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RESEARCH ARTICLE

Digital transformation: fresh insights to implement green supply chain management, eco-technological innovation, and collaborative capability in manufacturing sector of an emerging economy

Naila Nureen[1] · Huaping Sun[2,3] · Muhammad Irfan[4,5] · Alina Cristina Nuta[6] · Maida Malik[7]

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Abstract

The increasing significance of green supply chain management in developing countries' manufacturing sector is primarily driven by the deteriorating environment, signified by decreasing raw material resources, a surplus of waste sites, and rising pollution levels. Green supply chain management can provide competitiveness while boosting a company's environmental sustainability if implemented effectively. Therefore, it is necessary to determine the effect of green supply chain management practices on the firm performance of the manufacturing sector. This research aims to determine the moderating effect of collaborative capability and the mediating influence of eco-technological innovation and environmental strategy on the relationship between green supply chain management and firm performance. Five hundred fifty survey questionnaires are gathered from manufacturing firms of China. Utilizing structural equation modeling (SEM), the proposed hypotheses have been analyzed and investigated. The results show that green supply chain management indirectly affects the firm performance. Moreover, green supply chain management is positively related to environmental strategy and eco-technological innovation, which effectively enhance firm performance. The findings further indicate that environmental strategy and eco-technological innovation significantly mediate the association between green supply chain management and firm performance. Furthermore, collaborative capability significantly and positively moderates the relationship between green supply chain management and firm performance. As a result, the adoption of these factors influences firm performance positively and will assist the manufacturing sector in meeting diverse yet radically changing requirements and overcoming obstacles originating from a dynamic global business environment. Consequently, it is of the utmost importance that businesses must utilize green practices with relatively low environmental impacts. Companies can considerably maintain and improve their firm performance by reducing the environmental impact if they have effective collaborative capabilities, eco-technological innovation, and environmental strategies.

Keywords Collaborative capability · Eco-technological innovation · Firm performance · Green supply chain management practices · Environmental strategy · Manufacturing firms

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✉ Muhammad Irfan
irfansahar@bit.edu.cn

[1] School of Economics and Management, North China Electric Power University, Beijing 102206, China

[2] School of Economics and Management, University of Science and Technology Beijing, Beijing 100083, China

[3] School of Finance and Economics, Jiangsu University, 212013 Zhenjiang, People's Republic of China

[4] School of Economics, Beijing Technology and Business University, Beijing 100048, China

[5] Department of Business Administration, ILMA University, Karachi 75190, Pakistan

[6] School of Economics & Business Administration, Danubius University, Galaţi, Romania

[7] The NUST Business School, National University of Sciences and Technology, Islamabad, Pakistan

Introduction

The threats caused by climate change have grown so serious that the notion of "climate crisis" seems trite (Sharif et al. 2020b). The Intergovernmental Panel on Climate Change (IPCC) recently stated that sanctions toward unusual and pervasive worldwide climate change sources, including the carbon border adjustment mechanism (CBAM), are going to be intensified (Strandsbjerg Tristan Pedersen et al. 2021). Companies in nations with considerable reductions in greenhouse gas (GHG) guidelines, like CBAM, have relatively high expenses, which might result in trade imbalances by decreasing the competitiveness of green goods and raising worries regarding carbon dioxide leakage. The worldwide recognition of the deteriorating climate crisis has served as a significant impetus for businesses to adopt an innovative carbon–neutral direction (Adebayo and Kirikkaleli 2021), prompting them to improve their green supply chain management (GSCM) and firm performance (FRPR) (Maciej Serda et al. 2021). China aims to attain carbon neutrality by 2060 and peak carbon dioxide emissions by 2030. The International Energy Agency (IEA) predicts that China's energy policy in 2021 will emphasize energy, gasoline, and sustainable, effective, and digital technologies. The share of renewable energy, gas from natural sources, and power in China's consumption of energy is rising (Yuping et al. 2021). As CO2 emissions rise, it appears challenging to reduce contamination (Kirikkaleli and Adebayo 2021). The IEA emphasizes the power, manufacturing, and transport sectors, each contributing 42%, 19%, and 23% of CO2 emissions, respectively (Khan and Johl 2019). Fossil fuels have a negative relationship with environmentally friendly logistics activities. The higher the energy intake, the greater the adverse effect on economic development (Sharif et al. 2020a) and the sustainability of society and the environment (Nureen et al. 2023c). Moreover, businesses are under intense pressure to implement environmentally friendly procedures in their supply chains to increase their ecological and social sustainability (Nureen et al. 2022).

Given that stakeholders are more focused than ever on society as a whole, the environment, and economic growth, environmental sustainability is crucial for organizations as well as supply chains (Khan et al. 2019b). GSCM, additionally referred to as environmental supply chain management, becomes more significant in this setting. Inspecting GSCM is crucial for any business because GSCM practices are intended to improve firm performance (Cheema et al. 2020). This is because GSCM establishes possibilities to lower GHG emissions and the production of solid waste. An organization's capacity to consume fewer resources—materials, power, or water—and to identify eco-efficient alternatives by managing their supply chains better is a sign of a supply chain that is more environmentally friendly effectiveness which leads to improved FRPR (Khan et al. 2019a). But for businesses looking to argue for the deployment of GSCM, the absence of a direct link between GSCM adoption and better FRPR, whether environmental, economic, or operational, continues to be a hurdle (Tarigan et al. 2021).

