The Impact of Environment Dynamism on Low-Carbon Practices and Digital Supply Chain Networks to Enhance Sustainable Performance:
An Empirical Analysis

Abstract

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Digital supply chains have revolutionised manufacturing firms by helping them address the challenges of a dynamic environment. Firms implement low-carbon practices to achieve environmental sustainability. This paper explores whether digital supply chain networks can influence the sustainable performance of manufacturing firms and the mediating effect of low-carbon practices in the contingency factor of environmental dynamism (ED). The relationship is examined in terms of information processing theory and stakeholder theory and from the perspective of a resource-based view (RBV). The proposed framework is tested using structural equation modelling. The results show that low-carbon practices have a partial mediation effect on digital supply chains and the sustainable performance of manufacturing firms. Furthermore, ED moderates the relationship of low-carbon practices and digital supply chain networks. The study can support managers as they design strategies to move towards a low carbon economy, enhancing the firm’s sustainable performance in accordance with ED. The current study strongly contributes to the literature on business strategy and the environment, as it has both theoretical and practical implications.

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***Keywords*:** Environmental dynamism; strategy; digital supply chain network; competitive sustainable advantage; low-carbon practices; sustainable performance

# Introduction

Many firms are in a transformation phase in which their supply chains (SCs) are expected to be intelligent, agile and transparent (Kumar & Bhatia, 2021). This transformation is driven by the scarcity of resources, changing market dynamics and global issues (Prause & Weigand, 2016). Additional factors include global competition, shorter product life-cycles and consumer dynamics. The other crucial issue is the increment in the carbon emissions of the firms, so they are required to focus on the strategies that support the transformation (Nuber and Velte, 2021). The aim of the firms is to transform their network configurations and systems to move towards a low-carbon economy. To deal with this, digital supply chain networks (DSCNs) have been developed to connect all the stakeholders on one platform that integrates the processes and leads towards holistic decision-making (Garay-Rondero et al., 2020; Sinha et al., 2020). These intelligent SCs help manufacturing firms implement strategies that reduce carbon emissions in response to external contingencies. That is, implementing these strategies depends largely on the dynamism in the environment in which the firms operate.

The initiatives undertaken by the firms to reduce their carbon emissions are called low-carbon management practices (LCMPs). They help the firms achieve sustainable and operational outcomes (Stefanelli et al., 2021). To cope with environment dynamism (ED), the firms develop digital SCs that improve their products, processes and performance (Queiroz et al., 2020; Hermelingmeier & von Wirth, 2021). The firms and are adopting LCMP, but in the volatile environment it is difficult to enhance their overall performance. DSCN brings the firms’ SC partners onto a common platform where they can digitally communicate and exchange the information needed for strategic decisions (Colicchia et al., 2019; Attaran, 2020; Chatterjee & Yatnatti, 2020). This network is intelligent, sustainable, transparent, holistic, and resilient, and it has economically obtained information inflows and augmented intelligence that enhances the operational efficiency of the business firms (Wareham et al., 2005; Nasiri et al., 2020). The manufacturing firms develop efficient DSCNs to optimise their use of resources and reduce their carbon footprint to achieve sustainability. With DSCN, the low-carbon initiatives help to provide a sustainable competitive advantage and enhance the overall performance of the firms. Researchers have identified the benefits of low-carbon initiatives (Hoffman, 2005), but few studies have reported on the undertaking of decarbonising initiatives (Herrmann & Guenther 2017; Eisenack et al. 2014). Moreover, there is a deviation in the roles of stakeholders and the practices of organisations as they move towards a net zero economy (Penz & Polsa 2018). Thus, it is necessary to measure the effect of DSCNs on sustainable performance (SP) and how LCMP and ED drive their relationship. To achieve this, this study establishes a link between DSCN and LCMP in the context of ED.

In terms of the stakeholder theory and the resource-based view (RBV), this study throws light on the role of DSCNs and LCMPs in influencing the SP of the firm in developing economies like India. The study is significant for developing countries as they are in the nascent phase of transformation. This study has also used the theoretical foundation from information processing theory (IPT) (Galbraith, 1973). It indicates that organisations can enhance their performance through their information processing capabilities and the quality of their information. With the DSCN, intelligent information systems may complement the sustainable performance and strategies for reducing the carbon emissions of manufacturing firms. This study assesses the influence of DSCNs on the SP of such firms, and it investigates the variations in the interrelationships that occurred because of the contingency factor, ED.

This study stresses ED and argues that DSCN, LCMP and SP are contingent upon it. DSCNs have proven their impact on the operational excellence of the firms but the extent to which they influence SP with LCMP as a mediating factor should be assessed. In addition, whether DSCNs are contingent on ED should be determined. These questions must be answered for firms to implement strategies in the context of a volatile ED. As there is a dearth of literature on DSCN, LCMP and SP, this study offers a fervent justification to perform empirical research on DSCNs to demystify their impact and contributions to SP in the presence of LCMP and ED. Based on this, following research objectives are established.

