firm size and supply chain tiers, was assessed with Model 1. *H1a–H1d* and *H2a–H2d* were analyzed with Model 2, in which each of the four IVs was entered separately into the regression equation to examine the main effects on the dependent variables. We used Model 3 to obtain the *F* hierarchical values and incremental explained variance. Finally, *H3a–H3d* and *H4a–H4d* were tested with Model 4. Table 4 displays the regression results. The variance inflated factor (VIF) values were also calculated to assess multi-collinearity. The VIF values for each variable in all the models were below the 10 benchmark, ranging from 1.184 to 2.291, suggesting multi-collinearity was not a substantial concern (Hair et al., 2010).

As shown in Model 1, firm size only demonstrated significant effects on environmental performance and no significant association with economic performance was observed. In addition, the parameter estimation shows that OEM and Tier-1 suppliers had no significant effect on economic and environmental performance outcomes. Model 2 demonstrates positive relationships between the GSCM constructs and environmental performance, indicating that the GSCM implementation is associated with environmental improvements. *H1a–H1d* are thus supported. Interestingly, the results on *H2a–H2d* reveal another side to the story. While green purchasing and investment recovery are positively

Table 3
Descriptive statistics.

	Mean	s.d.	1	2	3	4	5	6	7	8	9	10
1. Size	3.42	1.39	1									
2. OEM	0.36	0.47	0.21**	1								
3. Tier 1	0.68	0.58	0.18	−0.48**	1							
4. GP	3.13	0.46	0.19*	−0.13	0.15	1						
5. GL	3.11	0.41	0.27*	−0.07	0.08	0.45**	1					
6. ED	3.75	0.55	0.25**	−0.10*	0.18*	0.38**	0.36**	1				
7. IR	2.92	0.52	0.13	−0.20	0.11	0.29**	0.27*	0.33**	1			
8. GIS	3.97	0.63	0.29**	0.17*	0.21	0.50**	0.48**	0.52**	0.30**	1		
9. ENP	3.54	0.50	0.24**	0.15*	0.07	0.41**	0.40**	0.45**	0.34**	0.49**	1	
10. ECP	3.36	0.56	0.22*	−0.09	0.13	0.32**	0.45*	0.41**	0.38*	0.44**	0.29**	1

Notes: Two-tail *t*-test was performed; * Significant at α = 0.05; ** Significant at α = 0.01; n = 189.
GP (Green Purchasing); GL (Green Logistics); ED (Eco-Design); IR (Investment Recovery).
GIS (Green Information Systems); ENP (Environmental Performance); ECP (Economic Performance).

Table 4
Hierarchical regression results.

Variables entered	Dependant variable				Dependant variable			
	Environmental Performance				Economic Performance			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
Control variables								
Firm size	0.15***	0.19**	0.14**	0.12***	0.21	0.23	0.12	0.19
OEM-Tier 2	0.12	0.21	0.08	0.10	−0.13	−0.06	−0.15	−0.10
Tier 1-Tier 2	0.17	0.13	0.09	0.11*	0.18	−0.09	−0.11	−0.06
Main effects								
GP		0.40*	0.36*	0.44*		0.31***	0.30***	0.27***
GL		0.32***	0.38**	0.35***		0.36	0.29	0.25*
ED		0.39***	0.35***	0.42***		−0.28***	−0.26**	−0.33***
IR		0.24***	0.21**	0.20**		0.19*	0.18*	0.19*
Moderator								
GIS			0.32***	0.34***			0.35***	0.38***
Moderating effects								
GP x GIS				−0.21**				0.19***
GL x GIS				0.18***				0.20**
ED x GIS				0.22***				0.15***
IR x GIS				0.29*				0.26
R^2	0.139	0.326	0.384	0.480	0.122	0.271	0.306	0.374
ΔR^2		0.187	0.058	0.096		0.149	0.035	0.068
F hierarchical		25.175***	4.227***	11.792***		21.256***	3.024**	8.916***

