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Examining the Role of Global Supply Chains and Promoting Circular Economy Models

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Abstract: Global supply chains are an essential part of contemporary production and distribution, but they add to such environmental problems as degradation, resource depletion, and waste. The circular economy paradigm aims to separate economic growth from environmental damage through resource efficiency and closed-loop systems. This study investigates how global supply chain integration facilitates circular economy practices and enhances sustainability performance. Through a quantitative explanatory research design, the information was collected among supply chain and sustainability managers in the different sectors, such as automotive, electronics, textile, and consumer goods. The measurement model was confirmed by confirmatory factor analysis, and the relationships were tested by structural equation modeling, including mediation effects of the different sizes and industries. The results show that GSCI plays a big role in promoting CEP ($\beta = 0.61$, $p < 0.001$), which has a positive influence on SP ($\beta = 0.55$, $p < 0.001$). The SP is also directly affected by GSCI ($\beta = 0.28$, $p < 0.001$), and the mediation analysis reveals that the indirect effect is mediated by CEP (0.34, $p < 0.001$), which is higher than the direct effect and thus, it is partially mediated. The strength of results is ensured by model fit factors and reliability. Multigroup analysis reveals greater GSCI and CEP effects in the manufacturing group and greater CEP SP effects in larger companies. The paper concludes that integrated GSCs play a key role in enhancing practices of CE and sustainability. Industry and firm-specific strategies can maximize results. The future study must be based on longitudinal research.

Keywords: Circular Economy Practices; Global Supply Chain Integration; Sustainability Performance; Structural Equation Modeling; Supply Chain Management.

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I. Introduction

The global supply chains are now the workhorse of the modern economic systems, allowing the large-scale production and distribution of goods across national boundaries. Nevertheless, their mounting complexity and geographical distribution have added to the deterioration of the environment, resource depletion, carbon emissions, and social inequalities. The global supply chains with linear take-make-dispose models of production are especially unsustainable as far as climate change, scarcity of raw materials, and increasing amounts of waste are concerned. The circular economy (CE) paradigm has been developed in response, and it highlights the areas of resource efficiency, product life extension, recycling, and closed-loop systems (Mishra et al., 2022; De Sousa Jabbour et al., 2021). Incorporating circular economy concepts in global supply chains provides a way to decouple economic development and environmental degradation and increase resilience and future competitiveness (Bag & Rahman, 2021; Malhotra, 2024).

The main goal of the study is to explore how global supply chains can facilitate or inhibit the implementation of models of the circular economy (Elia et al., 2020). Particularly, the research is aimed at examining the impact of supply chain designs, governance, and cross-border coordination on the circular practices of sustainable sourcing, remanufacturing, reverse logistics, and material recovery (Awan et al., 2022; Chari et al., 2022). The study will also be used to evaluate how circular supply chains can enhance environmental performance, decrease the reliance on virgin resources, and increase systemic sustainability (Awan et al., 2021; Zhou et al., 2023).

Although the circular economy strategies are becoming increasingly discussed within the framework of scholarly research, the current literature tends to assume that supply chains and circular economy models are two distinct analytical fields (Del Giudice et al., 2021). Empirical findings about the role of global supply chain designs in facilitating or hindering circular transitions are still fragmented, especially in multi-tier and transnational supply chains between countries (Saccani et al., 2022; Khan et al., 2022). Besides, a paucity of research critically analyzes how institutional structures, digital technologies, and coordination of stakeholders can be applied to scale up circular practices in the world economy (Hazen et al., 2021). This is a limitation in both theoretical development and practice of the principles of a circular economy in multifaceted global supply systems (Agyabeng-Mensah et al., 2022; Singh, 2025; Khan et al., 2021; Dwivedi et al., 2023).

The hypothesis of the article is that More integration and transparency in global supply chains are anticipated to be a crucial factor in hastening the implementation of the circular economy by enhancing the exchange of information, traceability, and coordination at multiple levels of production and distribution. The companies that are engaged in the global coordinated supply chains have more chances to gain greater degrees of resource effectiveness and waste minimization since these systems provide the possibility of closed-loop resource circulation, remanufacturing, and reverse logistics. Moreover, good institutional backing and regulatory alignment of countries can increase the effectiveness of the implementation of the circular economy as it reduces policy fragmentation, promotes compliance, and facilitates the cross-border operation of a circular supply chain (Rehman Khan et al., 2022).