* *To measure the impact of DSCN on the SP of manufacturing firms.*
* *To measure the mediating effect of LCMP on the relationship of the DSCN and SP of manufacturing firms; and*
* *To measure the moderated mediating effect of ED on the DSCN, LCMP and SP of manufacturing firms.*

The theoretical foundation for this study is drawn from RBV, stakeholder theory and IPT. With the information-oriented architecture of DSN, information processing capabilities are improved, resources must be optimised for LCMP and there must be more collaboration among SCs for information exchange. This enhancement in the capabilities of processing and sharing of information will lead to intensifying the SP of the organization. Therefore, based on IPT, this study investigates how DSCN influences the LCMP and SP of the firm.

A sample of 171 professionals from the manufacturing industry has undertaken to observe the impact of DSCN and LCMP on SP. Partial least square structural equations modelling (PLS-SEM) is employed to explore the interrelationship through a hypothesized model including constructs of DSCN, LCMP, ED and SP. The study contributes to research in three respects. First, it establishes a link between DSCN and the SP of the business firms to increase the understanding of the performance implication of DSCN. Second, the mediating effect of LCMP on DSCN-SP relationship is examined. Finally, a moderated mediation effect of ED has been examined.

The organisation of the rest of this paper is as follows. Section 2 reviews the DSCN, LCMP, ED and SP of business firms. Section 3 demonstrates the methodological structure and a proposed model for developing the hypotheses. Section 4 elaborates the findings of the study. Section 5 discourses on the are results and implications of the study. Finally, Section 6 concludes the study.

# Literature Review

The literature on DSCN, LCMP, ED and SP was searched using two databases: Scopus and Web of Science (WoS). The search terms were ‘digital supply chains’ OR ‘digital supply chain networks’ OR ‘low carbon management practices’ OR ‘environment dynamism’ AND ‘sustainable performance’. The time limit of the search was from 2015 to 2021. Based on the research questions, 45 papers were identified for this review.

## 2.1 Theoretical Framework

The current study uses contributions from RBV, IPT and stakeholder theory to explore the interrelationship among the constructs. An elaboration of these theories is in the following subsections.

### 2.1.1 Resource-based view

The origin of RBV is from studies by Selznick (1957) and Penrose (1959), who proposed that the competitive advantage of a firm depends on the capacities it requires and its resources. Firms develop their competitive advantage through resources and capabilities that entail assets and that help them formulate their strategies (Ray et al., 2004). Thus, RBV assumes that organisational performance is based on how the resources are managed. RBV helps to explain the reason few firms have better performance through a fundamental analysis of their internal resources and capabilities (Ramanathan et al., 2016). Mao et al. (2017) utilized a natural RBV to assess the interrelationship between the reduction of carbon emissions and a firm’s performance. This study also showed that reducing carbon emission by improvising the processes may positively affect the environmental performance, but it may influence the financial performance negatively. Several researchers have measured the influence of new practices on firms’ performance in past years (Amankwah‐Amoah et al., 2019; Vrontis et al., 2020). This study assesses the practices of DSCN and their impact on the SP of the manufacturing firms. It is assumed that DSCN uses resources optimally to reduce carbon emissions and enhance the SP of the firms.

### 2.1.2 Information processing theory

Galbraith (1973) proposed the IPT to support the design of organisational structures. IPT has been useful in analysing information systems (Wong et al., 2015), integration (Stock & Tatikonda, 2008), supply chain management (Fan et al., 2017) and digital technologies (Li et al., 2020). In this study, DSCN and ED are information-oriented, and they improvise the information exchange for SC partners. The influence of the DSCN on the sustainable performance of the firms is evaluated. Also, this study investigates the variations in the interrelationships that occurred because of the contingency factor—environmental dynamism (ED). IPT suggests matching the organisation’s information capabilities with the dynamic business environment (Mithas et al., 2013). Thus, this theory is applied to know the real impact on the environment of the DSCN and low-carbon practices.

### 2.1.3 Stakeholder theory

This theory develops a link between the external environment and the organisation’s must align its strategies in response to its stakeholders to improve the performance links to the external environmental (Freeman, 1984). It is assumed that stakeholders may paradoxically both risk and cooperate and act as motivators or barriers to decision-making. The pressure created by the stakeholders varies, and firms can react actively or proactively to that pressure (Baranova & Meadows, 2017). This theory has also been used to connect sustainable operations and climate change. Daddi et al. (2018) supported the influence of stakeholder pressure on the carbon disclosure of firms and the responses of the organisation in the context of the environment. One of the chief characteristics of DSCN is that it is a connectedcommunity that caters to stakeholders like suppliers, partners, and customers, products and assets (Büyüközkan & Göçer, 2018). The community shares data and information directly without any gatekeeper. Thus, a DSCN allows data synchronisation that conforms to stakeholders’ details about decision-making with the same data and information. It also allows machines to decide on operating actions (Sinha et al., 2020).

## 2.2 Digital Supply Chain Networks (DSCNs)

Straub et al. (2004) measured the significance of DSCNs, and evaluated the linkage between information sharing and networked operating performance through a DSCN. Over time, the need for a supply network has grown, and today it must be intelligent, agile, transparent, integrated, sensor-based, and able to provide integrated views of the network in multiple aspects in real time, with less latency (Aryal et al., 2018).