Notes: Note: ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$; ns: not significant.
The *F* hierarchical value was computed by comparing the changes in R^2 between a pair of models.
GIS (Green Information Systems).

and significantly associated with improvements in economic performance (supporting H2a and H2d), it was noted that green logistics does not significantly affect economic performance. Contrary to expectations, it was found that eco-design has a negative impact on economic performance ($\beta = -0.28$, $p < 0.01$). Thus, *H2b* and *H2c* are not supported. Our results suggest that while the GSCM implementation leads to improved environmental performance, it only partially yields economic improvements through green purchasing ($\beta = 0.31$, $p < 0.01$) and investment recovery ($\beta = 0.19$, $p < 0.10$).

It was further found that GIS differentially moderates the relationships between GSCM practices and performance outcomes as shown in Model 4. Drawing on environmental performance, all interaction terms are significant and positive, exclusive of GP x GIS. Surprisingly, it was identified that GIS negatively moderates the effect of green purchasing (GP) on environmental performance. Turning to economic performance, interestingly, it was found that GIS positively moderated the negative effect of eco-design on economic performance. Similarly, GIS was found to positively moderate the nonsignificant effect of green logistics on economic improvement. Moreover, while we did not find support for *H4d*, *H3d* was partially supported ($p < 0.10$) in that GIS positively moderates the effect of investment recovery on environmental performance. The moderation results are insightful, suggesting that GIS broadly strengthen the relationships between GSCM practices and performance improvements. Table 5 provides a summary of the hypotheses testing.

4.1. Post-hoc analysis

We employed additional analyzing methods to consolidate the robustness of our results. To this end, we used the partial least squares (PLS) procedure using SmartPLS 3.0 to simultaneously analyze our structural model and also applied bootstrapping procedures with 5000 sub-samples to examine the statistical significance of the posited path coefficients (Peng and Lai, 2012). The results of the PLS approach are largely consistent with our regression results, i.e., all the hypothesized relationships are statistically significant at 0.05 level, indicating that the results are not significantly different when each construct was included separately in our analyses.

Table 5
Hypotheses testing results.

Hypotheses	Independent variables	Dependent variables	Results
H1a	Green purchasing	Environmental performance	Partially supported ($p < 0.10$)
H1b	Green logistics	Environmental performance	Supported
H1c	Eco-design	Environmental performance	Supported
H1d	Investment recovery	Environmental performance	Supported
H2a	Green purchasing	Economic performance	Supported
H2b	Green logistics	Economic performance	Not supported (not significant)
H2c	Eco-design	Economic performance	Not supported (negative)
H2d	Investment recovery	Economic performance	Partially supported ($p < 0.10$)
H3a	Green purchasing x green information systems	Environmental performance	Not supported (negative)
H3b	Green logistics x green information systems	Environmental performance	Supported
H3c	Eco-design x green information systems	Environmental performance	Supported
H3d	Investment recovery x green information systems	Environmental performance	Partially supported ($p < 0.10$)
H4a	Green purchasing x green information systems	Economic performance	Supported
H4b	Green logistics x green information systems	Economic performance	Supported
H4c	Eco-design x green information systems	Economic performance	Supported
H4d	Investment recovery x green information systems	Economic performance	Not supported (not significant)

5. Discussion

This study empirically assessed the impacts of GSCM implementation on performance improvements, together with the contingent effects of GIS. The discussion that follows focuses on our findings' theoretical and managerial contribution.

5.1. Main effects

Our findings reveal a counter-intuitive view on performance outcomes arising from the GSCM adoption. They showcase that while GSCM practices yield improvements in environmental performance, not all sustainability initiatives pay off across the supply chain. For example, we found that eco-design has a negative effect on economic performance (*H2c*). A possible reason could be that the eco-design capability to diminish products environmental impact is counterbalanced by increases in the associated costs of obtaining required green expertise and resources. Although eco-design aims to mitigate products life-cycle environmental impacts without creating a trade-off with costs (Green et al., 2012a), such unintended consequence is likely to occur in practice. Adopting eco-design requires initial investments that can outweigh the short-term benefits of energy and material savings, and waste reduction. Green et al. (2012a) reported a similar observation, which states that acquiring eco-design capabilities can incur excessive costs.

