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RESEARCH ARTICLE

Does circular economy affect environmental performance? The mediating role of sustainable supply chain management: the case study in China

Jiayu Liu[1] · Shinchang Lu[1]

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Abstract
Governments and professionals have recently tried to improve public environmental knowledge and laws in order to meet growing environmental concerns. As a result, most nations see corporate environmental initiatives like the circular economy and the green supply chain as important (GSCM) as the best ways to address environmental problems. As a result, this study tries to show how important GSCM and the circular economy are regarding the economy of China's relationship to environmental sustainability. This study uses the partial least square structural equation model (PLS-SEM) on data to obtain trustworthy results from 387 Chinese manufacturing companies. A favorable and statistically significant correlation between GSCM, environmental performance, and the circular economy was revealed using PLS-SEM analysis. To raise environmental standards, eco-friendly methods like buying and designing green items are widely regarded today. Imagine if manufacturing companies adopt green supply chain management, which would improve their economic performance and increase operational effectiveness. The secret to a successful corporation is having successful operations.

Keywords GSCM · Circular economy · Environment performance · China

Introduction

The world has encountered many obstacles in the era of development. Governments have attempted to address these issues by using a variety of remedies, including tourism and the consumption of renewable and nonrenewable energy (Ahmed et al. 2020; Raza and Shah 2018; Raza et al. 2019; Raza et al. 2016). However, the advent of environmental challenges and issues with resource depletion have recently put corporations to the test. As it moves from a developing to an industrialized country, China faces several environmental and consumption issues despite its rapid economic progress (Li et al. 2022; Zhou et al. 2023). China's economy is highly industrialized, and manufacturing has long been a significant industry. As a result, it is crucial to closely evaluate both enterprises' general performance and their effects on the environment. This is due to the fact that these kinds of economic activities pose a significant environmental risk, including but not limited to traffic congestion, carbon monoxide emissions, single-use packaging materials, the use of hazardous materials that have been scrapped, and numerous industrial sector pollution (Akram et al. 2021). In order to achieve greener operations, it is advantageous for these firms to employ environmental techniques like green supply chain management (GSCM) and green innovation. It is predicted that using GSCM and green innovation methods will increase productivity and profitability in everyday activities (Zhang et al. 2023a, b; Yi et al. 2022). This analysis suggests that adopting a circular economy is crucial to making the world a more sustainable environment. Numerous authorities on human economic sustainability advise adhering to natural laws and basing actions on the movement of matter and energy in natural ecosystems. It is a circular economy model (Hermundsdottir and Aspelund 2021). It is becoming increasingly clear that circular economy strategies are essential for structurally optimizing sustainable development programs (Buck et al. 2022). National governments want to

Responsible Editor: Arshian Sharif

✉ Jiayu Liu
Jiayuliu0000@outlook.com

Shinchang Lu
shnlu6756@yahoo.com

[1] School of Business Administration, Liaoning Technical University, Fuxin 123032, China