Normally, a company's operations rely on the environment in which it operates, but since there are frequently many accidents—earthquakes, regional conflicts, pandemics, etc.—its supply chain is often interrupted (Khan et al. 2021). As a result, its business is always impacted by such occurrences (Suki et al. 2020). An organization should increase its FRPR to continue operating its company during a supply chain interruption (Tumpa et al. 2019). Addressing the mechanisms of FRPR piques the interest of many scholars. A company has to retain the lowest possible price or bottom line that includes the resources and competencies needed for commercial operation whenever an accident disrupts its supply chain. To swiftly adapt to the outside environment and transform challenges into prospects, businesses must seek resources that can be replaced or modify company procedures (Wu et al. 2022). Robust FRPR enables a company to swiftly adjust to the changing environment and redirect resources for a speedy recovery (Khan et al. 2019a). Digital transformation is a more effective way to increase FRPR than other strategies for regaining business. Firms must update their digital infrastructure to enable eco-technological innovation (ETIN) to retain an edge over others in an evolving marketplace, encouraging them to enhance the digital transformation approach (Huang et al. 2022). Huang et al. (2022) assert that the influence of digital transformation on a firm's operations is connected to its size and feature. Nevertheless, digital transformation has various impacts on state-owned companies and major corporations. According to Guo and Xu (2021), ETIN serves as a bridge between technological advances and FRPR, and the application of ETIN may enhance both corporate innovation and digital transformation. The ability, responsiveness, and adaptability of an organization may be improved by ETIN, which substantially influences improving its FRPR (Chege et al. 2020). While most businesses struggled during the COVID-19 pandemic, and a lot of them were forced to close down when their supply chains suffered delays or obstructed, the ones with adaptable supply chains and creative resources were in a position to anticipate, recognize, and act on unforeseen adverse occurrences rapidly (Xu et al. 2019). But it is commonly acknowledged that ETIN is important for both difficult scientific research and long-term investment in digital assets in the digital age (Arranz et al. 2019).

Since environmental strategy (ENST) has often been cited as a key factor in determining FRPR, it is remarkable how little is known about how it affects the kinds of GSCM practice businesses use (AlSuwaidi et al. 2021). Only a few empirical research (i.e., Laari et al. 2018; Laosirihongthong et al. 2013) have tried to establish a connection between ENST and the adoption of GSCM in the past decade. The bulk of these research has not made a clear-cut relationship between various GSCM practices when investigating the effect of ENST and FRPR, despite the fact that they have contributed to our knowledge of how ENST may affect GSCM and FRPR (e.g., Testa et al. 2015). The recent research also restricted their inquiry to specific supply chain management techniques (Laari et al. 2016) or took into account the influence of competitive strategy on general approaches to supply chain management. Therefore, despite their differences, all studies implicitly assume that ENST will have a comparable effect on GSCM practices and FRPR. This is problematic because it might result in a scenario where the strategic objectives and GSCM processes are not aligned, which could lead to company failure. Because of this, the first goal of our research is to conduct a careful analysis to pinpoint the mediating impact of ENST on GSCM practices and FRPR. However, contradictory empirical findings about this link were found in the earlier research. While some research (Nureen et al. 2023c) reported a favorable influence of GSCM practices on FRPR, other studies (Khan and Qianli 2017) found the reverse. Furthermore, it is clear that these contradictory results also apply to the effects of certain GSCM techniques. For instance, Abdullah and Yaakub (2014) found no evidence of a positive association between investment recovery and FRPR. These contradictory findings might be attributable to the various settings (country and sector) and conceptualizations of GSCM methods used in these investigations. This shows that more empirical research is required before there can be agreement on the effect of GSCM on FRPR. In addition, most earlier research was carried out in industrialized nations, with very few considering emerging nations (Bhatia and Gangwani 2021). Developing nations have particular corporate, institutional, and cultural contexts that influence how their enterprises are seen when using GSM practices as competitiveness tools. The study's second objective is to investigate how GSCM practices affect FRPR in developing nations. In order to identify the linkages between GSCM practices and FRPR in the setting of the manufacturing sector, this study addresses the vacuum in the literature by offering novel elements.

The contributions of this study are as follows: Since, to the greatest of the authors' understanding, no study has been done in this perspective yet under this novel research framework, this investigation is the first one to be carried out from the viewpoint of a developing nation, especially China. Secondly, little is known about the relationship between GSCM, ETIN, CLCP, ENST, and FRPR. Since the natural resource-based view (RBV) theory focuses the aforementioned factors as vital in considering the firm's continuous advancement, this study aims to fill these gaps in knowledge by employing ENST and ETIN as mediators (Hart 1995). Thirdly, this study employed CLCP as a moderating element in the linkage between GSCM and FRPR. This research discovers the association between GSCM and FRPR thoroughly, in view of the already-existing elements and the aforementioned unique dimensions. Therefore, the following are the study's primary objectives:

i. The formation of a research framework to investigate the impact of GSCM on the FRPR, as well as the mediating influence of ENST, ETIN, and moderating impact of CLCP between GSCM and FRPR.
ii. Assessment of the results based on the natural RBV theory of Chinese manufacturing firms.

The rest of the paper is structured as follows: a literature review is explored in the second part. The description of our study framework and hypotheses follows this section. The study methodology and data analysis are mentioned in the third section, and the results are discussed in the fourth section. Lastly, the research discussion, implications, and conclusion are provided in the fifth section.