We also find green logistics is not significantly associated with improvement in economic performance (*H2b*), contradicting the findings of Zailani et al. (2012b). One explanation for the lack of significant effect on economic performance is that environmentally friendly logistics providers tend to give higher price quotations than traditional third-party logistics (3 PL) providers (Hsu et al., 2016), hindering the green logistics gains from being reaped in terms of economic benefits and profitability. It appears that green logistics management that fosters eco-friendly packaging and transportation is restrained by increases in associated costs, perhaps related to sourcing biodegradable materials and biofuels that are still considered to be costly.

The positive relationships between GSCM practices and improvements in environmental performance were unequivocal, mirroring the findings of the vast majority of the extant literature (Fang and Zhang, 2018; Tseng et al., 2019). However, it appears that achieving environmental improvements is associated with lower levels of economic performance, ultimately compromising profitability, which characterizes a paradoxical view of enhanced environmental sustainability versus economic inefficiency. A key insight here is that implementing GSCM practices will result in environmental improvements but may inevitably come at a financial cost that constitutes the sustainability trade-offs between environmental and economic objectives. The said trade-offs build on the idea that superior performance in one competitive dimension of sustainability is fundamentally gained by compromising performance in another (Fracarolli-Nunes et al., 2020).

Contrary to a general assumption in the GSCM literature that often overemphasizes the "easy wins", it is contended that pursuing SC environmentally-related initiatives can bring trade-offs into play in terms of sustainability versus profitability. This finding is important for theoretical advancement in GSCM studies as it adds a more realistic and richer view of the economic aspect of supply chain sustainability theory. Thus, we emphasize that greening the supply chain does not consistently deliver economic benefits and further highlight the fallacy of profitable green supply chains, offering a more concrete understanding of GSCM practice-performance relationships.

5.2. Moderating effects

Turning to the more interesting moderating effects of GIS, we find that GIS significantly strengthens most of the relationships between GSCM practices and performance outcomes. However, we also discovered some unanticipated and mixed moderating effects. Particularly, we found that GIS had a negative moderating effect on the relationship between green purchasing and environmental performance (*H3a*). This indicates that firms with low levels of GIS-traceability had a more positive rate of improved environmental performance when implementing green purchasing initiatives than those who comparatively possessed the capability of high traceability.

One possible explanation for this counter-intuitive finding may lie with the experience of many automotive companies and somewhat other manufacturing firms when applying traceability systems for environmental compliance and monitoring purposes. Firms with low levels of transparency and traceability have bounded insights into the environmental compliance of sub-tier suppliers as well as a limited assessment of sub-tiers' environmental monitoring (Bai and Sarkis, 2020). Whereas firms with high levels of supply chain traceability or low levels of information asymmetry can more effectively track and trace materials and processes across the entire supply network. This level of visibility furnishes firms with a clear picture of the myriad challenges they face in managing suppliers compliance to environmental standards along their supply chains. Therefore, the ability of the firm, with high levels of SC traceability, to achieve improvement in environmental performance is constrained in sub-tiers suppliers (Meinlschmidt et al., 2018). Our observation corresponds with the finding by Cousins et al. (2019) that traceability was perceived to have a negative influence on the relationship between GSCM practices and environmental performance.

Moreover, our findings demonstrated positive moderating effects of GIS on the relationships between other GSCM practices and environmental performance (*H3b-H3d)*. A potential explanation for these findings is that developing effective information systems and high traceability capabilities can provide firms with tools and mechanisms to monitor environmental activities and requirements throughout the supply chain, from source to customer, which in turn yields a more positive rate of environmental improvement. Accordingly, it is argued that firms with stronger GIS capabilities can identify and tackle environmental risks within their supply chains more effectively and are thus expected to capitalize on environmental improvements when implementing GSCM practices, maximising the contribution to environmental sustainability.