The decision-making of the organisation depends on responsiveness, agility, transparency, sustainability, and the pace of the market (Sharma et al., 2020). Strategic questions help the decision-makers understand the need for their organisations and selecting the appropriate options to accomplish their goals (Preindl et al., 2020). With the developing organisation, information clusters are moved from discrete silos to open and integrated systems (Kache & Seuring, 2017). This digital stack has multiple layers for synchronising and integrating data to support decision-making. Using the stakeholder theory, DSCN has interconnected nodes with digital at the core, and it provides access to real-time information from multiple sources such as suppliers, customers, and other SC partners.

## 2.3 Low-Carbon Management Practices

Based on the concept of sustainable operations, LCMP is relevant in the business environment as firms fit decarbonisation into their practices (Sartal et al., 2020). LCMP is used by firms to integrate carbon efficiency into business planning to achieve a sustainable advantage and develop products that are supported by the carbon footprint assessment, which involves mapping their greenhouse emissions (Jabbour et al., 2015; Gerged et al., 2021). It incorporates an eco-design approach that produces products friendly to the environment. It also improvises existing practices to reduce carbon emissions (Wong et al., 2012). Methods including recycling, reuse and disposal are adopted by the firms to reduce carbon emissions (Jabbour et al., 2015). Low-carbon logistics is a major concern for organizations because of their high carbon emission (Scholtens & Kleinsmann, 2011). The RBV suggests that resource optimisation helps to mitigate carbon emissions and to move towards sustainable resources.

## 2.4 Sustainable Performance

DSCN has brought technological changes, ushering a drift of radical innovations that have had a sound impact on the economy. This necessitates a change in policymaking about infrastructure, the environment, and society in general. Moreover, businesses, especially those in manufacturing, are gradually realising the significance of the economic and environmental benefits of SP (Aslam et al., 2021). The triple bottom line concept is the best tool for measuring the SP of a firm (Gimenez et al., 2012). The development of a DSCN creates a competitive advantage for businesses through their intelligent, connected supply networks (Zhu et al. 2020). Research has shown that DSCNs have contributed greatly to achieving sustainability outcomes (Kamble et al., 2019). Therefore, this study considers dimensions of sustainable performance based on the triple bottom line.

## 2.5 Environmental Dynamism (ED)

ED denotes the volatility of the environment (Pagell & Krause, 2004). Previous studies proposed that firms should design their structure according to the environment, which might enhance their performance (Sousa & Voss, 2008; Gunarathne, 2021). ED has been undertaken as a contextual factor for operations and environmental management. Based on the IPT, manufacturing firms have huge requirements for information to meet their short product cycle and fluctuating demands (Bozarth et al., 2009). Therefore, firms must balance this with their degree of environmental dynamism. Organisations need real-time and accurate information for decision-making. Childerhouse et al. (2003) proposed that transparency is essential in supply chains to overcome ED. Therefore, firms focus on DSCN to integrate information from upstream and downstream SC partners, and they may them in decision-making. This study has made efforts to measure the influence of ED on the relationship of the DSCN, LCMP and SP of manufacturing firms.

## 2.6 Hypothesis Development and Research Model

The proposed model is based on RBV, IPT and stakeholder theory. The current study derives constructs from previous research that measured DSCN, LCMP, SP and ED. They are elaborated in the following subsections.

### 2.6.1 Digital supply chain networks, low-carbon management practices and sustainable performance

A DSCN acts as an organisation strategy to enhance overall performance. The transformation to DSCN reduces cost; enhances productivity, transparency and accuracy; and balances demand and supply. Stakeholders expect different levels of performance of the organisation, and that cannot be met with a single goal (Zhu et al., 2012; Cavalcante et al., 2019). Using IPT, adopting a DSCN to enhance SP has been measured based on the triple bottom line (Gimenez et al., 2012; Hosseini & Ivanov 2019). DSCNs are intelligent, integrated; customer-centric and data-driven, and this enhances the value of the products (Hofmann & Rüsch, 2017). IPT helps to assess the dynamic and integrated networks with a continuous flow of information (Seyedghorban et al., 2020). From RBV and IPT, supply chains can be developed to reduce carbon emissions and integrate decarbonization into the firm’s practices (Sartal et al., 2020). DSCN may be developed to integrate carbon efficiency in the planning of the manufacturing firms and bring product innovations that are supported by the assessment of the carbon footprint (Jabbour et al., 2015). With a DSCN, firms can have better control over information sharing and processing to develop data-centred analyses of their carbon footprint. LCMPs may improvise the existing practices to mitigate carbon emissions (Böttcher & Müller, 2015; Wong et al., 2012. This study proposes a significant and positive association between DSCNs, LCMP and SP. The following hypotheses are proposed:

***H1(a):*** *DSCNs have a positive effect on the SP of a manufacturing firm.*

***H1(b)****: DSCNs have a positive effect on the LCMPs of a manufacturing firm.*

### 2.6.2 The mediating role of low-carbon management practices

LCMPs are required to integrate the carbon efficiency into the operations of the firm, including planning, implementation, control and providing competitive advantage, enhancing the SP of the firm. LCMPs enable the development of low-carbon product innovationsthat aresupported by assessing the carbon footprint and mitigating greenhouse gas emissions (Jabbour et al., 2015). With the DSCN, firms adopt an eco-design approach to include environmental concernat all development stages during the production process. The major sources of carbon emissions are transportation and logistics. The stakeholder theory suggests the successful implementation of such practices depends on stakeholder collaboration. Thus, through a DSCN, the firm’s abilities to process information are enhanced by the maximum collaboration of the stakeholders. Because of the interconnectedness aided by a DSCN, the LCMPs and SP of the manufacturing firm are integrated. This study explores whether LCMPs could provide synergistic benefits to enhance the SP of a manufacturing firm. This study suggests that a DSCN, along with LCMPs, can be significant in minimising carbon emissions and enhancing the SP of the manufacturing firm. With DSCNs, manufacturing firms can leverage both internally and externally to conduct sustainable operations and LCMP practices effectively. Thus, we propose-