Review of literature and development of hypotheses

Natural resource-based view theory

In contrast to Barney et al. (2011), Hart (1995) took a stance that an "internally oriented" approach to the competition may not be sufficient because of the difficulties of external links. The author, on the other hand, acknowledges the difficulties that natural and social settings provide and thinks that a business's competitiveness and strategies are probably founded on its capacity to support environmentally friendly acts. The natural RBV theory, which Hart theoretically proposed and which, encompasses three approaches: (1) pollution prevention, a prudently nebulous strategy that can result in a company's fundamental cost minimization serving as its key competitive edge; (2) product stewardship, which aids a company in lowering the costs associated with its products on an economic and social level; and (3) a vision statement for sustainable growth by lowering CO2 emissions and illustrating significant relationships with different stakeholders, which ought to draw potential customers and maintain competitiveness.

According to the natural RBV theory, a firm's resources and capabilities play a critical role in determining its level of rivalry. The RBV theory, which claims that enterprises may achieve sustainable competitiveness by minimizing environmental difficulties, is also enhanced by this theory. According to Hart (1995), there are several problems with RBV theory. For instance, it breaks the connection between a company's natural surroundings and the company itself. Natural resources, expertise, and less pollution improve business success. They specifically emphasized that successful long-term FRPR growth and achievement are influenced by pollution management practices, resources related to the environment, and the company's capabilities (Barney 2000).

Green supply chain management practices and firm performance

Supply chain management (SCM) is a combined system of management for carrying out the operations of material procurement and choice, design of products, and production from the producer to the final consumer. As societal members' knowledge and curiosity about environmental concerns rise, research on GSCM is undertaken in SCM (Ahmed et al. 2020). GSCM incorporates environmental understanding into SCM processes; it comprises green manufacturing, greener transportation, and greener reverse logistics (De Giovanni and Esposito Vinzi 2012). In other words, because it may accomplish the profits of businesses and the marketplace's common objectives through minimizing environmental hazards and consequences, GSCM has become accepted as a crucial business approach that will enhance environmentally friendly sustainable development and indicate to organizational shareholders (Micheli et al. 2020). Therefore, reducing costs and use of resources, reducing environmental pollution via green goods, enhancing the social and environmental performance of the firm, and achieving economic performance are the main objectives of implementing GSCM (Kumar et al. 2020).

Green indicators show the benefits of GSCM activities for a business and every link in its supply chain. According to Uddin (2021), when the ecological outcome of a company's dedication to protecting and enhancing the environment is mandatory, it can enhance its FRPR. The firm can decrease air, water, and solid trash, as well as the ingestion of toxic and hazardous chemicals, and it may decrease the rate of environmental mishaps, claim (Hoejmose et al. 2012). GSCM has been proven to significantly improve environmental performance in previous talks, leading to improved FRPR. According to a further study, implementing various GSCM practices, such as ecological design and greener buying, has a detrimental impacts, particularly on economic performance (Dong et al. 2021). So, this research hypothesized the following:

H1: GSCM practices have a significant effect on FRPR.

Green supply chain management practices, eco-technological innovation, and firm performance

The planet's resources are running out as the planet's human population grows. The standard of living for humans will rapidly decline to a point beyond repair in the absence of a comprehensive viewpoint for maintaining natural resources. In light of this, GSCM is one method of incorporating proper environmental oversight into supply chains (Tarigan et al. 2021). According to De Giovanni and Esposito Vinzi (2012), GSCM may be considered a network of businesses that participate in green initiatives to achieve resilience throughout the whole chain via their internal operations and initiatives. The adoption of sustainable practices by a factory may be assisted by GSCM, according to Ersoy et al. (2022), and this might help to save resources. The effectiveness of an environmentally friendly supply chain refers to a company's ability to enhance SCM while using lesser water, power, and other resources. In order to defend the deployment of GSCM, industrial businesses must now overcome the absence of a direct link between the GSCM deployment and enhanced environmental, economic, or operational performance (Li et al. 2021). In addition to ETIN, information exchange, and FRPR, the previous study stream on GSCM is primarily examined (Dong et al. 2021; Teixeira et al. 2016). According to these studies, GSCM has a favorable impact on ETIN and boosts a company's financial and environmental performance. We discovered a lack of interest in earlier research on the antecedents of GSCM, which are very likely to have an impact on ETIN and FRPR. This is why we contend that ETIN and GSCM are important factors that may support enhanced FRPR (Dong et al. 2021).

The production and distribution procedures become more effective and flexible due to ongoing ETIN. Additionally, it alters the relationships between the various supply chain layers and enhances FRPR (Dominguez et al. 2018). We will examine the relationship between ETIN and FRPR in manufacturing enterprises after examining literature that finds ETIN may boost the FRPR. The digital transformation which ETIN has not only altered the corporate environment but also the company structure and business plan (Fernandez-Vidal et al. 2022). ETIN is the key source of support for business innovation, as shown, for example, in the integration of GSCM with contemporary digital and technological infrastructures to boost the rivalry of manufacturing firms (Aksoy and Durmusoglu 2020). ETIN is how businesses respond to the changing external environment. An organization becomes more inventive as it uses more ETIN. High-speed ETIN may increase a supply chain's transparency and make the hazards it faces easier to forecast by giving its partners access to additional information-sharing tools (Brandon-Jones et al. 2014).

H2: GSCM practices significantly effect ETIN.
H3: ETIN significantly effect FRPR.

