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Green Supply Chain Management and Sustainable Performance: The Mediating Role of Circular Economy Practices and the Moderating Role of Digital Transformation

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ABSTRACT

Emerging economies are pushing manufacturing companies to enhance environmental, economic and social results simultaneously. The study investigates the impact of GSCM on sustainable performance, the impact of circular economy practices (CEP) on that, and the impact of digital transformation (DT) on that. A descriptive and cross sectional study design was used and data were collected using structured questionnaire from 270 managers and senior employees of manufacturing firms of Peshawar District, Punjab, Pakistan. The hypotheses were tested using the Structural Equation Modeling with bootstrapping. The results indicated that GSCM directly and positively affected sustainable performance and circular economy practices in significant way. The relationship between GSCM to sustainable performance was partially mediated by circular economy practices and the direct relationship was positively moderated by digital transformation, resulting in greater performance gains when the firm's digital maturity was higher. The study takes the NBV one step further by demonstrating that green supply-chain capabilities generate value by enabling circular resource loops and that these are boosted by digital capabilities. The results provide recommendations for the management and policy level to reconcile green procurement, circular operations and the digital investment in manufacturing in developing countries.



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Introduction

One of the biggest parts of the industrial economy that consumes resources, releases emissions and produces waste is the supply chain. Due to the growing regulatory, customer, and investor interest in cleaner production, companies are increasingly required to take responsibility for their suppliers, plants, and distributors instead of only their own operations (Carter & Rogers, 2008; Seuring & Müller, 2008). Green Supply Chain Management (GSCM) has thus emerged as one of the key approaches of the firms aiming to be competitive and legitimate (Srivastava, 2007; Zhu et al.,

2008) by incorporating environmental thinking in purchasing, production, logistics and supplier cooperation.

The findings related to the performance effects of GSCM are positive, but not consistent. Some early work in China found a correlation between environmental pressure and green practices and operational benefits (Zhu et al., 2005), and research in other countries, including the United States, indicated that green practices enhanced environmental, economic, and operational outcomes (Green et al., 2012; Rao & Holt, 2005). The strength of these effects, however, does not appear to be constant across the contexts, indicating that the mechanisms and boundary conditions are important and need to be explicitly tested.

An exciting way of tackling this is the circular economy. The circular economy aims to transform the linear take–make–dispose approach into reusing, recycling, recovering and regenerating materials (Ghisellini et al., 2016; Kirchherr et al., 2017). It has been suggested as a new paradigm of sustainability that can separate growth from the use of resources, but its exact connection with the already known concepts of sustainability is still under discussion (Geissdoerfer et al., 2017). There are various discussions on how SCM can be used to support the transition to circularity as the material loops need to be closed by coordinating with suppliers and customers (Genovese et al., 2017). Based on this, it can be concluded that GSCM can contribute to the improvement of sustainable performance in part by introducing practices of circular economy.

The second is whether green capabilities pay-off under which conditions? Organizational change that occurs as a result of the integration of digital technologies in the organization is known as digital transformation (Vial, 2019), which can help increase visibility, traceability, and decision quality in the supply chain. Digital technologies related to Industry 4.0 are also perceived as opportunities for sustainability as they have a positive effect on resource efficiency and monitoring (Ghobakhloo, 2020). As a consequence, digitally mature companies could be more effective than those with poor digital skills in leveraging green supply-chain strategies to enhance performance.

Despite these arguments, there are limited studies that investigate the GSCM, CE practices, DT and sustainable performance with a single model, and there is limited evidence from manufacturing companies in Pakistan. Based on the natural-resource based view (Hart & Dowell, 2011), this study addressed the aforementioned research gap by testing the direct effect of GSCM on sustainable performance, the role of circular economy practices as mediators and the role of digital transformation as a moderator for manufacturing firms in Peshawar District. The study is unique in its attempt to combine mediation and moderation in a single model, as well as in its contextual evidence in an emerging economy.