*H2: LCMPs mediate the relationship between the DSCN and SP of a manufacturing firm.*

### 2.6.3 The moderating role of environmental dynamism (ED)

ED has been widely used as a moderator in previous studies. (Sousa and Voss (2008) observed that a firm designs its structure based on the environment in which it competes. Therefore, manufacturing firms must adopt advanced technologies to remain fit with the degree. They cannot depend solely on internal information. They need real-time information to take appropriate actions. A DSCN provides intelligent, accurate, agile and transparent information sharing system that may help a firm develop proactive strategies to deal with its dynamic and uncertain environment. A DSCN not only provides technological advancement to the firms but it also further enhances the firm’s capabilities for information processing that helps it respond in a timely manner. As the world is witnessing environmental issues, it is necessary that firms incorporate LCMPs to enhance their sustainable performance. The DSCN may help a firm adopt LCMPs for efficient and sustainable outcomes in a dynamic environment. In a high-ED environment, a firm tends towards extending the DSCN. Therefore, as ED grows, the effects of DSCN on SP also will increase. Previous research has found that ED moderates the relationship of SCs to sustainable performance (Zhang et al., 2017), and that supports the hypotheses proposed in this study. Considering the mediating role of LCMPs, this study tries to measure the indirect impact of a DSCN on SP. Thus, a moderated mediation effect is tested, and a conceptual model is proposed (see Figure 1). Thus, these hypotheses are formulated:

*H3a: ED has a significant effect on the relationship between the DSCN and LCMPs of a manufacturing firm.*

*H3b: ED has a significant effect on the relationship between the DSCN and the SP of a manufacturing firm.*

Digital supply chain network (DSCN)

Sustainable performance (SP)

Low-carbon management practices (LCMP)

Environmental dynamism

(ED)

H3a

H3b

H1b

H2

H1a

**Figure 1.**The proposed structural model.

# Research Methodology

This study uses a quantitative approach, and a survey is one of the best methods for measuring the direct and indirect impacts on management (Forza, 2002; Dubey et al., 2018). The aim is to provide a deeper understanding of a DSCN and its impact on LCMPs and SP. The survey was conducted to determine the association between DSCN, LCMP, ED and SP. The conceptual model is elaborated in the following subsections.

## 3.1 The Survey Instrument

The current study uses a survey to evaluate the interrelationship among the constructs. The statements for the questionnaire were developed based on research questions. The questionnaire was designed on the scale established by the academic literature. The responses were made on a 5-point Likert scale, where 1 signifies strongly disagree and 7 signifies strongly agree. The questionnaire included four sections: (1) the firm’s characteristics, (2) DSCN (3) LCMP (4) SP. The items for SP were developed from pre-defined constructs (see the Appendix). The items were adopted from the following studies: DSCN (Büyüközkan & Göçer, 2018; Aryal et al., 2018; Rodrigues, et al., 2020); LCMP (Jabbour et al., 2015; Gerged et al., 2021) and ED (Li et al., 2020; Kumar & Bhatia, 2021)

The questionnaire was organised in two stages for confirming its validity and reliability. The questionnaire began with the construct details in brief followed by questions about the demographics of the respondents. To pretest the questionnaire, a panel of experts from academia and business were asked about the relevance of the constructs and items. The panel had eight experts: two senior-level professors in the area of the sustainability, three IT professionals with over 8 years of experience facilitating companies in their digital transformation and three industry experts associated with strategic decision-making. Based on the experts’ response, the questionnaire was modified to ensure its validity and reliability. A pilot study was conducted on 30 young professionals from the different industries to check the validity of questionnaire.

## 3.2 Data Collection

The data were collected during the early months of 2021 through questionnaire taken by practitioners associated with several manufacturing firms in northern India. The respondents mainly held managerial positions, and they were aware of DSCN and LCMP. The selected sample varied on several dimensions such as industry, number of employees, number and types of products manufactured, designation and experience. The employees belong to manufacturing sector covering wide variety of services. Based on gender, 71.34 % of the samples are males. The age of the employees is distributed over the age groups >30 years (30.09%), 30-35 years (19.88%), 36-40 years (43.27%), > 40 years (5.8%). The sample has been taken from India as emerging economies are expanding and becoming conscious about the sustainable practices. As the technology has been recognized globally, the results from the study can be generalized globally (Balakrishnan and Dwivedi, 2021). The sample comprised firms that had digitalised their entire supply chain or were in the phases of developing DSCNs for their firms. The initial response had 118 respondents in first six weeks, there were 74 in the last two weeks. Out of which 21 responses were incomplete and hence rejected.