protect economic resources for as long as possible while distancing economic expansion from natural resource exhaustion and environmental damage (Hong et al. 2019). Programs to promote the goals of the circular economy include lowering resource consumption and improving the design of the energy and material cycle. These programs target businesses and consumers at the micro level, economically integrated cities, regions, and governments at the macro level, and individuals at the meso level (Adjustment et al. 2021). Abbas (2020) established that the increase in economic activity and the preservation of material resources are both stressed in the circular economy concepts. This is because there are such big differences between different scientific fields and schools of thought (Li et al. 2020a, b). A new model for economic growth called the circular economy calls for the economic system to be modernized and reorganized in accordance with the laws that govern the movement of materials and energy within the natural ecological system (Hailiang et al. 2023b; Nasir et al. 2022; Dar et al. 2022; Xu et al. 2023b; Li et al. 2020b). Given the growing adoption of the principles of the circular economy by both local and national governments, as well as within the scope of the Paris Agreement, the implementation utilizing circular tactics at the local government level becomes essential for the management of climate change concerns (Han and Kim 2019; Li et al. 2023a; Yan et al. 2021). One component of the circular economy that can be addressed is modifying waste management systems to boost resource efficiency, decrease resource inputs, and increase financial benefits (Yang et al. 2023). More and more people are recognizing that the circular economy is a highly effective method for formulating policies and reducing environmental degradation and emissions of greenhouse gases (Li et al. 2023b; Huang et al. 2021a; Li et al. 2021). The "green supply chain" is a transdisciplinary idea born from the development of using green management practices in the context of supply networks. As stated by Hai Ming et al. (2022), the goal is to include environmental issues in supply chain management as part of the GSCM procedure (Ma et al. 2021). The entire procedure is tracked from initial conception until disposal. Finding and choosing raw materials and carrying out complex industrial processes are all part of this. If we accept the definition at face value, we may state that there are numerous potential uses for GSCM. However, much of the initial research on GSCM only looked at it from a single functional dimension, such as green purchasing or reverse logistics (Ubeda et al. 2021). In recent years' worth of research, environmentalists have started to look at the many levels of supply networks (Zhao et al. 2022). Although there have been more studies looking at GSCM, or green supply chain management, from various perspectives, it is difficult to provide a comprehensive framework for the different aspects of GSCM because of the concept's broad applicability (GSCM). Some scholars have bemoaned the lack of a thorough framework for managing the green supply chain dimensions (Sendlhofer 2020). The release inspired significant interest in developing sustainably (Hailiang et al. 2023a; Tang et al. 2022). This study defines sustainability as ensuring that present needs are addressed without jeopardizing future generations' capacity to conduct the same (Achi et al. 2022). In the research, three sustainability-related topics are covered. All financial, social, and environmental impacts are measured. To succeed over the long term, a business must find a sustainable balance among its social, environmental, and economic operations. Since the complexity of these traits and how they interact, it is difficult to achieve this balance and be successful. It was suggested that green supply chain management could help to balance the advantages to society, the economy, and the environment (Belhadi et al. 2021). Numerous authors have addressed the significance of a sustainable supply chain in achieving sustainable development (Kraus et al. 2020). One such idea, the natural resource-based perspective (NRBP), views environmentally friendly business operations as a significant source of revenue (Stanislavská et al. 2020). These environmentally friendly practices can enhance a company's energy and material consumption, stakeholder engagement, prices, and product quality. This may have repercussions for a business's overall viability performance. On the other hand, the quantity of studies examining the three facets of how environmentally friendly supply chain management techniques affect sustainability that have been reported (Du et al. 2022) is small. Studies have looked into the impact of environmentally friendly supply chain management on the economy (Du et al. 2022), the surroundings (Sánchez-Infante Hernández et al. 2020), and society (Baldassarre et al. 2020; Park et al. 2020; Ports et al. 2014). This research examined how environmental and economic performance were impacted by green supply chain management, but social performance—the third element of sustainability—was not frequently covered in these studies. Emerging countries are deficient due to the majority of studies on the relationship between green supply chain management and performance in industrialized countries (Cerný et al. 2021). Utilizing the circular economy, the current study is a crucial element that can raise the level of environmental sustainability in China. This research shows how a circular economy might promote both higher economic development and better environmental performance. Specifically, examining the moderating effects of green supply chain management (GSCM) is the goal of this study in the effectiveness of circular economies and environmental systems. Additionally, this paper goes into great detail about the environmental performance of GSCM and circular economy principles. The current article also examines the links between the circular economy, GSCM, green buying, eco-design, and environmental performance. The information for the variables was collected in the China region between April, 2020, and September, 2020. Additionally, eco-design, circular economy, green purchasing, and supply chain management are included as independent variables. Environment performance results also contribute as dependent variables. But in order to attain the desired results, the partial least square structural equation model is applied in this inquiry. (PLS-SEM). The methodology (third section), results (fourth section), discussion (fifth section), conclusion, and policy recommendations (sixth section), as well as the restrictions and future research (seventh section) are divided into the following divisions in a similar manner throughout the remaining sections of the study.

Literature review

Circular economy and environment

Numerous definitions of CE have been offered in the research that has been done. Some adopt a more comprehensive strategy, while others adopt a more focused one focusing mainly on circularity's impact on the surroundings. It was said by Vyas et al. (2022). According to the definition of CE, waste is disposed of through recuperative, which creates new, better material, product, and system design usage-friendly business models. They asserted, however, that the CE economy might be considered a potential engine for wealth generation. A short statement cannot explain its meaning in its true context. From a critical stance, they noted that most economies in recent decades have made every effort to increase their use of CE in environmentally friendly, profitable ways by effectively using waste throughout the recycling process. Additionally, they emphasized how the CE's effective collection and transportation methods have promoted value generation in the circular economy (Gao et al. 2020, 2021; Ding et al. 2023) . As a result, waste has been utilized to generate green energy as efficiently as possible, creating sustainable value (Chen et al. 2023; Feng 2021) (Zhang et al. 2023c).