Interestingly, we found significant contingent effects of GIS on the relationships between green logistics (*H4b)*, eco-design (*H4c)* and economic performance. It appears that green logistics best facilitates the economic performance in the presence of GIS. This finding exhibits the critical role of SC traceability and effective information sharing in achieving improvements in economic performance when implementing green logistics initiatives. An effective GIS enhances the focal firm information-processing capacity to deal with the high levels of uncertainty and complexity involved in green logistics management without incurring extra costs, which strengthens the effectiveness of logistics integration and customer cooperation on both green transportation and eco-friendly packaging. Moreover, high levels of transparency and robust monitoring systems enabled by GIS foster better coordination and communication with 3 PLs and customers, which allows the firm to capture data related to their green packaging and transportation efforts. The data can be analyzed to identify cost improvement opportunities in materials and logistics management. As such, firms may be able to reap this cost improvement benefit due to effective coordination among supply chain partners arising from the reduced information asymmetry. Drawing on the information theory, this study argues that profitable GSCM requires the development of GIS capabilities.

Another positive moderation of GIS was found in the ecodesign-economic performance link. This finding manifests the important role of improved levels of information sharing and transparency in attenuating the trade-off between environmental sustainability and economic performance. This may be because more comprehensive and robust information systems provide the firm with the data related to the environmental outcomes of their manufacturing processes, generating the information necessary to make eco-design decisions effectively concerning energy usage, materials consumption, recycling and reuse of used items and end-of-life products. From the perspective of information theory, an effective GIS can mitigate information asymmetry across the supply chain by enabling the firm to closely interact and communicate with its customers and suppliers about various environmental preferences and standards. A well-developed GIS helps firms to obtain, track and monitor customer-related information about their green choices associated with energy usage, resource consumption, emissions, and waste generation, which are often established in the product development stage. So, the existence of effective GIS will improve firms decision-making capabilities with said initiatives and optimize material and resource utilization, which contributes to cost performance. Intuitively, this may yield further economic improvements through commensurate costs savings from energy consumption, purchased materials, recycling efforts and waste treatment.

We also note a positive moderation effect on the green purchasing-economic performance relationship. A possible explanation is that high levels of information sharing and transparency enabled by GIS allow SC partners to engage more effectively in environmental collaboration. Through this platform, the focal firm can quickly and easily share information with its suppliers to avoid information asymmetry and achieve smooth collaborations with them for green purchasing. Effective environmental collaboration, the key enabler for green purchasing (Carter and Jennings, 2004), deliver environmental risk and penalties cost savings that may assist in offsetting costs of GSCM implementation. This finding corresponds with Green et al.'s (2012b) observation, which states that successful environmental collaboration hinges on the firm's capability to share information between SC actors related to environmental actions that bolster performance improvement in both environmental and cost-based performance.

Our findings further contribute to the information theory by demonstrating the synergistic benefits of GIS. Drawing on the information theory, which postulates that firms deploy information sharing activities and information acquisition that best tackle the information asymmetry they are faced with in terms of the absence of information (uncertainty) or the messiness of information (equivocality) (Aben et al., 2021). From the perspective of information theory, a well-developed GIS facilitates smooth communications and seamless environmental information sharing among different cross-functional units both within the firm and with its suppliers and customers (Sanderson et al., 2022), mitigating information asymmetry. We observed that GIS, as an overarching platform for smooth communication, effective coordination and integration with suppliers and customers regarding green purchasing, production, packaging and logistics across the supply chain, enables firms to deal with the uncertainty and ambiguity involved in managing GSCM practices without incurring excessive costs. The existence of an effective GIS will influence the effectiveness of GSCM undertakings (i.e., cost reduction, resource optimization, and carbon footprint minimization) through enhanced communication and coordination and better information traceability. Building on information theory, we suggest that GIS is a strategic tool to balance the trade-off between environmental sustainability and economic performance in GSCM undertakings and to go beyond that, a well-established GIS can act as an enabler for profitable green supply chains.