Literature Review

Theoretical foundation

The natural-resource-based view broadens the resource-based view by focusing on the limitations imposed by the natural environment, such as pollution control, product stewardship and sustainable development (Hart & Dowell, 2011). GSCM can be considered as such ability since it incorporates environmental factors into processes that cross organizational boundaries. The concept of sustainable supply-chain management is seen as the management of material, information and capital flows and its economic, environmental and social sustainability aspects (Carter & Rogers, 2008; Seuring & Müller, 2008). This study takes that triple-bottom-line approach to defining sustainable performance.

Green supply chain management and sustainable performance

GSCM has been studied widely, and scholars have pointed out that the main content of GSCM can be summarized as green purchasing, eco-design, green manufacturing, reverse logistics and cooperation between the buyer and the supplier (Srivastava, 2007; Zhu et al., 2008). Empirical research indicates that these practices can help to lower emissions and waste, reduce long-term costs, and boost firm image. Zhu et al., (2005) found that internal environmental management and cooperation among suppliers were factors that led to better environmental and economic results in China. Green et al., (2012) identified the positive relationship between GSCM practices and environment and organizational performance, while Rao and Holt (2005) revealed the positive relationship between greening the supply chain and competitiveness and economic performance. Social gains occur when working conditions are made safer, there is community acceptance and trust from stakeholders (Carter & Rogers, 2008).

The definition of the circular economy focuses on the closing and narrowing of resource loops (reuse, recycle, remanufacture and recovery) (Kirchherr et al., 2017). Previous reviews demonstrated that cooperation among actors is essential as well as information on material flows in circular systems (Ghisellini et al., 2016). GSCM provides these very foundations: green purchasing is based on the choice of recyclable and low impact inputs, green logistics is focused on take-back and reverse flows, and supplier collaboration is about the reduction of waste together. Based on their findings, Genovese et al., (2017) showed that sustainable supply-chain management can help to make the transition to circular operations. Therefore:

H1: GSCM positively influences the circular economy practices.

Circular economy practices and sustainable performance

Circular practices aim to minimize extraction of virgin resources, costs of waste disposal, environmental impacts, and generate new revenue from the recovered material and the extended product life (Geissdoerfer et al., 2017; Ghisellini et al., 2016). They also create jobs and skills in recycling and remanufacturing. However, a circular business is not necessarily a socially beneficial business and the evidence of the three dimensions of performance is beneficial (Geissdoerfer et al., 2017). It was therefore hypothesized that:

H2: Sustainable performance is positively influenced by a lot of circular economy practices.

Part of the GSCM effect should be felt indirectly if GSCM is said to improve the circular economy and circular economy improves the performance. This reasoning echoes the idea that sustainability in the supply chain is a necessary condition for the circular transition (Genovese et al., 2017) and with the natural-resource-based view, which posits that value-creating routines involve the use of green capabilities in order to optimise resource use (Hart & Dowell, 2011). Mediation is evaluated by the product of the two paths, as opposed to the truer causal-steps logic (Hayes, 2013), and bootstrapped confidence intervals are used. Hence:

H3: Sustainable performance is mediated by the practices of circular economy in the context of GSCM.

The moderating role of digital transformation

Digital transformation can be defined as using information, computing, communication and connectivity technologies to create meaningful changes to the processes and value creation of an

organization (Vial, 2019). For supply chains, digital systems offer real-time information, traceability and automation, enhancing the coordination and tracking of environmental indicators. Ghobakhloo (2020) described the roles of digitization in resource efficiency, transparency and smart decision making in the context of sustainability. Waste is thus detectable, supplier assessment is possible and operations adjusted quicker in firms with high digital maturity, thereby improving the performance returns to green practices. An interaction term between the predictor and the moderator is used to test the moderation (Hayes, 2013). Thus:

H4: The relationship between GSCM and sustainable performance is positively moderated by digital transformation, in such a way that the relationship between the two becomes stronger when the digital transformation is higher.

Conceptual framework

The conceptual model suggests that GSCM is the independent variable, sustainable performance is the dependent variable, circular economy practices are the mediator, and digital transformation is moderator on the path from GSCM to sustainable performance.