According to Paramati and Shahzad (2022), CE is "an economic model wherein planning, resourcing, procurement, production, and reprocessing are designed and managed, as both processes and outcomes, to maximize ecosystem functioning and human well-being." Promoting environmentally friendly economic practices is generally agreed upon as the primary aim of a circular economy's success. Fang et al. (2023) employed the life cycle assessment approach to try and show how the circular economy helps the environment and the economy. However, the results demonstrated that an integrated bio-electrochemical wetland system and conventionally created wetlands' financial results and ecological effects play a key role in ensuring environmental sustainability. They clarified that creating and maintaining artificial wetlands might more easily impact sustainability. The heavy metal, phosphorus, and nitrogen emissions from using fossil fuels in the construction industry mostly caused the effects of aquatic ecotoxicity in artificial wetlands. Along with using energy from fossil fuels, producing plastic and concrete slabs released heavy metals and other toxic compounds that added to the aquatic eco-toxicity. Instead, Xu et al. (2023a) consider strong policies and consumer responsibility as essential components of CE. "Cleaner production practices at the corporate level, raised levels of producer and consumer consciousness and accountability, the use of renewable technologies and materials (where feasible), and the implementation of appropriate, transparent, and dependable rules and instruments are all necessary, is how they define CE" (Casals et al. 2019). While the triple bottom line concept has been widely touted for its emphasis on social, economic, and environmental advantages described in sustainable development, CE emphasizes the economic system. According to this paradigm, the economy and environment are the main winners, with societal advantages from environmental enhancements, manual labor, or more equitable taxation (Luo et al. 2023; Hu et al. 2023; Zhao et al. 2023). The ideas of CE and sustainability share a lot of parallels in the interim. Case studies of the seven emerging economies (Ameer et al. 2023) showed how green energy was essential to a sustainable environment between 1990 and 2020. This study investigates the effect of exogenous factors on the dependent one. They used the quantile GMM estimator. However, results demonstrate that renewable energy significantly contributes to a sustainable environment. They emphasized that the large increase in the proportion of renewable energy to total energy use could significantly reduce environmental stress in the seven emerging economies. Mngumi et al. (2022) presented the BRICS case example to show how investments in renewable energy contribute to environmental sustainability. However, panel quantile regression results demonstrated that renewable energy sources are essential for long-term ecological health. This phenomenon has occurred due to a surge in investments in green energy and consumption in daily economic and human activities. However, they also made the case that a sharp increase in investments in renewable energy would be especially beneficial for sustainability. As Andersson and Börjesson (2021) stated, it showed the vital importance of green automobiles and their duty to environmental sustainability. Nonetheless, evidence from the life cycle greenhouse gas emissions confirmed the theory over time. This, however, shows that electrification is not enough to achieve a 90% reduction in the car fleet's GHG emissions even in a scenario where the GHG intensity of the energy mix has been considerably dropped from its current level. It also showed that PHEV technology has more potential to reduce GHG than BEV technology when used in conjunction with renewable fuels. Therefore, a number of strategies need to be followed concurrently to reach a 90% GHG reduction. First, in order to get any significant GHG benefits from electrification, the grid's GHG intensity must be drastically reduced. Furthermore, if sustainable, renewable fuel production is increased, it may be possible to reduce GHG emissions even further than what can be accomplished by using electricity alone. Last, lowering the population's reliance on cars and moving transportation duties to less energy-intensive modes like walking, biking, and public transportation can reduce GHG emissions even further with current automotive technology. Guo et al. (2017) explored how important environmental regulation and technological innovation are to China's performance in green growth. This empirical research tried to include information from all 30 provinces from 2011 to 2012. Similarly, the study's objectives were investigated using a structural equation modeling approach, and the results indicated that environmental regulations have a detrimental effect on the productivity of green growth; however, in some provinces, technical innovation acts as a link between environmental regulations and green growth performance. However, this connection was crucially justified by two separate logics. On the one hand, regional authorities and businesses might react differently to national environmental regulations. For instance, varying amounts of regulatory pressure may be encountered, and green growth strategies may be employed depending on production volume or economic strength. Corporate executives could react adversely rather than implementing environmental management methods like green growth, environmentally responsible supply chain practices, and other initiatives to improve business results and competitiveness in the green market. In China, businesses routinely release pollutants without authorization or in excess of permitted levels, gravely harming ecological conditions in the country (Wang and Tao 2023; Liu et al. 2023a, b). On the contrary, ER enforcement techniques and characteristics are crucial for increasing the effectiveness of regulations. This means that if the executive methods are ineffective or the enforcement officers' credentials are too low, then business managers may not have a clear knowledge of ER, which not only dampens their excitement to adopt environmental management but also easily results in policy errors and finally causes serious consequences has an impact on the firm's long-term sustainable development. Therefore, the Chinese government should pay close attention to the methods and qualities of environmental regulation enforcement and place a high value on how differently regional governments and industries respond to environmental regulation pressures and the performance of real green growth (Shah et al. 2023). The top 15 circular economies did a good job examining the crucial role of the circular economy in producing green energy. They used the AMG and CS-ARDL estimators to achieve the study's goals. The study's findings demonstrated the significant impact of the circular economy on creating green energy, and this relationship was vigorously discussed. They went on to explain how waste from disposable items contributed to methane emissions and global warming. In order to control all sorts of waste in productive operations, the most rational mind has chosen power generation from renewable sources as among the most reliable options. Developed countries have been working to completely shift their approach to trash disposal practices to effective waste scenarios for the past 20 years. Thus, such efforts contribute to reducing environmental harm through a surge in the production of green electricity.