Green supply chain management practices, environmental strategy, and firm performance

Energy efficiency and a decrease in CO2 emissions are crucial for China's industrial sector, which uses more energy than Germany, Britain, France, Spain, and Japan combined (Akram et al. 2021). The initiatives include crucial steps to support the manufacturing sector's sustainable growth in China. To address issues with the economy and the environment, manufacturing firms must combine lean and green manufacturing (Nureen et al. 2023a). At the point of FRPR, green approaches and ENST are crucial. The ENST represents the management approach to the sustainability of the environment. ENST has a significant impact on how environmental management policies are put into practice, especially in companies that are environmentally conscious. The ability of a company to quickly respond and impact environmental issues that are sustainable depends on ENST (Adomako et al. 2021). Senior managers are in charge of the company's resources, personnel, and standards for the environment (Nureen et al. 2023b). The past study demonstrates that ENST moderates the relationship between GSCM and FRPR. GSCM procedures may improve the ecological behavior of employees. The actions and attitudes of senior-level managers are essential for carrying out ecologically sound activities that improve GSCM and FRPR throughout the adaption and implementation of ENST (Amir and Chaudhry 2019).

As a result, the association between GSCM and ENST is crucial for developing employee competence, dedication, and FRPR potential. An important component of ENST that promotes company competitiveness is preventing pollution, expanding manufacturer responsibility, and sustainable development (Cho 2022). Recent research has shown the effects of ENST on FRPR in general. As a result, GSCM may encourage the use of sustainable manufacturing, green design, reverse logistics, and customer and supplier participation, strengthening organizational commitment to mitigating environmental challenges (Riaz et al. 2022). Additionally, senior management using GSCM principles could lead to better implementation of ENST, boosting the FRPR. A manufacturing firm with a weaker ENST, on the other hand, would neglect environmental norms and values and provide fewer resources to environmental problems that have an impact on FRPR. Therefore, we proposed the following:

H4: GSCM practices have a significant influence on ENST.
H5: ENST has a significant influence on FRPR.

Mediation of eco-technological innovation and environmental strategy

GSCM approaches are technological improvements made to goods and processes with the goal of improving resource efficiency and reducing the potentially harmful impacts on the environment. Many research investigations have been conducted to determine the connection of GSCM practices with various constructs to accomplish these goals and emphasize their significance (Noorliza 2023). Khan and Qianli (2017) and Mumtaz et al. (2018) examined how GSCM procedures affected the FRPR in Pakistani manufacturing enterprises. The mediating function of innovation performance in the link between GSCM abilities and a firm's environmental performance was identified by Jermsittiparsert et al. (2019). Our study effort specifically suggests that the link between GSCM practices and FRPR is mediated by ETIN. Such capacities might manifest in ENST as ongoing cost-cutting measures (tacit), bringing together stakeholders to ward off competition (socially complicated), and a common vision of environmentally friendly growth that guarantees a firm's place in the future (rare) (Hart 1995). Due to the route dependency and social embeddedness of environmental challenges, capabilities may either be developed sequentially (Khan et al. 2023) or simultaneously when tied to ENST. An ENST that gives rise to a competitive edge has been defined in the literature as being prospective and heading in addition to complying with legislation (Aragón-Correa et al. 2020), carrying out pollution-preventing innovations with goods and procedures (re)design or modification (Adomako and Nguyen 2020) and is expressed in administrative and organizational principles and incorporated into organizational structures and ENST (Hart 1995). Developing ENST may enable businesses to reduce production expenses, gain a competitive edge, incorporate throughout operations, acquire knowledge, and innovate as an initial step regarding integrating and reinventing how they interact with the environment (Yang et al. 2019; Marsat et al. 2021). According to Hart (1995), the link between GSCM and FRPR may be explained by ENST and ETIN. In order to balance GSCM and FRPR, ETIN and ENST are employed as mediating variables. Consequently, we hypothesized the following:

H6: ETIN significantly mediates the linkage between GSCM practices and FRPR.
H7: ENST significantly mediates the linkage between GSCM practices and FRPR.

Collaborative capability as a moderator

As stated by Dyer and Harbir (2013), manufacturing firms have the ability to produce relational rents, which appear to be extraordinary earnings generated through collaboration in a relationship of exchange and can only be achieved through dedicated cooperation partners' shared peculiar collaborations. In utterly unknown economic situations, these linkages aid businesses in lowering transaction costs and promote sustainable rivalry (Kale et al. 2002). Additionally, as noted by Choi and Hwang (2015), organizational-wide skills highlight the idea that CLCP should not be limited to certain people or roles but rather be present across all linked departments' staff members. The goal of several businesses has been to maximize investment recovery value via the cooperation of closed-loop supply chain participants. Effective GSCM practice adoption may improve both the environmental and the financial performance of enterprises. Their research concluded that by assuring the cooperative engagement of their partners in the execution of GSCM initiatives, businesses might increase their financial performance.

In fact, collaboration is now essential to environmentally friendly design and is no longer optional. For instance, one of the fundamental components of L'Oréal's environmentally friendly design program is collaborative environmental evaluation (Fayolle et al. 2008). L'Oréal, in particular, closely collaborates with its suppliers to assess the environmental effect of its raw materials all through the course of their life cycle. This is a crucial component of L'Oréal's ongoing ENST, which seeks to acquire all its basic ingredients from environmentally friendly sources by 2020. CLCP is also essential to the endeavors made by Levi Strauss & Co. to reduce the amount of water used during the production of its new "Waterless" jeans line. Levi's adopted the Better Cotton Initiative, a program that aids cotton suppliers in making cotton environmentally friendly since it was discovered that the bulk of water consumption is for the cotton manufacturing process. By selling more than 13 million pairs of "Waterless" jeans from the collection's 2011 debut, Levi's has conserved over 770 million L of water. These examples unequivocally demonstrate the need for group improvement initiatives to maximize the advantages of environmentally friendly design (Choi and Hwang 2015). Through the CLCP attempts of closed-loop supply chain participants, several businesses have tried to optimize the value associated with investment recovery. For example, Nissan Motor Corporation in Japan collaborates with various partners of supply chain for increasing the recovery rate. Nissan is dependent on its auto dealers, which gather scrap bumpers. These scrap bumpers are ground up by Nissan so that the resources may be utilized to create new bumpers. Furthermore, Nissan and the Sumitomo Corporation are working to assess whether the Nissan LEAF battery can be recycled for use in industry. Nissan retrieved almost 100,000 tons of the auto shredder waste that was gathered from automobiles in Japan, making a profit of over 800,000,000 JPY (8,000,000 USD) (Waiyawuththanapoom et al. 2022). These examples unequivocally show the benefits of group development initiatives in maximizing investment recovery. Figure 1 represents research framework. Thus, we hypothesized the following:

H8: CLCP significantly moderates the relationship between GSCM and FRPR.

Research methodology

Data collection and samples

A quantitative method was used as the basis for the study design using survey questionnaires. Various Chinese manufacturing firms participated in the data collection. A convenient sampling technique was used to collect the data. We ensured the confidentiality by minimizing the possibility of common method variance (CMV). Respondents

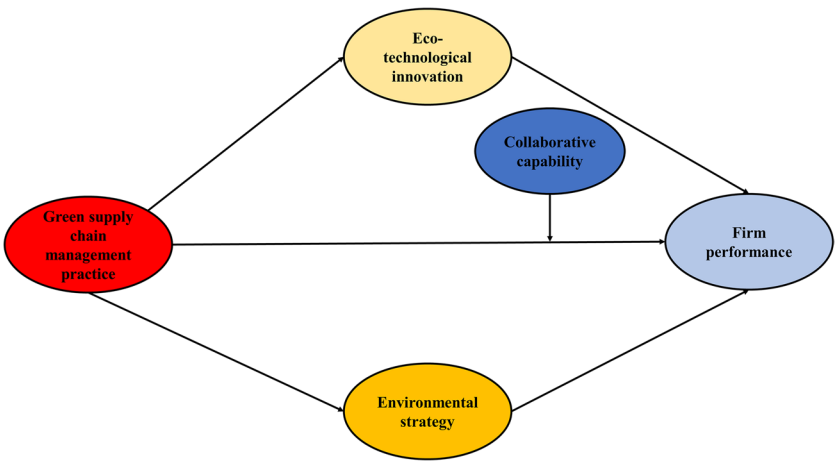

Fig. 1 Research framework

Table 1 Respondents' demography

Features	Options	Frequencies	(%)
Age	20–30	220	40.00
	30–50	205	37.27
	Above 50	125	22.72
Gender	Male	360	65.45
	Female	190	34.54
Level of education	Primary	90	16.36
	High school	100	18.18
	College degree	210	38.18
	Graduate	150	27.27
Experience	Below 5 years	120	21.81
	5–10 years	300	54.54
	Above 10 years	130	23.64

may decide not to provide further personal and business details in order to reduce the influence of common raters (Ahmad et al. 2021). Data was obtained between February 2023 and April 2023. By supplying the URL for online survey questionnaire, surveys were distributed. To maximize the responses, we firstly sent questionnaires to 800 respondents, then those participants forwarded the survey to their referrals. We have received 550 valid questionnaires. Table 1 represents the respondents' demographic details.

Development of the questionnaire

The GSCM practices were estimated employing seven items from (Nureen et al. 2023c). ETIN consists of seven items and has been taken from Shahid et al. (2020). ENST consists of a five-item measure developed by Hussain et al. (2022). CLCP is quantified by five items taken from Samad et al. (2021). All items were calculated by using a five-item Likert scale where 1 = strongly disagree and 5 represents strongly agree. The four items for FRPR were taken from Vijayvargy et al. (2017).

Data analysis

The software programs SPSS (version 26) and AMOS (version 26) are used for statistical analysis. The expected hypotheses are evaluated using structural equation modeling (SEM). When examining the relationship between many elements, SEM is considered a realistic approach that produces reliable and genuine outcomes and has 3 key benefits over earlier approaches: (I) a suitable evaluation of measurement imprecision; (ii) estimating latent constructs using observable data; (iii) the model's applicability in evaluating and running a sequence based on data compliance. The multiple multivariate approaches also purposefully overlook measurement errors. The SEM uses estimating errors to study dependent and independent structures despite this. This approach provides precise and reliable results because of its durability and adaptability (Schepers and Wetzels 2007).

The SEM generates exact results and allows the production of distinctive indication patterns for each component. The erroneous parts of the examined variables are also evaluated. As a consequence, the link between the variables produces accurate findings. Moreover, it can inspect complicated linkages and various hypotheses, which other prototypes and models cannot do (García Alcaraz et al. 2022) due to the inclusion of group assessments and mean. Relying on the advantages of this approach, we used this technique in our study because of to its effectiveness in determining the association between all parameters under investigation (Nureen et al. 2023a).