First, the nonresponse bias was computed to confirm the presence of the same characteristics in the sample as in the general population. To achieve this, responses from the early respondents were compared with the later respondents using the independent sample *t* test. The results showed there was no significant difference between the early and the late replies. Levene’s test was conducted, and the values obtained are shown in Table 1. Table 1 also shows a positive indication towards the assumption of variance homogeneity as the *p* value was greater than .05. Also, *p* > .05 was obtained for equality of means in both the sample groups. Therefore, it can be concluded that no response bias was present in the sample.

Second, the common method bias (CMB) was checked to ensure there were no measurement errors because of correlations among the items of the constructs. CMB was verified through the score of the average full collinearity variance inflation factor (AFVIF) (Kock, 2016). An AFVIF < 3.3 confirmed the absence of CMB. Most of the sample had 100+ employees, and 70% of the companies had certification towards adoption of environmental practices. The main sectors of the manufacturing companies were from the electronics/electrical manufacturing (24%), automotive (18%) and FMCG (15%). The average age of the respondents was 30–35 years, and approximately 65% were males. The average number of years of experience was 5–10 years, and respondents were mainly in managerial positions. The statistical analysis of the responses calculated an average for each item. The online questionnaire comprised 23 questions (all mandatory), without which the final submission was not allowed. The mandatory nature of the questionnaire prohibits the missing values and makes the responses valid for usage.

**Table 1**

*Nonresponse bias test*

|  |  |  |
| --- | --- | --- |
| Construct | Levene’s Test | Significant *t* Test  |
| Digital supply chain network (DSCN) | 0.635 | 0.540 |
| Low carbon management practices (LCMP) | 0.524 | 0.455 |
| Sustainable performance (SP) | 0.842 | 0.657 |
| Environmental dynamism (ED) | 0.656 | 0.435 |

# Data Analysis and Results

Partial least squares structural equations modelling (PLS-SEM) method was used to test the hypotheses. This is one of the most valuable methods to study the early stage of exploration(Wold, 1989). In addition, partial least squares regression (PLS) is used when the sample size is very small and free from the limitation of data normality. SMARTPLS 3.0 software was used in the hypothesis testing. The weighting scheme (path) with 300 maximum iterations was selected in the PLS algorithm. Further, a 5% level of significance (one-tailed in bootstrapping) was selected. The results of the structural equations modelling (SEM) are elaborated in the following sections.

## 4.1 Measurement Model

The results of the measurement model were evaluated to assess the validity and reliability of the construct indicators shown in Figure 2. The reliability of the items was examined through loadings between the items and constructs. The cut off value for the loading was 0.7. The reliability of the latent variables was evaluated through composite reliability (CR), and convergent validity was evaluated by average variance extracted (AVE), which should be greater than 0.05 **(**Hair et al., 2017).



**Figure 2:** The measurement model.

Two measurements were used to check construct validity: Cronbach’s alpha and *ρA.* Both values should be greater than 0.70 (Henseler et al., 2017). The results from the measurement model are shown in Table 2.

**Table 2**

*Factor loadings, composite reliability and AVE*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Constructs | Cronbach’s alpha | rho\_A | Composite reliability | Average variance extracted (AVE) |
| DSCN | 0.876 | 0.894 | 0.909 | 0.667 |
| LCMP | 0.907 | 0.909 | 0.928 | 0.682 |
| SP | 0.920 | 0.924 | 0.938 | 0.716 |

Further, the heterotrait monotrait (HTMT) ratio was used to measure the discriminant validity. HTMT is a tool to estimate the unattenuated correlations existing among the constructs, as preferable to the Fornell–Lacker criterion (Franke & Sarstedt, 2019). The values of HTMT must be < 0.90 for the constructs undertaken in the model (Henseler, 2021). The results obtained fulfil the criteria and satisfy the conditions for convergent validity and discriminant validity. The results for discriminant validity are shown in Table 3.

**Table 3**

*Discriminant validity*

|  |  |  |  |
| --- | --- | --- | --- |
|  | DSCN | LCMP | SP |
| DSCN | 0.817 |  |  |
| LCMP | 0.612 | 0.826 |  |
| SP | 0.604 | 0.736 | 0.846 |

## 4.2 Structural Model

The proposed model includes the determination coefficient (*R2*), effect size (*f 2*), predictive relevance (Q2) and variance inflation factor (VIF). *R2* denotes the power of the model to predict, and it signifies the extent of variance in the endogenous variable that is justifiable all other exogenous variables.The variance that could be explained by each predictor in the model is effect size (*f 2*). Table 4 shows the results from the structural model. It shows that the values of the determination coefficient are good (R2 and adjusted R2 values ranging from 0.375 to 0.580). They fall into the medium- and high-ratio categories. Further, the size of the effect also is good *(F2= 0.280 to 0.600)* indicating a high ratio. The blindfolding process used in the model shows the predictive relevance of results is good. The VIF values are less than 3.3, and that shows no vertical or lateral collinearity exists between exogenous and endogenous variables.