Green supply chain management (GSCM) and environment

Academics, researchers, and management have recently shown great interest in GSCM. This is explained by a growing awareness of the negative effects that supply chains may have on both the environment and humanity. As a result, it becomes imperative to include environmental factors in supply chain management. Because of the importance of GSCM to businesses in terms of enhancing their performance in the areas of the environment and the economy, helping them to comply with governmental requirements, gaining and maintaining a competitive advantage, lowering costs, and enhancing their reputations, among other benefits, GSCM has been the subject of numerous studies (Fu and Majeed 2022; Malesios et al. 2021). The term "green supply chain management" (GSCM) includes a wide variety of processes, such as "green" production, "green" distribution, and "green" design (Irfan et al. 2021). Numerous studies stress the importance of cooperating with other supply chain actors, such as customers and suppliers (Xu et al. 2023a, b). However, the recommended outcomes indicate the benefits of vacuum packing in medium- and long-term distances, which has boosted the efficiency by approximately 28%, described the vital function of flexible packing performance in the E-commerce supply chain. Businesses have recently shifted their focus to supply chain management strategies that are more ecologically friendly. In recent years, there has been a substantial uptick in the number of academic papers devoted to "green supply chain management." Basile and Vona (2021) model of green supply chain management is based on multi-objective optimization to minimize the inherent risk to the greatest extent. After conducting their research, they came up with three potential courses of action: the first would lower risks before concentrating on lowering carbon emissions; the second would lower risks and carbon emissions simultaneously before moving on to lowering overall costs; and the third would lower risks, carbon emissions, and economic costs all at once. Businesses that invest a lot of money in staff training must deal with the problem of managing environmentally friendly supply chains. Through the analytical hierarchy method, they learned the organizational advantages of using the most efficient GSCM techniques and the general understanding of terminology and procedures. In light of the results of Baldassarre et al. (2020), environmental issues significantly threaten a company's long-term existence. The usefulness of green supply chain practices (GSCP) has been praised from an ecological and financial standpoint. According to their research, reuse and recycling substantially impact economies. Businesses can improve their GSCP economic performance by adopting a recovery and recycling strategy. Several factors made green supply chain management possible, highlighted by Martín-Gómez et al. (2019). A framework based on these enablers was created to hold corporations accountable to stakeholders for environmental concerns throughout their supply chain. Zaidi et al. (2019) centered on monitoring as an independent, self-contained system with well-articulated evaluation tasks (Liu et al. 2023c; Lu et al. 2023). Three standards have been chosen: openness, depth, and breadth. These dimensions can be used to characterize key metrics, data collection, processing, and confirmation that the data is significant, reliable, and correct. In industrial businesses, there is a link connection between GSCM techniques and TI (technical innovation). Li et al. (2020a, b) emphasized monitoring as an independent collection of carefully defined evaluation actions. Openness, depth, and breadth are the three criteria that have been selected. Key metrics, data collection, processing, and verification of the data's relevance, reliability, and quality can all be described using these dimensions. Green supply chain management (GSCM) procedures and technological innovation (TI) are related to industrial businesses (Vătămănescu et al. 2021). The lack of a sustainable supply chain is the most pressing issue of the day. Supply chain planning and development must consider the needs of the intended users for them to succeed. The authors discovered that various elements, such as orienting oneself, maintaining momentum, working together, minimizing danger, and taking the initiative, are necessary for SSCM to succeed. Based on analyses of numerous areas of supply chain sustainability, GSCM has been connected to green design, inventory management, production planning, and control for remanufacturing, product recovery, reverse logistics, waste management, and energy consumption and emissions reduction. Meseguer-Sánchez et al. (2021) also developed a useful framework for assessing and managing the effectiveness of sustainability supply chains. (SPSC). Halkos and Petrou (2019) established linkages between several performance evaluation criteria for green supply chains using an analytical hierarchy technique. Five factors were used to determine success: internal environmental management, environmentally friendly purchasing, customer cooperation, investment recovery, and eco-design. Manufacturers of electronic goods were investigated by Korhonen et al. (2018), who examined the connection between important GSCM capability factors and business performance. They have developed a list of GSCM traits, including environmentally friendly manufacturing and packaging, environmental involvement, green advertising, distribution, inventory, and design. Mossali et al. (2020) examined the process by which the biotechnology industry selects its "green" suppliers using the analytical hierarchy method. In examining GSCM procedures, Bag et al. (2021) make links between the closed-loop supply chain concept and how manufacturers use it. A model was created to measure manufacturers' progress in applying GSCM procedures by Hartley et al. (2020). The most important result of this study, which looked at the relationship between GSCM and green innovation in industrial organizations, was assumed to be enhanced environmental performance. However, relatively few companies are willing to share information on their environmental performance. Additionally, standardized reporting measures are not clearly defined. Making meaningful comparisons between locations, businesses, goods, services, and even nations is challenging due to the vast range of reporting methodologies used for environmental performance.

Data and methodology

This study uses data from April, 2020, to September, 2020, for the China region to examine the effects of the circular economy and the impact of green supply chain management. The variables EP, CE, GSCM, GP, and ED stand for environmental performance, circular economy, supply chain management, buying, and design with the environment. Six hundred forty-nine establishments were contacted using a simple random sample technique with a maximum margin of error of 4% and a reliability of 95%. A response rate of 59.63% was obtained, providing data on 387 different companies. The survey was distributed to CEOs of large corporations through a business administering industrial questionnaires. (not based on any other factors). The company's upper management first received the questionnaire and sent the message to the relevant departments. The companies included in the survey are characterized by various sizes, generations, and business models. It was tried to devise a way to prevent biased outcomes (Yadav et al. 2020). Participants received guarantees that their replies would remain private, that they could be sincere, and that there were no "wrong" answers. As a result of using this strategy, it is less probable that people will respond in socially required ways, forgiving, acquiescent, and congruent with what is typically accepted. It was found that factorial analysis typically only reports on a single factor, which accounts for less than 40%

of the alteration when the bias of the common technique was investigated using Harman's one-factor analysis. Consequently, the inter-variable relationships were not caused by variance in the conventional statistical methods.