Analysis and results

Descriptive statistics, correlation, and discriminant validity analysis

Table 2 displays the descriptive statistics of the data, which includes the standard deviation, mean, and coefficient of variation. Correlation analysis was used to examine the interdependencies between variables. The examination revealed substantial correlations between the variables. The discriminant validity was examined using the square root of average variance extracted (AVE). The discriminant validity is supported by the fact that the square root of AVE is higher than its correlation with other factors. Comparing the values of AVE to those of maximum shared variance (MSV) for each construct is another method for determining discriminant validity. The discriminant validity is attained when the AVE value for a variable is greater than its MSV value. These findings are supported by the fact that the values of the AVE for all constructs exceed the MSV values. Subsequently, a convergent validity analysis was carried out employing AVE and item loadings to determine the extent to which the components are possibly related. The results

Table 2 Descriptive statistics of the data

Variables	Observations	Items	Mean	Std. dev	Coefficient of variation (CV)
GSCM	530	7	2.35	0.19	0.08
ETIN	530	7	3.04	1.74	0.57
ENST	530	5	2.56	0.79	0.31
CLCP	530	5	3.94	0.91	0.23
FRPR	530	4	2.85	1.82	0.64

GSCM, green supply chain management; *ETIN*, eco-technological innovation; *ENST*, environmental strategy; *CLCP*, collaborative capability; *FRPR*, firm performance

demonstrated that the AVE values for each construct were greater than 0.50, indicating that the latent constructs kept more than 50% variance (see Table 3).

Reliability analysis

Cronbach's alpha was calculated to determine the items' reliability. The outcomes indicate that values of Cronbach's alpha for all variables surpass the minimum permissible limit of 0.70 (Nunnally 1994), confirming the data's reliability. A composite reliability (CR) analysis was performed to determine the consistency of all variables' components. The analysis indicates that the values of CR surpassed the cutoff limit of 0.70 (Hair et al. 2017) (see Table 4).

Factor analysis

As a subsequent phase, CFA was conducted for identifying the framework. CFA confirms the structure of the extracted factors in EFA. Measuring the framework's unidimensionality is the initial stage to identify framework. Items with substantial loadings (greater than 0.7) on the primary variables should be retained. As per outcomes, each loading was greater than 0.70. The validity of the measurement model was also confirmed, as all items were loaded onto their respective constructs (see Fig. 2). When considering these results, it is evident that the data fits the measurement model well.

Hypotheses results and structural model

We used covariance-based curve estimation and the SEM to scrutinize the model's linkages. The investigation generated the high *f*-value, indicating that all linkages are linear. Various fitness examinations were also done to assure that the structural model and the data are perfectly matched. The analysis reveals that all fit index values meet the prescribed criteria, representing that the structural model and the data are sufficiently matched (Lucianetti et al. 2018).

Figure 3 illustrates a schematic view of SEM as well as structural pathways. The path coefficient of the variables GSCM has no impact on FRPR significantly ($\beta = 0.469$). Therefore, H1 was rejected. In contrast, GSCM influences ETIN ($\beta = 0.154$, p-value $= 0.01$) and ENST ($\beta = 0.176$, p-value $= 0.05$) significantly. Accordingly, H2 and H4 were accepted. Similarly, ETIN ($\beta = 0.113$, $p = 0.05$) and ENST ($\beta = 0.196$, $p = 0.1$) have a significant connection with FRPR. Thus, we accepted H3 and H5. The mediation effects of ENST and ETIN between the relationship of GSCM and FRPR were also estimated. Results showed that both ETIN ($\beta = 0.149$, p-value $= 0.01$) and ENST ($\beta = 0.289$, p-value $= 0.01$) fully mediate the link between GSCM and FRPR. Therefore, H6 and H7 were also accepted. Finally, CLCP moderates the link between GSCM and FRPR ($\beta = 0.023$, p-value $= 0.01$). Thus, we accepted H8. Table 5 represents hypothesized paths and hypotheses validity.

Discussion

The findings of SEM demonstrate a considerably good impact of GSCM procedures on ETIN. Numerous investigations have shown similar results (Carvalho et al. 2020; Song and Gao 2018; Vachon and Klassen 2008; Habib et al. 2021 Ghrakahani et al. 2012). According to Lee et al. (2014), there is a strong correlation between ETIN and internal environmental management, ecological design, and investment recovery. The manufacturing companies' capacity for innovation will increase as a result of using GSCM. Efficient GSCM practices will have a significant influence on ETIN. The research also shows a strong correlation between ETIN and FRPR. ETIN has been shown to improve FRPR greatly. The same results from earlier studies support the idea that ETIN will lead to positive changes in how an organization operates. FRPR is increased through ETIN in both the final product and the production method. Firms must increase their capacity for ETIN to provide high-quality goods at competitive pricing, which will aid in retaining customers over the long run. The research also reveals the importance of GSCM practices and their impact on FRPR (Al-Sa'di et al. 2017; Ju et al. 2016). In accordance with the results, GSCM practices indirectly influence FRPR. Our study also found that implementing GSCM will enhance the quality of goods and adaptability and lower operating costs through ETIN and ENST, which tends to increase the FRPR of the manufacturing company. The mediation's outcome demonstrates

Table 3 Discriminant validity and correlation analysis

Variables	GSCM	ETIN	ENST	CLCP	FRPR	AVE	MSV
GSCM	**0.796**					0.633	0.281
ETIN	0.530	**0.828**				0.686	0.281
ENST	0.268	0.354	**0.765**			0.586	0.125
CLCP	0.223	0.230	0.317	**0.841**		0.707	0.118
FRPR	0.174	0.314	0.335	0.343	**0.712**	0.507	0.118