Using the tenets of the information theory (Sarkis et al., 2011), we bring forward the argumentation that effective information sharing and coordination arising from reduced information asymmetry among supply chain partners may result in improved GSCM performance and in turn attenuate the trade-offs between sustainability and profitability. Our findings showed that GIS plays a contingent role on the relationships between GSCM practices and performance outcomes and could act as a crucial strategic resource to drive cost minimization when implementing SC sustainability initiatives. We argue that by developing high levels of SC traceability, monitoring and information sharing capabilities, firms can create further economic and environmental advantages when implementing GSCM practices, capturing both enhanced sustainability and economic efficiency. Our study extends the GSCM theory by offering some remedial directions to attenuate the sustainability trade-offs that is absent in the extant research.

While not the primary focus of this paper, it is worth noting that the firm size was significantly related to environmental performance. This may be because larger firms possess more green resources and expertise on the adoption of GSCM practices than smaller firms who may be lagging in that respect. This complements prior research showing that the larger the firm, the better the environmental performance (Gimenez et al., 2012).

5.3. *Managerial implications*

Our findings offer valuable insights for manufacturing firms on how to be more effective with GSCM implementation and generate practical implications to guide the firm's sustainability efforts. First, we suggest managers prioritize implementing core GSCM practices, mindful of their degree of effectiveness on the firm's performance improvements. Second, our study can help managers identify those areas of GSCM where improvements are required relative to areas where "low hanging fruits" are readily available. Most significantly, our research furnishes managers with new pathways to balance the trade-off between sustainability and profitability, such that high levels of GIS could assist in offsetting costs of GSCM implementation, offering a practical mechanism to attain superior economic performance in their GSCM undertakings. This allows managers seeking to promote and justify the adoption of GSCM initiatives to senior management teams to craft their message around such positive effects on the firm's financial performance.

Manufacturing firms and particularly automakers that often have complex and geographically dispersed supply chain networks are encouraged to develop more comprehensive and robust information systems as key strategic resources and exploit the GIS capabilities of improved levels of information sharing, SC traceability, environmental monitoring and data capture. This allows managers to improve cost performance when adopting the SC sustainability initiatives, contributing to environmental protection and economic efficiency. Also, firms should seek opportunities to reconsider their traditional business models to embrace GSCM as a trade-off-ridden and long-term undertaking that may not provide immediate financial gains, but holds the potential to balance long-term profitability and environmental sustainability. This research also serves as an initial benchmarking tool and an invaluable audit framework for organizations to assess their supply chain sustainability efforts to decide whether to continue, discontinue or further consider a GSCM initiative.

6. Conclusion

This study offers several contributions to the knowledge bank of GSCM. First, although emerging studies have loosely hinted that implementation of GSCM practices does not guarantee improved economic performance in contrast with the preponderance of extant literature that suggest otherwise, no detailed and comprehensive study has reported that GSCM undertakings yield trade-offs between environmental sustainability and profitability. In contrast with existing research on the GSCM practices-performance relationships (Geng et al., 2017; Tseng et al., 2019; Fang and Zhang, 2018), this paper offers some of the first empirical evidence that GSCM adoption does not always yield improved economic performance and should not necessarily be deemed a profitable business practice. The study thus casts doubts on the conjecture that "going green" truly pays off and refutes the fallacy that "low-hanging fruits" are readily available when adopting the SC sustainability initiatives and criticizes the literature for overemphasizing the "easy wins" concerning profitability. Our research extends supply chain sustainability theory by elucidating the mixed views about the GSCM implementation and its economic effects and further demonstrating that the argument of truly profitable green supply chains is unfounded. We contend that pursuing SC environmentally-related initiatives can bring trade-offs into play in terms of enhanced sustainability versus less economic efficiency, offering a more nuanced and contemporary understanding of the GSCM theory.