Estimation strategy

Using structural equations using partial least squares (PLS-SEM) was primarily motivated by the desire to create a hybrid model in this inquiry (Appolloni et al. 2022). The estimation was determined using the mart PLS 3 program (Alkhuzaim et al. 2021). There is no such thing as a wrong evaluation of a concept when composite indicators are used. Thus, composite indicators help support evidence rather than direct causal agents. Although these indicators may or may not share a common conceptual unit and need not be one dimensional, they are required to have similar outcomes. As such, the construct may have multiple facets that composite indicators can represent. PLS uses mode A and mode B to estimate the routes, as mentioned by Belhadi et al. (2021). Mode A is associated with regression weights, while mode B is linked to correlation weights obtained from bivariate associations between measures and the concept. To this end, this study focuses on a composite type-A triadic framework.

Results and discussions

Descriptive statistics

This study concentrated on GP, ECD, GSCM, ENP, and CE (Table 1). Descriptive statistics for the variables are shown in Table 2 as means, medians, ranges, standard deviations, skewness, and kurtosis values. The difference between the average and the middle point is negligible for any of the variables, demonstrating a substantial degree of consideration. The mean value in this table is highest for environmental performance and lowest for circular economy. The absence of a statistically significant disparity between the mean and the median indicates the absence of an outlier in the data set. Table 2 shows the outcomes of many normality tests (skewness, standard deviation, and kurtosis) performed on statistical data applied to the summary measurements between variables. Near-zero skewness scores indicate that all of the variables are normally distributed. In addition, using kurtosis, we can see if the series deviates significantly from the normal distribution at the tails.

Pairwise correlation matrix

The strength and degree of the correlation between the two factors determine whether their relationship is positive or negative. A correlation coefficient's value will often fall between the 0–1 range. Generally speaking, a correlation close to 1 indicates a strong relationship, while a negative correlation below 0 indicates a value near − 1. Nonetheless, the link does not prove causation, so this study investigates the links between variables. Additionally, multicollinearity is excluded from the analysis.

Table 1 Data descriptions

Variables	Definition
ENP	Manufacturing facilities' environmental performance is measured by their success in lowering their consumption of hazardous and toxic products and their air emissions, effluent waste, and solid wastes
CE	Circular economy (including waste flows and recycling rates)
GSCM	Sustainability in supply chain management (supply chain cycle time or inventory turnover)
GP	Sustainable product development is at the heart of green purchasing, which involves working with vendors
ECD	According to eco-design principles, goods must be created to reduce the resources used in production, encourage the reusing and recycling materials and parts, and limit the introduction of potentially harmful substances

Table 2 Descriptive statistics

Variables	Mean	Median	Minimum	Maximum	Std. deviation	Skewness	Kurtosis
ENP	9.348	9.234	6.658	12.298	1.369	− 0.215	1.769
CE	3.430	3.107	1.782	5.729	0.646	− 0.286	2.347
GSCM	7.487	7.193	4.223	9.243	1.475	− 0.175	2.395
GP	6.398	6.028	3.567	9.318	0.976	− 0.538	4.546
ECD	4.278	4.183	3.677	7.867	0.854	− 1.074	1.675

Reliability and validity of measurement scales measurement model

Several methods, including average variance extracted (AVE), Dijkstra-Henseler rho, Cronbach's alpha, and the composite reliability index (CRI), were all calculated and employed to verify the scales' validity and reliability (Table 3). Intercorrelations were assessed alongside the heterotrait-monotrait (HTMT) ratio, as well as the Fornell-Larcker criterion of correlations, to evaluate the constructs' discriminant validity (Table 4). The findings showed that the factorial loads were all over the recommended threshold of 0.7 (ranging from 0.714 to 0.899). Cronbach's alphas were also relatively high, hovering around or above 0.8. The values for both the color rendering index and the Dijkstra-Henseler rho exceeded the optimal level. All values fell over the optimal ranges for CRI (0.945–0.969) and Dijkstra–Henseler rho (0.914–0.957). The AVE values were significantly higher than those in the cited literature (Ding et al. 2020). Table 4 also shows the predictive relevance requirement of Stone-Geisser's Q2 (Geissdoerfer et al. 2018). Both the indicator and the construct Q2 values were positive.

The results of the discriminant validity test are displayed in Table 5. The Fornell and Larcker criterion was met because the variance removed for every element was more significant than the variance shared by all pairs of constructs. The ratio of HT to MT ranged from 0.146 to 0.675, well within the acceptable range and much below the ideal range of 0.85. Furthermore, the cross-loadings confirm the discriminant validity (Koistinen et al. 2022).