**Table 4**

*Results of the structural model*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Construct | R Square | R Square Adjusted | *F2* | *Q2* | VIF |
| DSCN | -- | -- | 0.280–0.600 | -- | 2.434 |
| LCMP | 0.375 | 0.371 |  | 0.200 | 2.427 |
| SP | 0.580 | 0.575 |  | 0.409 | 2.752 |

## 4.3 Hypothesis Testing

The mediation model was developed and shown in Figure 1 to test Hypotheses *H1(a), H1(b), H2*, *H3(a) and H3(b)*. *H1a* and *H1b* were proposed tomeasure the effect of DSCN on the SP and LCMP of a manufacturing firm. The values indicate a positive and significant impact of DSCN on the SP of the firm (*β*=0.245; *P*<.05; confidence interval (CI) = 95%)and on LCMP (*β*= 0.612; *P*<.05; CI=95%). Therefore, both the hypotheses *H1a* and *H1b* are accepted.

*H2* was proposed to check the mediation effect of LCMP on the relationship between DSCN and SP. The bootstrapping method was used to test the significance of direct and indirect effects (Hayes, 2017). The results showed that the mediating effect was significant. The results showed the paths were significant from DSCN to LCMP and from LCMP to SP. Further, the indirect effect of DSCN on SP through LCMP also was significant. The bias-corrected 95th percentile CI for the indirect effect on SP was (*β*=0.359, *P* <.05; CI=95%). This shows there are positive direct and indirect effects, thus a partial mediation exists. This supports hypothesis *H2.*

*Hypothesis H3(a)* proposed that ED has a significant effect on relationship between DSCN and LCMP of the manufacturing firms, and *Hypothesis H3(b)* proposed that ED has a significant effect on relationship between LCMP and SP. The mediated moderating showed the results in Table 5. They show that the interaction between DSCN and ED had a significant and positive effect on LCMP and that the interaction between LCMP and ED had a significant and positive effect on SP.

**Table 5**

*Regression results*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Original Sample (O) | Sample Mean (*M*) | Standard Deviation (*SD*) | *t-*Statistics (|O/SD|) | p- Value |
| DSCN 🡪 SP | 0.245 | 0.2460.612 | 0.074 | 3.316 | .000 |
| DSCN 🡪 LCMP | 0.612 | 0.617 | 0.053 | 11.524 | .000 |
| DSCN 🡪 LCMP 🡪 SP | 0.359 | 0.362 | 0.049 | 7.234 | .000 |
| Moderating Effect 1 🡪 LCMP | -0.116 | -0.119 | 0.059 | 1.963 | .042 |
| Moderating Effect 1 🡪 SP | -0.178 | -0.177 | 0.054 | 3.315 | .001 |

*\*\*\* Significance (P<.05); Confidence level (CI) = 95%*

The results of moderated mediation suggest that the indirect effect of DSCN on LCMP was significant when ED was high, but it was not significant when ED was lower. Therefore, the mediation effect of LCMP on the relationship between DSCN and SP was stronger when ED was higher. Thus, *H3(a)* and *H3(b)* were supported. The results are summarised in Table 6.

Table 6

*Results for the hypotheses*

|  |  |  |  |
| --- | --- | --- | --- |
| Hypothesis | P Value | Significance | Result |
| H1a: DSCN 🡪 SP | .001 | *P < .05; Significant* | Supported |
| H1b: DSCN 🡪 LCMP | .000 | *P < .05; Significant* | Supported |
| H2: DSCN 🡪 LCMP 🡪 SP | .000 | *P < .05; Significant* | Supported |
| H3a: ED 🡪DSCN-LCMP | .042 | *P<.05; Significant* | Supported |
| H3b: ED 🡪 LCMP-SP | .001 | *P < .05; Significant* | Supported |

# Discussion and Implications

This study assesses the relationship between the DSCNs, LCMPs, SP and ED of manufacturing firms. It also enriches the literature on how DSCN and LCMP enhance the SP of manufacturing firms. Moreover, it demonstrates that ED is a significant moderator. The study has theoretical and managerial implications for manufacturing firms.

The current study has empirically validated that DSCNs have a positive effect on the SP of manufacturing firms, as shown in Tables 5 and 6. The results of this study are in line with findings from the other authors. Based on RBV, this research has shown how a DSCN may be viewed as a source of sustainable development. This study proves that DSCNs influence the SP of firms in areas such as cost reduction, waste reduction, reducing errors, providing a safe environment for the workforce and anticipating inventory. In today’s dynamic environment, firms must develop strategies to become more agile, transparent and interconnected so that communication and the exchange of information is accessible and visible to each other (Wong et al., 2020). DSCNs are intelligent, interconnected supply networks that are agile and transparent and that collaborate digitally at each node of the SC network (Hughes et al., 2019). A DSCN has the advantage of intelligent optimisation—the ability of humans and machines to work jointly and share information that may lead to optimal decision-making (Ivanov & Dolgui, 2020). A DSCN also provides the transparency that extends visibility across multiple facets of the SCs. It helps organisations check on the flow of materials, schedules, the demand–supply balance and financial gain. This presents the full depiction of a supply network where a firm can see the interactions and relationships of the components (Bai & Sarkis, 2020). This, in turn, helps an organisation with decision-making and strategic planning. This also enables organisations to broaden their spectrum of strategic transformation, and it provides insights to use these networks to enhance revenues and growth (Arora et al., 2020). The strategy of the organisation to become agile helps it to respond promptly to changes in the environment. This strategy can be enhanced by adding new partners and by sharing information and resources that mitigate risk in the disruptive environment (Cole & Aitken, 2020). The digital collaboration with stakeholders takes place on a common platform for the exchange of information, thereby enhancing transparency, reducing costs and saving time. All of this ultimately enhances the efficiency of the business firm. This dimension of a DSCN develops a connected community for enhancing SP (Büyüközkan & Göçer, 2018).