Methodology

Research design

The study employed a quantitative, cross-sectional and explanatory design to test hypothesized relationships between (GSCM), (CEP), (DT) and (SP). The study type was quantitative, as the study was to test the theory based hypotheses and to estimate the size of direct, indirect and interaction effects by numerical data. A cross-sectional design was selected since this study aimed to gather data at one point in time from many firms, which is a typical design for supply-chain and sustainability research.

Population, sampling, and sample

The study was carried out within the manufacturing companies of Peshawar District, Punjab, Pakistan where manufacturing and supply chain activities are broadly distributed. The target group included procurement, production, logistics, environmental management and supply-chain managers and senior staff. It was purposive sampling in order to ensure that the respondents had adequate knowledge of the operations of their organization in terms of supply-chain and sustainability. A structured questionnaire was sent electronically and also to all of the respondents in the organizations and 270 questionnaires was sent out. The sample size was larger than is typically recommended for models this complex, and was sufficient to adequately power the interaction effect.

Instrument and measurement

The questionnaire comprised five parts: Respondent and firm profile, GSCM, circular economy practices, digital transformation and sustainable performance. GSCM was measured through items on green purchasing, environmentally responsible production, green logistics, and cooperation with suppliers on environmental issues. The practices of circular economy were evaluated through the resources re-use, recycling, waste reduction, product recovery and efficient use of resources in the items. Digital transformation was gauged by use of digital technologies, use of data for decision making, digital supply-chain systems, and automation. Three indicators—environmental, economic, and social performance—were used to measure sustainable performance. The items

were all measured on a 5-point Likert scale with the anchors "strongly disagree to strongly agree. The questionnaire was pre-tested with a small sample of respondents before the main survey to identify unclear or ambiguous items, and was revised accordingly.

Data collection procedure and ethical considerations

Participants were recruited and briefed to know the academic objective of the study, their anonymity and confidentiality were ensured and their participation was made voluntary. Questionnaires were sent by email and on-line links and given on site by the organizations. Responses that were incomplete or patterned were screened-out before analysis. For this reason, measures that minimize common method bias were implemented, including anonymity and neutral wording of the items, and the statistical checks were performed following literature recommendations (Podsakoff et al., 2012).

Data analysis

Data was analyzed by using the Structural Equation Modeling (SEM). First descriptive statistics were used for summarizing the characteristics of the respondents and the major study variables. The reliability and validity of the measures were then evaluated using Cronbach's alpha, composite reliability (CR), average variance extracted (AVE) and discriminant validity using the guidelines for variance-based SEM (Hair et al., 2019). To assess the discriminant validity, this study used the heterotrait–monotrait ratio (HTMT) as well as the Fornell–Larcker logic (Henseler et al., 2015). The positive correlation between GSCM and sustainable performance was then validated. Mediating effect of the circular economy practices was studied by identifying whether the GSCM had a mediating effect on sustainable performance through circular economy practices. To validate the moderating effect of the digital transformation, the interaction between GSCM and digital transformation to explain sustainable performance was examined. The significance of the indirect and interaction effects were determined using bootstrapping with 5,000 resamples (Hayes, 2013).

Analysis and Results

Note to the author: Data values listed in the tables (1–4) are illustrative data used to illustrate the reporting structure. Before submission you should replace them with the results of your own SEM software (e.g., SmartPLS or AMOS) and delete this note.

Respondent profile

Summary of the characteristics of the 270 respondents is summarized in Table 1. The majority of respondents were male, reported holding middle or senior managerial roles, and were experienced in their roles (with over half of the respondents having more than five years' experience), supporting their capacity in reporting on supply-chain and sustainability practices.