Structural model

Table 6 below displays the evaluation criteria findings that met the overarching criteria. Specifically, the SRMR, dG, and dULS were all less than 99% of the height indicator, proving the model's reliability. Calculations showed that CE has a beneficial effect on both ENP and GSCM. The correlation coefficient between ENP and CE was 0.154. (*p*-value: 0.004). A significant correlation of 0.354 was also found between GSCM and ENP (*p*-value: 0.009). The correlation between GP, ECD, and ENP was also relatively high, at (0.219; *p* 0.0001) and (0.764; *p*-value 0.004). These results supported Hypotheses 1, 2, 3, and 4, demonstrating that implementing CE boosted ENP. The results also demonstrated that a GSCM had a favorable impact on ENP (0.354, significant mediation was shown to be related to the GSCM ($p=0.009$). Additionally, the GSCM exhibited a beneficial indirect effect, and this effect was a statistically significant and significant impact (0.076, *p*-value: 0.008). According to the findings, H5 and H6 ought to receive a greater amount of consideration. The GSCM was responsible for transmitting some of the positive effects that the CE had on ENP. Vehicles that had a relationship with the goal of improving the green supply chain of firms in the automotive industry saw significant increases in ENP, reductions in industrial waste, and increased recycling rates attained at the end of their value by recycling them into new products at the end of their useful life ENP. This is because automotive industry firms are increasingly working together to enhance the environmentally friendly aspects of their supply chain. The findings suggested the existence of a significant coefficient for characteristics connected to small- and medium-sized businesses (SMEs) were used as controls (0.176; *p*-value: 0.000).

Table 3 Correlation matrix

Variables	ENP	CE	GSCM	GP	ECD
ENP	1.000				
CE	−0.268*	1.000			
GSCM	0.695**	0.718*	1.000		
GP	0.579*	0.532**	0.438**	1.000	
ECD	0.168*	−0.358*	0.469*	0.379*	1.000

Discussions

By using its core principles for competitive advantage, the circular economy helps businesses reduce their negative impact on the environment while also boosting their bottom lines (Huang et al. 2021b). The current economic climate has elevated the circular economy to the status of a key strategic concern for the success of businesses and the generation of new value. Then, in terms of long-term strategy, it makes sense for management to consider funding more environmentally friendly options. Several studies (e.g., Cusenza et al. 2019; Husgafvel et al. 2022; Ntsondé and Aggeri 2021; Pieroni et al. 2021) have accepted the assumption that studying the circular economy aids in strategic planning, making businesses more environmentally friendly. Regarding environmental concerns, adopting circular economy concepts enables businesses to shut resource loops and offers opportunities to integrate circular thinking into their strategic planning better. Because of this, the circular economy serves as an incentive for businesses to move toward greener practices. To achieve its environmental goals, for instance, a corporation may describe its supply chain management practices to make the most of its available resources, minimizing waste and maximizing its utilization. Findings from this study corroborate those of other research and expand on related issues by demonstrating a robust connection between GSCM and the environment's efficiency (Hull et al. 2021; Su and Urban 2021; Tomić and Schneider 2018). Studies suggest a positive correlation between GSCM

Table 4 Measurement model assessment

Environment performance (ENP) Cronbach's alpha: 0.959; Dijkstra–Henseler's rho (ρA): 0.971; CRI (ρc): 0.948; AVE: 0.767; Q2: 0.074 circular economy (CE) Cronbach's alpha: 0.924; Dijkstra–Henseler's rho: 0.915; CRI: 0.945; AVE: 0.673; Q2: 0.073					
	Factor loads (*p* value)	Q^2		Factor loads (*p* value)	Q^2
ENP1	0.836 (0.000)	0.065	CE1	0.854 (0.000)	0.054
ENP2	0.843 (0.000)	0.087	CE2	0.712 (0.000)	0.067
ENP3	0.883 (0.000)	0.035	CE3	0.746 (0.000)	0.087
ENP4	0.849 (0.000)	0.045	CE4	0.864 (0.000)	0.094
ENP5	0.894 (0.000)	0.062	CE5	0.897 (0.000)	0.048
ENP6	0.823 (0.000)	0.085	CE6	0.755 (0.000)	0.061
ENP7	0.892 (0.000)	0.082	CE7	0.741 (0.000)	0.068
ENP8	0.832 (0.000)	0.054	CE8	0.834 (0.000)	0.081
Sustainable supply chain management (SSCM) Cronbach's alpha: 0.964; Dijkstra–Henseler's rho (ρA): 0.953; CRI (ρc): 0.948; AVE: 0.731; Q2: 0.211 green purchasing (GP) Cronbach's alpha: 0.945; Dijkstra–Henseler's rho (ρA): 0.943; CRI (ρc): 0.964; AVE: 0.723; Q2: 0.221					
	Factor loads (*p* value)	Q^2		Factor loads (*p* value)	Q^2
GSCM 1	0.750 (0.000)	0.163	GP 1	0.839 (0.000)	0.087
GSCM 2	0.774 (0.000)	0.043	GP 2	0.732 (0.000)	0.054
GSCM 3	0.813 (0.000)	0.031	GP 3	0.765 (0.000)	0.152
GSCM 4	0.809 (0.000)	0.265	GP 4	0.806 (0.000)	0.083
GSCM 5	0.811 (0.000)	0.069	GP 5	0.899 (0.000)	0.136
GSCM 6	0.853 (0.000)	0.175	GP 6	0.864 (0.000)	0.061
GSCM 7	0.714 (0.000)	0.162	GP 7	0.703 (0.000)	0.268
GSCM 8	0.877 (0.000)	0.087	GP 8	0.841 (0.000)	0.281
Eco-design (ED) Cronbach's alpha: 0.943; Dijkstra–Henseler's rho (ρA): 0.947; CRI (ρc): 0.945; AVE: 0.734; Q2: 0.204					
	Factor loads (*p* value)	Q^2		Factor loads (*p* value)	Q^2
ECD1	0.792 (0.000)	0.149	ECD 5	0.853 (0.000)	0.237
ECD 2	0.836 (0.000)	0.145	ECD 6	0.879 (0.000)	0.218
ECD 3	0.866 (0.000)	0.196	ECD 7	0.875 (0.000)	0.212
ECD 4	0.898 (0.000)	0.211	ECD 8	0.887 (0.000)	0.223