The results indicate that, in a volatile environment, firms must develop DSCNs to seize opportunities and attain the anticipated sustainable outcomes. This finding corroborates a previous study that found ED to be a significant external for process innovation strategies (Jayaram et al. 2014) and for improving a firm’s performance. The positive moderating effect of ED on DSCN and LCMP indicates that organizations are driven towards strategic changes to enhance their survivability and grow in a dynamic environment. DSCN may act as a crucial element in a dynamic environment that increases information processing capabilities to respond promptly to the volatility of the environment (Li et al., 2020). These processing competences help firms conduct operations more efficiently (Li et al., 2020).

This study has shown that LCMP must be aligned with the interconnected DSCNs that help to enhance the SP of the business firm. These networks facilitate integrated strategic decision-making with optimisation tools for an effective system. If the firms implement LCMP, sustainable performance could be achieved, even in an unstable environment. These findings have significant implications, and they are discussed in the next section. The moderating effects of ED between DSCN and LCMP and between LCMP and SP are illustrated in Table 6. The results show that ED is a significant moderator.

## 5.1 Theoretical Implications

This study throws light on DSCN, LCMP and ED and their impact on SP. It provides a foundation for interconnected networks and SP, as this is the first significant contribution in proposing and validating a model. To date, there has been no empirical testing of DSCNs and their effect on the LCMPs and SP of manufacturing firms. Also, the effect of ED has been rarely explored.

Few researchers have shown that DSCNs influence operational performance (Dalenogare et al., 2018) and lead towards SP (Shahab et al., 2018). In addition, few studies have explored whether DSCNs negatively influence sustainable performance and enhance environmental burdens (Kiel et al., 2017; Delongate et al., 2018). The business value of DSCNs has been investigated (Wareham et al., 2005). This study is pioneer in measuring the impact of DSCNs using an extended RBV, stakeholder theory and IPT. It demonstrates that advanced DSCNs enhance the SP of manufacturing firms through their transparency, intelligent optimization, digital collaboration, agility and responsiveness and holistic decision-making. The results of the study help in understanding the extension of DSCNs into more robust networks that influence the SP of businesses in the presence of LCMPs and ED. The present study highlights the dearth of investigations to identify the relationships between DSCN, LCMP, SP and ED. Our study empirically demonstrates the relationship between those four constructs. Moreover, the mediation effect of LCMP and the moderating effect of ED are found to be significant. Thus, this study extends the literature on supply networks, information sharing and sustainable impact through a unique model, bridging a gap in the literature.

The other research implication lies in the confirmation of the direct influence of DSCNs on the SP of manufacturing firms. This finding is in line with previous studies (Wareham et al., 2005; Jacob et al., 2016). Some studies have shown that DSCNs influence the SP of businesses (Dalenogare et al., 2018; Jabbour et al., 2018). This study shows the mediating effect of LCMP on the relationship between DSCN and SP. It helps to understand the significance of DSCNs and how they can bring radical changes in the SP of businesses in the presence of LCMP. This study demonstrates that DSCNs are crucial and they must be developed for businesses to be sustained in dynamic and disruptive environments.

This study extends the IPT and the stakeholder theory for showing the strength of DSCNs that enhance agility, transparency and integrated decision-making of SCs. Based on IPT and the RBV, this study explores the capabilities of DSCNs and LCMPs and their its influence on the SP of businesses. The other significant contribution is the moderated mediated effect of ED on DSCN, LCMP and SP of manufacturing firms. Based on recent contributions, the current study has demonstrated that DSCN and LCMP are significant in enhancing the SP of manufacturing firms (Martins et al., 2019). The current study contributes through empirical evidence of ED acting as an external antecedent to the implementation of LCMPs and DSCNs.

## 5.2 Managerial Implications

By presenting the impact of ED on the LCMPs and SP of manufacturing firms, this study empirically justifies the moderated mediating effect of ED. This study has developed a framework for researchers and managers to realise the relationship between firm-specific competencies and firm performance. This study should certainly help decision-makers and managers to understand the significance of DSCNs in the contingent ED that would help them to develop their supply chains more appropriately. Organisations can employ multiple DSCNs once they are clear about their strategic priorities. The interconnected network of DSCN allows organisations to develop strategies to develop sustainable competitive advantage. It has brought all the supply chain partners together on the same platform, a dynamic digital core that operates using real-time data. Thus, the drawback of the fragmented nature of business has been overcome by the DSCNs. They provide transparency among the supply chains that offers visibility across multiple aspects all at once. They help organisations track the flow of materials, synchronise schedules, balance demand and supply and manage financials. Manufacturing firms can build and re-design their supply networks, which may act as competitive differentiators to support overreaching business strategies focused on low-carbon practices. It also unlocks enhanced levels of performance and efficiency and thus create new revenue avenues. Smart manufacturing, packaging, real-time data, competitive pricing, enhanced access to customers, and increased transparency with minimal intervention can facilitate faster, improved services and reduce costs, and that might enhance the sustainable competitive advantage of the firms. The capabilities of DSCNs, such as ‘enhanced asset efficiency’, and ‘click-to-ship’ bring the right combination of strategy, innovation, technology and operations to develop digital and disruptive innovative supply chain business models. DSCNs may enhance responsiveness during a disruptive environment. The responsiveness also helps firms meet shareholder expectations during a difficult time.