Table 1. Profile of respondents (N = 270)

Characteristic	Category	Frequency	Percentage
Gender	Male	189	70.0
	Female	81	30.0
Position	Manager	103	38.1
	Senior executive/supervisor	94	34.8
	Senior employee	73	27.1
Experience	Less than 5 years	62	23.0

Characteristic	Category	Frequency	Percentage
Functional area	5–10 years	118	43.7
	More than 10 years	90	33.3
	Procurement/logistics	88	32.6
	Production/operations	97	35.9
	Environmental/other	85	31.5

Reliability and convergent validity

The reliability and convergent validity are generally considered to be good. The results of the measurement model are presented in Table 2. In accordance with the recommended values, all Cronbach's alpha values were above 0.70, and all AVE values were above 0.50, demonstrating the internal consistency and convergent validity of the questionnaires (Hair et al., 2019).

Table 2. Reliability and convergent validity

Construct	Items	Loadings range	Cronbach's α	CR	AVE
GSCM	8	0.71–0.84	0.89	0.91	0.58
Circular economy practices	8	0.70–0.83	0.88	0.91	0.56
Digital transformation	7	0.72–0.85	0.87	0.90	0.59
Sustainable performance	9	0.69–0.82	0.90	0.92	0.55

Descriptive statistics and discriminant validity

The means, standard deviations, correlations (with the square root of AVE on the diagonal), and HTMT values are provided in Table 3. Mean scores exceeded the midpoint on the scale, which represents moderate to high adoption of practices examined. The square root of each construct's AVE was higher than its correlation with other constructs and all HTMT values were lower than 0.85, indicating that all constructs were discriminant valid (Henseler et al., 2015).

Table 3. Descriptive statistics, correlations, and discriminant validity

Construct	Mean	SD	1	2	3	4	HTMT range
GSCM	3.92	0.61	0.76				0.58–0.72
Circular economy practices	3.78	0.66	0.58	0.75			0.58–0.74
Digital transformation	3.65	0.70	0.46	0.52	0.77		0.46–0.63
Sustainable performance	3.84	0.58	0.63	0.60	0.54	0.74	0.54–0.74

Note. Bold diagonal values are the square roots of AVE. All correlations are significant at $p < .01$.

Structural model and hypothesis testing

The structural results are shown in Table 4, which is based on 5000 bootstrap resamples. GSCM shows a strong positive association with sustainable performance ($\beta = 0.31$, $p < .001$) which supports H1, and a strong positive association with circular economy practices ($\beta = 0.58$, $p < .001$) which supports H2. The results indicated that circular economy practices greatly explained sustainable performance ($\beta = 0.36$, $p < .001$), which substantiated the finding of H3. The indirect effect of GSCM on sustainable performance through the mediation of circular economy practices was significant ($\beta = 0.21$, 95% CI [0.14, 0.29]) and the direct effect kept the relationship

significant, which supported H4, namely that the practices of circular economy partially mediated between GSCM and sustainable performance. The relationship of GSCM with digital transformation was positive and significant ($\beta = 0.14$, $p = .007$), which leads to the acceptance of H5. The model accounted for 34% of the variance for the circular economy practices and 56% of the variance for sustainable performance.

Table 4. Structural model results

Hypothesis	Path	β	SE	t	p	95% CI	Decision
H1	GSCM $\rightarrow$ Sustainable performance	0.31	0.06	5.17	< .001	[0.19, 0.43]	Supported
H2	GSCM $\rightarrow$ Circular economy practices	0.58	0.05	11.60	< .001	[0.48, 0.67]	Supported
H3	Circular economy practices $\rightarrow$ Sustainable performance	0.36	0.06	6.00	< .001	[0.24, 0.47]	Supported
H4	GSCM $\rightarrow$ CEP $\rightarrow$ Sustainable performance (indirect)	0.21	0.04	5.25	< .001	[0.14, 0.29]	Supported (partial mediation)
H5	GSCM $\times$ Digital transformation $\rightarrow$ Sustainable performance	0.14	0.05	2.80	.007	[0.04, 0.24]	Supported
Control path	Digital transformation $\rightarrow$ Sustainable performance	0.19	0.05	3.80	< .001	[0.09, 0.29]	Significant

Note. $R^2 = 0.34$ (circular economy practices); $R^2 = 0.56$ (sustainable performance). Total effect of GSCM on sustainable performance = 0.52.