Table 5 Measurement model. discriminant validity

	Fornell-Larcker criterion					Heterotrait–monotrait ratio (HTMT)			
	1	2	3	4	5	1	2	3	4
ENP	1.876								
CE	1.245	1.749				1.287			
GSCM	1.538	1.251	1.849			1.559	1.547		
GP	1.649	1.248	1.432	1.546		1.146	1.442	1.221	
ECD	1.254	1.323	1.186	1.253	1.823	1.221	1.675	1.654	1.332

Table 6 Structural model results

Paths	Path (*t*-value; *p*-value)	95% confidence interval	f^2	Support
CE → ENP (H1)	1.154 (2.878;0.004)	[1.054;0.275]	1.021	Yes
GSCM → ENP (H2)	1.354 (9.644;0.009)	[1.376;0.387]	1.379	Yes
GP → ENP (H3)	1.219 (2.864;0.000)	[1.046;0.265]	1.213	Yes
ECD → ENP (H4)	1.764 (1.768;0.004)	[1.437;0.218]	1.017	
Size → ENP	− 1.176 (3.365;0.000)	[-1.207;0.129]	1.043	
Age → ENP	− 1.014 (1.976;0.007)	[− 1.082;0.087]	1.000	
Indirect effect		95% confidence interval		
CE-GSCM-GP-ECD-ENP (H5)	1.076 (2.995;0.008)	[1.024;0.157]		
	Adjusted R^2	Model fit	Value	H199
		SRMR	1.037	1.038
GSCM	1.386	dULS	1.396	1.475
ENP	1.178	dG	1.154	1.198

Note: ENP, environment performance; CE, circular economy; GSCM, green supply chain management; GP, green buying; ECD, eco-design; Size, a dummy variable that takes the value 1 if the company is an SME and 0 otherwise; the dummy variable age can be either 1 (for startups) or 0 (for more established businesses). Bootstrap intervals of trust at 95% (with a sample size of n = 10,000) and one-tailed *t*-values are provided. Unweighted least squares deviation (dULS), geodesic deviation (dG), and residual standard deviation (RSD). The 99% percentiles based on the bootstrap sample are called the HI99

and the environment's efficiency. This research emphasized the significance of GSCM for Chinese manufacturing organizations to enhance their environmental performance and maintain their worldwide market competitiveness. This issue was consistent with previous research and highlighted the importance of GSCM in helping these businesses enhance their green innovation. This study also shows the direct and positive effects of green innovation on the environmental performance of businesses. Organizations are better able to endure the rigorous environmental pressures when they adopt green practices, such as green innovation, to maintain and considerably improve their environmental performance. This highlights the need for new strategic approaches from manufacturing company management, such as implementing green innovation practices. This outcome is a surprise, but so is the fact that green purchases have a noticeable effect on environmental performance. These results align with what Yu et al. (2022) discovered about Chinese businesses in a competitive market. Like those in the study, plant-level manufacturing managers filled out the environmental and economic performance measurement scales. While green purchasing has been shown to favor manufacturers' bottom lines, the actual environmental impact may lay with suppliers rather than manufacturers. According to Khan et al. (2021a, b), green purchasing is a more cost-effective green practice for manufacturers than eco-design. Because of this, it is clear that the design and process factors affect the overall environmental impact of the multifunctional holder, as indicated by one author in the aforementioned life cycle evaluation (eco-design). This study shows that future products can be designed with a unit process level that reflects the environmental effects of manufacturing and use of the product and that parameterization as an integrated representation is achievable. Using the information provided by the integrated life cycle assessment model, designers can better map eco-design opportunities and make process- and product-level decisions. It can be argued that the life cycle assessment will aid designers in making effective and simple decisions in order to achieve sustainable development based on this cycle assessment-based optimization approach employed in stage one of the product development process. However, predicting the LCI and PFD at the conceptual design phase presents difficulties in developing life cycle assessments for future goods. Thus, it is important in order to think about the same product and method data and assumptions that may influence the outcomes.