Bold values represent the root square of AVEs

Table 4 Factor loadings and results of reliability analysis

Variables	Items	Standard loadings	Cronbach α	CR
Eco-technological innovation			0.985	0.895
	ETIN 1	0.805		
	ETIN 2	0.879		
	ETIN 3	0.903		
	ETIN 4	0.921		
	ETIN 5	0.836		
	ETIN 6	0.747		
	ETIN 7	0.677		
Green supply chain management			0.851	0.938
	GSCM 1	0.611		
	GSCM 2	0.838		
	GSCM 3	0.750		
	GSCM 4	0.739		
	GSCM 5	0.844		
	GSCM 6	0.688		
	GSCM 7	0.671		
Environmental strategy			0.932	0.907
	ENST 1	0.782		
	ENST 2	0.824		
	ENST 3	0.878		
	ENST 4	0.864		
	ENST 5	0.852		
Collaborative capability			0.926	0.923
	CLCP 1	0.836		
	CLCP 2	0.890		
	CLCP 3	0.760		
	CLCP 4	0.793		
	CLCP 5	0.684		
Firm performance			0.926	0.804
	FRPR 1	0.713		
	FRPR 2	0.748		
	FRPR 3	0.685		
	FRPR 4	0.701		

Extraction method, maximum likelihood; rotation method, Promax with Kaiser normalization

how ETIN has a mediating effect on GSCM practices and FRPR. This finding suggests that the connection between GSCM practices and FRPR is mediated by ETIN and ENST. According to the empirical findings, CLCP substantially impacted the relationship between GSCM practices and FRPR. These results align with earlier research by Choi and Hwang (2015), which shows that a business's CLCP may influence how GSCM practices and FRPR are related.

Theoretical implications

The widespread implementation of GSCM practices is a significant worldwide problem that has compelled businesses to embrace cutting-edge green procedures for better FRPR while maximizing their ETIN. It has been shown that adopting GSCM practices has a significant impact on FRPR. The correlations between GSCM, ETIN, ENST, CLCP, and FRPR were investigated in the current research in accordance with the natural RBV theory, and the findings have certain theoretical along with practical implications. The implications of GSCM on FRPR have received little attention in the literature, which is especially true given China's status as a developing nation. A greater awareness of the relationships between GSCM practices and FRPR, which consists of environmental, operational, and economic performance, was made attainable by the combination of the ETIN, CLCP, and natural RBV when investigating the implementation of GSCM practices. According to the findings, the FRPR had the greatest impact on how the GSCM practices, ETIN, and ENST were implemented. Therefore, ETIN fosters FRPR,

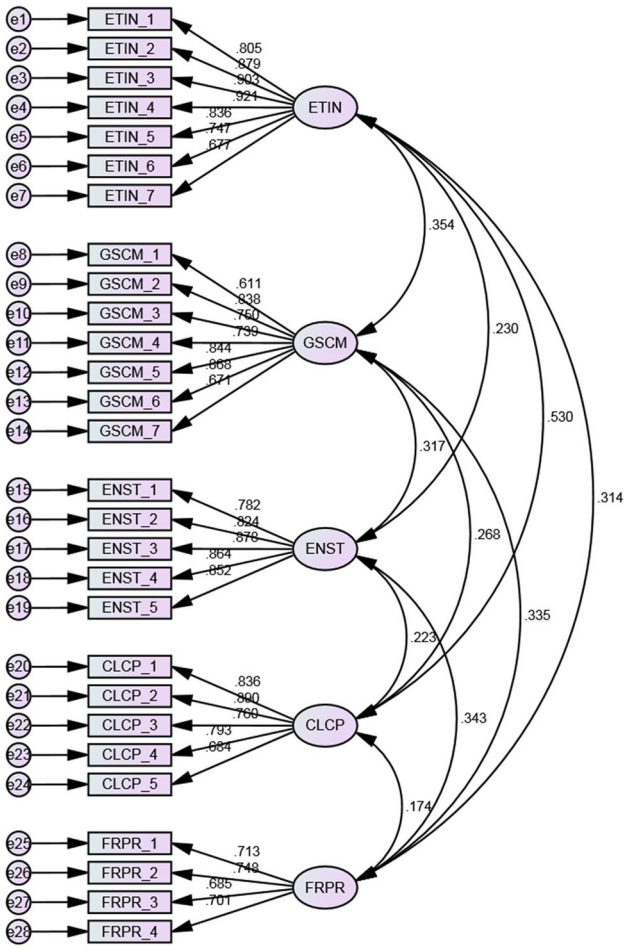

Fig. 2 Confirmatory factor analysis, representing measurement model. *Source:* authors' calculations

which in turn fosters consumer happiness. As a consequence, manufacturers will experience improved levels of FRPR if their GSCM practices are more linked with ETIN, ENST, and CLCP. As a result, businesses that use GSCM, ETIN, ENST, and CLCP would be able to provide creative solutions to environmental issues and client demands, thereby enhancing their FRPR. An organization with the lowest environmental value is often far less lucrative than others, according to FRPR assessments of various stakeholder groups in the businesses. Consequently, in order to prevent pollution and preserve natural resources, managers in business must devise solutions to contemporary environmental issues.

Managerial implications

The findings of this research offer several recommendations for corporate managers, authorities, and specialists. The study framework aims to direct significant manufacturing organizations about the effects of GSCM, ETIN, ENST, and CLCP on the FRPR. The model of research in emerging economies can help managers and policymakers reduce pollution, save power and waste products, save resources that are not renewable, and reduce greenhouse gas emissions, as well as save water, among other measures which optimize FRPR. Nowadays, managers and legislators established a high priority on FRPR. The results show that GSCM practices indirectly impact FRPR; nevertheless, this connection has been mediated by ETIN and ENST and moderated by CLCP. Therefore, while calculating FPR, general managers of large industrial businesses cannot ignore GSCM practices, ETIN, ENST, and CLCP. These factors should be prioritized by policymakers and organizational management in order to measure FRPR.