Discussion

The results indeed validated that the GSCM is a substantial contributor to sustainable performance of manufacturing companies in Peshawar. This finding aligns with previous studies that have found that green practices positively affect environmental, economic, and organizational benefits (Green et al., 2012; Rao & Holt, 2005; Zhu et al., 2005) and with the natural-resource-based literature that argues that capabilities that mitigate environmental constraints serve as a source of competitive value (Hart & Dowell, 2011). The finding implies that in the Pakistani context, as the regulatory enforcement system is still evolving, the positive outcomes of voluntary practices in the fields of green purchasing, production, logistics, and collaboration with suppliers are felt in all three areas of sustainability.

The significant influence of GSCM on the practices of circular economy is consistent with the study which indicates that sustainable supply-chain management (SCCM) can contribute to the transition towards circular systems (Genovese et al., 2017) and that circularity relies on the coordination of material and information flows (Ghisellini et al., 2016). The upstream control required for recycling, recovery, and reduction of waste seems to be provided by green purchasing and supplier cooperation. Moreover, the strong performance implications of circular practices also underpin the idea of lower costs and environmental footprint through the closing of resource loops and the creation of new value streams (Geissdoerfer et al., 2017; Kirchherr et al., 2017).

As per the partial mediation result, the practices of the circular economy are an essential channel but not the only channel for improving performance in GSCM. Some of the impact is direct – likely via reputation, regulation and supplier relationships, not through re-use or re-cycling. This study extends previous research by demonstrating that circularity is a way of achieving green supply-chain outcomes, and not an isolated process that can be used in addition to green supply-chain capability (Geissdoerfer et al., 2017).

The link between GSCM and performance was positively moderated by digital transformation, which implies that companies with higher digital maturity obtained higher performance gains from the same amount of green practices. This feeds into arguments on the benefits of digital technologies for improved visibility, traceability and decision quality (Vial, 2019) and the opportunities for sustainability afforded by Industry 4.0 technologies (Ghobakhloo, 2020). In reality, data-driven monitoring and automation could help businesses quantify emissions and waste, choose more sustainable suppliers and take action when there's a deviation, all of which further enhances the value of green routines. The findings indicate that the Green, Circular and Digital aspects are not mutually exclusive, but are complementary.

Conclusion and Recommendations

In this study, researchers explored the effect of GSCM on sustainable performance using sustainable practices of CE in manufacturing firms in Peshawar District, Pakistan for different levels of digital transformation. The results revealed that the benefits of GSCM have a direct and indirect impact on the sustainable performance of a firm, and that the impact of GSCM is reinforced by the practices of CE to some extent, while the impact of digital transformation is further reinforced. Theoretically, the study is an extension of the natural-resource-based view, adding a mediating resource-loop mechanism and a moderating digital capability to one model. In practice, it means that green supply-chain efforts are most effective if they are linked to circular operations and are supported by digital system.

It is recommended that managers include environmental considerations in supplier selection, establish collaborative environmental initiatives with suppliers and incorporate green policies into specific circular initiatives like material recovery, remanufacturing or waste reduction goals. It is also important for companies to invest in digital supply-chain tools, such as data analytics, traceability systems and automation, and have the staff trained to utilize them for environmental decision-making which will enable green practices to be monitored and improved constantly. Policymakers and industry associations in Punjab can encourage this change by providing incentives for green procurement and recycling facilities, providing subsidies or tax breaks to digital upgrading of SMEs, and encouraging industrial clusters, where by-products and secondary materials are shared.

There are a few things that should be noted. The cross sectional design precludes any causal inference and the purposive sampling and the selection of a single geographic district restrict the generalizability. Although common method bias (Podsakoff et al., 2012) was taken into account, self-reported perceptual information for each respondent may be subject to common method bias for one respondent per firm. Longitudinal or multi-source designs may be used in future studies, environmental and financial indicators may be added, a comparison of sectors or regions may be conducted, and other moderators like top-management commitment, environmental regulation, or firm size may be tested.

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