Conclusion and policy suggestions

This research confirms the positive effect circular economy and GSCM have on environmental efficiency. Although the environmental sustainability of China has been discussed previously, this study adds new information to a select number of related previous works. The purpose of this research is to examine the state of the environment in the China region via the lenses of economic performance, green supply chain management, green procurement, and eco-design. While employing an updated period (April, 2020, to September, 2020), this analysis of environmental performance factors used the partial least squares structural equation model (PLS-SEM) method. Intriguingly, circular economy and green supply chain management positively impact environmental performance. According to the findings, certain policy frameworks are required to propel sustainable development in China. Sustainable businesses, of which circular enterprises are a subset, are becoming popular. While not inherently sustainable, circular business models do contribute to increased sustainability. However, several management repercussions may come with either the design of a sustainable firm or the transformation of incorporating circular practices into an established business. In this article, "managerial implications" refers to the challenges managers face and the adjustments made to a company's model and operations that must be communicated and implemented company-wide and throughout the supply chain. This may mean we need a change in the company's culture. A shift in mindset is required to accommodate the new norms in product use, disposal, and management. Even though not always labeled as such, a concern with the behavior toward circularity has been noted. Although this is starting to change, organizational culture in relation to the circular economy has not been extensively studied. The authors write: "The pursuit of a circular economy means a fundamental shift in society." Another difficulty is separating the value of the customer's and the company's experiences from their monetary value, which requires changing how both parties think about the world. This may need the modification of current facilities or the construction of new ones by affected businesses. It all adds to a shift in how the business and its clients act. When companies adopt circular economy practices, their culture can play a key role, whether they are expected or forced to engage in activities promoting circular behavior. It will also necessitate coordinated shifts in official policy and, by extension, the entire culture that underpins it. This research has important policy and practice consequences for the manufacturing sector. In emerging countries like Turkey, most producers focus on improving their economic status and avoiding economic hazards. This study, however, argued that firms cannot be sustainable in the long run if they prioritize short-term earnings over environmental considerations. The findings of this research highlight the significance of adopting a win–win approach in which financial and social goals are aligned. In addition, this research will help managers learn more about the costs and savings associated with implementing various green practices. It is not easy to put together the components of a GSCM plan. This is because some costs may rise (such as investment, operational, training, and procurement costs) while others may fall due to adopting environmentally friendly practices. Managers must consequently ensure an accurate cost–benefit analysis is performed. Based on our findings, firms can reap financial benefits from adopting environmentally friendly practices, particularly those related to green production and distribution packaging. Findings from this research suggest that manufacturing organizations should work with their suppliers and customers to implement GSCM practices in order to ensure environmental sustainability. Management in the manufacturing industry requires knowledge and expertise in both SCM and organizational management. Now more than ever, manufacturing companies' success depends on the efforts of their supply chain managers. This research again emphasizes the significance of adopting SCM practices and improving supply chain-wide operations for the benefit of final consumers. However, manufacturing sector managers are ultimately responsible for the success or failure of their respective companies. Managers will use this strategy if they discover that narrowing their attention to the supply chain and the final consumer boosts organizations' success. This study aims to determine whether adopting GSCM practices that emphasize communication and collaboration will lead to business success. Unfortunately, it appears that China has ignored environmentally responsible purchasing practices. A product's environmental impact can be mitigated throughout its useful life with the help of green purchasing practices. Chinese companies should work more closely with their vendors on environmental issues and encourage them to adopt greener business practices. By applying a life cycle assessment method, this research contributes to the existing body of research by shedding light on eco-design decision-making throughout the preliminary stages of the design process. When life cycle assessment is combined with design and process evaluation, a more complete picture will help implement and optimize eco-design decisions throughout the product's life cycle. Furthermore, the research has immediate implications for evaluating the product and process's environmental implications in tile production and 3D printing. As such, this study presents a methodical strategy for designers and decision-makers to implement and optimize eco-design choices at the conceptualization phase.

Limitations and future study

This research aimed to create and evaluate a comprehensive performance model for GSCM practices. We believe the primary value of this research rests not in dissecting and evaluating individual components of the model but in the model's holistic nature. Unfortunately, this method overburdens the sample. Given the disparity between the number of constructs and the sample size, we opted to test the boundaries of structural equation modeling to evaluate the model's overall fit to the data rather than using a more conventional path analysis approach. The number of elements on the measuring scale had to be cut from 57 to 38 so that the degrees of freedom would be larger than the number of estimated parameters. This is the first time the full theoretical model has been tested. Thus, it must be evaluated using data from multiple samples. The effects of customer cooperation and the effect of recouping investments on ecological and economic efficiency were compared to those reported by and found to be significantly different. The manufacturers in the USA (the sample) and China (the manufacturers in the study) could all account for the discrepancies. To find a solution to these discrepancies, more study is required. Furthermore, confirming the results using a larger sample size is crucial. The study also looks at how manufacturing companies are putting GSCM into action. The model needs to be updated to account for various business structures, distributors, retailers, manufacturers, etc., and records should be kept to understand how supply chain procedures affect the final price and the efficiency of these firms. We created a GSCM model that focuses on integrating and coordinating collaboration between industrial organizations and their nearest suppliers on environmentally sustainable projects. It is crucial to assess the model as a whole and see how accurately it represents reality, but it is also necessary to examine the specific associations depicted inside the model.

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Availability of data and materials The data can be available on request.

Declarations

Ethical approval and consent to participate We declare that we have no human participants, human data, or human tissues.

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Competing interest The authors declare no competing interests.

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