This research has important management ramifications for Chinese and other emerging country manufacturing companies. First and foremost, businesses must recognize the value of GSCM processes and take greater initiative to put them into effect with ETIN, ENST, and CLCP. Designing eco-friendly goods, ETIN, using eco-friendly manufacturing processes, ENST, and buying eco-friendly resources are

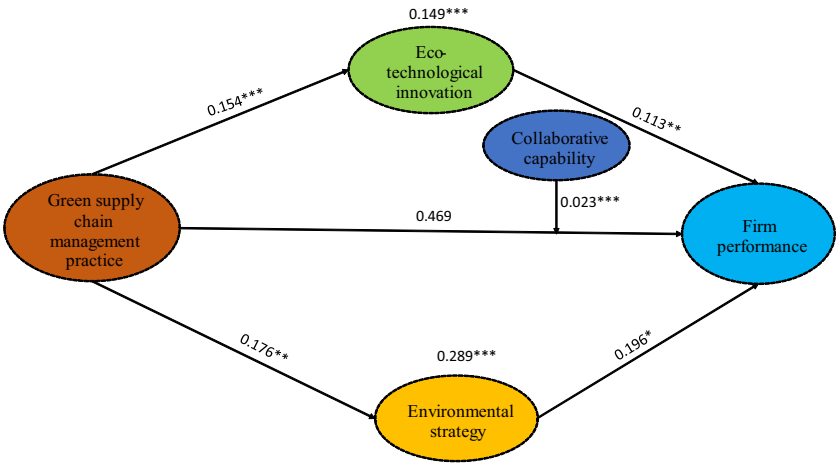

Fig. 3 Path diagram of structural equation modeling. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. *Source:* authors' calculation

Table 5 Hypotheses' results

Hypotheses	Structural paths	β-value	f-value	Results
Direct effects				
H1	GSCM → FRPR	0.469	171.4***	Rejected
H2	GSCM → ETIN	0.154***	223.9***	Accepted
H3	ETIN → FRPR	0.113**	186.3***	Accepted
H4	GSCM → ENST	0.176**	203.9***	Accepted
H5	ENST → FRPR	0.196*	208.4***	Accepted
Indirect effects				
H6	ETIN → GSCM → FRPR	0.149***	173.6***	Full mediation
H7	ENST → GSCM → FRPR	0.289***	197.3***	Full mediation
H8	CLCP * GSCM → FRPR	0.023***	228.6***	Full moderation

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

significant elements that manufacturing businesses must implement to increase FRPR. The second practical application of this research is to show businesses how to improve GSCM practices via a better awareness of the ETIN and ENST that may be used in their businesses. Additionally, the research offers businesses a self-diagnostic tool to help them identify and assess their firm's present state of the process and product development and enhance it by emphasizing on these techniques. Thirdly, adopting these measures can help business owners and managers who are working to increase FRPR metrics, including product quality, operating expense decrease, and system adaptability. Managers and business owners may develop reasonable goods and process-based methods to lessen their goods' and processes' negative environmental consequences by establishing GSCM practices, ETIN, CLCP, and ENST. Finally, the research makes it easier to integrate GSCM methods in enterprises and advance ETIN, ENST, and CLCP to enhance FRPR and lessen adverse environmental effects.

Conclusions and limitations

This study used the natural RBV theory to comprehend how GSCM, ETIN, ENST, and CLCP may enhance FRPR. The results demonstrate the necessity for managers in emerging economies to focus on and give the ETIN and ENST more consideration. They must increase their CLCP spending. This research illustrates the significance of ETIN, ENST, and CLCP for improved FRPR and shows the mediation relationship of ENST, ETIN, and moderation of CLCP. SEM tests have proven these relationships. Additionally, compared to their highly developed nations, industrial companies in underdeveloped countries are less sophisticated and more adept at embracing GSCM. The government, as well as local and international clients, put severe environmental restrictions on several industrial enterprises. As a consequence of consumers believing that GSCM, ETIN, ENST, and CLCP are a fast answer for these issues, it has only ever been employed to fulfill their desires, expectations, and requirements. The developed countries, on the other hand, put a great focus on these factors since they are conscious that they would be unable to achieve their intended objectives without using these factors. The client's requests would not be met by them (Prasad et al. 2019).

This study, in contrast to other studies, has several limitations that provide possibilities for more research. Scholars are dubious that GSCM, ETIN, ENST, and CLCP in significant manufacturing organizations would achieve comparable benefits over time since a cross-sectional technique was first used. In order to ascertain if the effects last longer, future researchers might use the same study design. The data used in this study are obtained from Chinese manufacturing companies; additional research may be undertaken by gathering data from SMEs and the services sector in other developing nations to determine the results. Future studies should consider the importance of green perceived organizational support as mediating element and environmental regulations in the connection between GSCM and FRPR.

Author contribution N. Nureen: conceptualization, writing—original draft, and methodology. H. Sun: supervision and funding acquisition. M. Irfan: formal analysis, data handling, methodology, and writing-review and editing. A. C. Nuta: writing—review and editing and variable construction. M. Malik: writing—review and editing.

Data availability All data generated or analyzed during this study are included in this article.

Declarations

Ethics approval and consent to participate This research study was conducted according to the Declaration of Helsinki guidelines. The Institutional Review Board of North China Electric Power University has approved the study (protocol code 12637–5 on August 23, 2022).

Consent for publication Informed consent was obtained from all respondents belonging to this research study.

Competing interests The authors declare no competing interests.

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