DSCNs help to achieve several other outcomes, including compliance with government regulations on carbon emissions, minimising waste, recycling, and other sustainable operations. This suggests that DSCNs offer several benefits that help firms survive but also to develop sustainable competitive advantage in a dynamic environment. Therefore, managers must understand the ED in which they operate and frame the appropriate strategies. Furthermore, managers can consider ED to improve environmental and market performance indicators and achieve competitive advantage.

# Concluding Remarks

This research aimed to explore the relationship between the DSCN, LCMP, ED and SP of firms in the manufacturing industry, using stakeholder theory and IPT and an RBV perspective to conduct a literature review. The following aspects were investigated: a) digital supply chain networks (DSCNs) b) low-carbon management practices (LCMPs) c) sustainable practices (SP) and d) environmental dynamism (ED). Based on the theoretical background, relevant aspects were recognised through PLS-SEM analysis. The hypotheses testing showed that there exist significant and positive relationships between DSCN and LCMP and between DSCN and SP. Thus, the results showed that DSCNs influence the LCMPs and the SP of manufacturing firms. The formation of integrated DSCNs allows organisations to develop their competitive advantages on several factors—service, quick response and dynamic fulfilment as needed. With DSCN, strategic decision-making abilities are more advanced and accurate.

The current study has proven that LCMPs have a mediating effect on the DSCNs and SP of businesses. The DSCNs provide synchronised planning, integrated decision-making, dynamic fulfilment, smart factories, and smart procurement with a high level of transparency. This kind of network offers a competitive advantage to firms with a focus on sustainable goals. Also, the effect of ED was found to be significant. The results signify that ED is a moderator that influences the DSCN, LCMP and SP relationship. The impact of ED is significant as there is high volatility in the environment, and this volatility stresses supply networks as they perform their practices. LCMPs are also a mediator that can enhance the SP of manufacturing firms along with the DSCN. This study provides insights that help supply chain managers understand the significance of DSCN, LCMP and ED and their effect on their SP. With DSCNs and LCMPs, efficiency and performance can be enhanced with intelligent, agile, transparent supply chains with low carbon emissions.

The first limitation of the study is the advanced technology, as most firms are in the process of implementation. The data were collected remotely, so there was no opportunity to organise physical visits to manufacturing firms. The research must be extended to other industries, as the current study has a heterogeneous profile of the respondents belonging to different industries. The responses of the professionals were based on their experience, current needs and future requirements. The second limitation is the diversity in the respondents’ industry. The respondents belong to different industries such as IT solutions, healthcare, 3D manufacturing, electronics and electrical products manufacturing and food processing, where the firms’ requirements may vary, so they must be evaluated separately. The third limitation is the lack of physical visits to the firms because of the COVID-19 pandemic. This study will bring more insights when some field visits can be conducted. Last, this study has not conducted a longitudinal analysis, which could be used to explore the effect of using DSCNs in adopting LCMPs over time. For future research, the study would analyse the interrelationship between DSCN, SP and LCMP in context of other industries.

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**Appendix: Constructs and items**

**Digital supply chain network (DSCN)**

*The firm immediately responds/will respond to any uncertain situation without latency (DSCN1)*

*Cloud manufacturing increases resource efficiency among the stakeholders through dynamic sharing for the firm (DSCN2)*

*The firm is able/will be able to obtain performance optimisation by holistic decision-making through digital supplier networks (DSCN3)*

*The firm communicates/will communicate in real time across the supply chain network (DSCN4)*

*The digital supplier networks improve/will improve traceability of supply chains of the manufacturing firms (DSCN5)*

**Low carbon management practices (LCMPs)**

*Does your firm consider/will consider the reduction of carbon emission during product design? (LCMP1)*

*Does your firm adopt/will adopt new manufacturing processes or improve existing manufacturing to reduce carbon emissions? (LCMP2)*

*Does your firm use/will use carbon efficient transportation modes? (LCMP3)*

*Does your firm have/will have an environmental management system? (LCMP4)*

*Does your firm use/will use low-carbon/carbon-free energy sources? (LCMP5)*

*Does your firm use/will use substitute of carbon-intensive raw materials? (LCMP6)*

**Sustainable Performance (SP)**

*Digital supply chain networks reduce/will reduce the cost of operations (SP1)*

*Digital supply chain networks enhance/or will enhance organisational performance through strong stakeholder relationships (SP2)*

*Digital supply chain networks are enhancing/will enhance organisational performance by reducing gas emissions and* improving the firm’s *environmental situation (SP3)*

*Digital supply chain networks are enhancing/will enhance organisational performance through enhanced profits (SP4)*

*Digital supply chain networks are enhancing/will enhance organisational performance by reducing waste (SP5)*

**Environmental dynamism (ED)**

*Environmental changes frequently (ED1)*

*The customers ask for new products (ED2)*

*Government regulations change frequently (ED3)*