Second, prior studies offer very limited insights into how sustainability trade-offs may be resolved. Also, what has not been fully addressed is how firms can capture the economic value from undertaking the SC sustainability activities and remain commercially viable. While there is a nascent stream of studies pointing out resultant unintended consequences of the GSCM adoption (Matos et al., 2020; Fracarolli-Nunes et al., 2020), they seldom offer some remedy and provide limited guidance on the ways to resolve the trade-off between sustainability and profitability. This study offers the first wave of empirical evidence of how digital technologies can be leveraged for GSCM to attain better performance outcomes, shedding some light on the crucial role that GIS plays in attenuating the sustainability-profitability trade-offs, which has been largely omitted in GSCM studies. We show that the sustainability trade-offs are theoretically resolvable, and the full benefits of the GSCM adoption are realized in the presence of a well-developed GIS. This study complements and extends the GSCM theoretical development by emphasizing the value of effective GIS in attaining better performance outcomes and balancing sustainability trade-offs. Exploring the contingent role of GIS on the GSCM practices-performance relationships that has been largely overlooked in the literature further distinguishes our contribution from earlier studies (Zhu et al., 2012, 2013; Brandenburg et al., 2014; Yang et al., 2018; Vanalle et al., 2017; Micheli et al., 2020).

We show supercharged benefits for economic improvements can occur in the GSCM implementation where the firm has strong GIS capabilities such as traceability, monitoring and information sharing. This study highlights the crucial role of strategically developing more comprehensive and robust information systems, such that facilitate effective coordination and environmental collaboration among SC partners arising from the reduced information asymmetry, which ultimately assist firms in extracting the economic benefits from their GSCM activities. This can be a tipping point in resolving the paradoxical situation of greater environmental protection versus less economic efficiency, providing valuable insights into the current debate “does it pay to be green?“. Thus, our research deepens the supply chain sustainability theory and taps into the relatively uncovered area of paradoxical trade-offs and tensions in GSCM (Zhang et al., 2021), exhibiting that profitability and sustainability can veritably co-exist. It is also worth noting that our research focuses on individual core GSCM practices to gain richer and more in-depth insights into each specific GSCM practice-performance relationship. This study thus further contrasts with previous research (Cousins et al., 2019; Agarwal et al., 2018), which generically treat GSCM practices on an aggregate level and do not explore the specific component parts of the GSCM implementation.

6.1. Limitations and future research

Given that we only collected data from the automotive sector, generalization of our findings to the wider manufacturing industry should be made with caution. Future research may thus examine and extend our theoretical framework beyond the automotive industry and even in other contexts, such as service organizations. Second, our study only focused on environmental and economic performance, neglecting the social dimension of sustainability. Future research should incorporate social performance measures such as safety, diversity, equity and inclusion policies regarding ethnic minorities, forced and child labour, philanthropy, health and welfare directed at the firm’s supply chains to map a more comprehensive landscape of GSCM performance. Moreover, we largely assessed the economic performance through cost-saving measures consistent with prior literature. Future studies should explore the opportunities beyond cost reduction when measuring the GSCM effects on economic performance, paving the way for future contributions.

More importantly, an interesting extension to our theoretical model would be to incorporate constructs that reflect new technologies in OSCM, such as blockchain technology, cloud computing, Internet-of-Things (IoT), and digital twin (Feng et al., 2022), and assess whether these practices can improve sustainability performance. In addition, future researchers can explore additional explanatory factors of GIS (e.g., information technology systems for green innovation and consolidating servers using virtualization software) to have an even more fine-grained understanding of Green IS. Future research may also examine emerging economies, where IT infrastructures remain relatively limited, to compare our findings and contrast the potential effect of the economy and country-level variance. Our findings also showed that large companies have higher impacts on improved environmental performance than small firms. Future research may investigate this conjecture further by focusing on SMEs. Finally, future studies should explore the opportunities for employing longitudinal or quasi-experimental designs to extend the scope of our findings beyond inferences of association to inferences of causality and assess whether the effects of GSCM practices on performance might change over time. Employing secondary data that can enhance causal inference and reduce the likelihood of rival method-based explanations would be another opportunity for future research.

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Declaration of competing interest

None.

Data availability

The authors do not have permission to share data.

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