This study contributes to the sustainability and supply chain management literature by developing an integrated framework that links global supply chain dynamics with circular economy adoption. It offers empirical and conceptual evidence of the role of the structure of governance, technological enabling factors, and international facilitation of coordination processes in the creation of circle transitions. The study provides practical policy, multinational, and sustainability practitioner implications by linking the global supply chain analysis with the circular economy theory to help them operationalize the circular models at scale.

This paper is structured in the following way. Section 1 presents the background of the research, objectives, hypotheses, and contributions with an emphasis on the sustainability issues of global supply chains and the applicability of the circular economy models. Part 2 is a literature review on global supply chains, the practice of circular economy, digital technologies, and the mechanisms of governance, finding the main gaps in research. Section 3 outlines the research design, data collection, measurement of variables, and data analysis using structural equation modeling. Section 4 reports the empirical findings that comprise descriptive statistics, measurement, structural model evaluation, hypothesis test, mediation, and multigroup analysis. Section 5 talks about the findings and theoretical and managerial implications. Section 6 ends with some main conclusions, limitations, and future research directions (Lopes de Sousa Jabbour et al., 2023).

II. Literature Review

Nowadays, global supply chains (GSCs) are the core of modern-day production and consumption systems, but the classical linear approach has been one of the main factors of environmental degradation, overuse of resources, and generation of waste. To address these issues, the concept of the circular economy (CE) has come into being as an example of a new supply chain redesign with a focus on closed-loop designs (where supply chain value creation centers on reuse, recycling, remanufacturing, and sustainable value generation). There are multiple recent investigations that acknowledge that the success of the application of CE lies in the organization, management, and digitization of the global supply chains. An increasing amount of empirical evidence has been placed on the contribution of supply chain capabilities and flexibility towards realizing circular economy outcomes. The enhancement of sustainable supply chain flexibility by (Bag & Rahman, 2021; Sarkar et al., 2022) is proven by dynamic capabilities, which consequently enhance the performance aiming at the circle of the economy. On the same note, (Malhotra, 2023) concludes that CE practices enhance the supply chain capability and flexibility that results in better sustainable supply chain performance. These results indicate that the companies that are engaged in global supply chains have to acquire adaptive and learning based abilities to cope with the complexity of circular transitions. (Chari et al., 2022) also associate the dynamic capabilities with the resilience and Industry 4.0 technologies in circular manufacturing supply chains (Hofstetter et al., 2021).

The use of digital technologies and Industry 4.0 is commonly known as the key facilitators of the practices of the circular economy throughout the global value chains. (Awan et al., 2022) state that by using the Internet of Things, big data analytics, and automation, it is possible to improve the supply networks, which are situated worldwide, in terms of material tracking, reverse logistics, and resource efficiency (Bressanelli et al., 2021). Following this perception, (Awan et al., 2021) and (Khan et al., 2022) report that transparency, coordination, and traceability are the primary needs of scaling the models of the international scale of digitalizing the industries. Particularly, Blockchain technology has been demonstrated to enhance trust, information sharing, and organizational performance in circular supply chains (Khan et al., 2022). Another theme that dominates the literature is the structural redesign of supply chains. The authors emphasize that the use of reverse logistics and closed-loop supply chains is one of the central elements of the implementation of the circular economy (Mishra et al., 2023). As shown by (Saccani et al., 2022), the way to overcome the barrier to operations and institutions, particularly in the industries that are globally fragmented (textiles and fashion), is to employ orchestration of supply chain circles and multi-actor coordination.

Institutional pressures and governance mechanisms also play a significant role. (Agyabeng-Mensah et al., 2022) demonstrate that the external pressures, environmental commitment, and strategic alliance can improve circular supply chain capability and performance, whereas Singh, (2025) establishes that green supply chain strategies are of significant support to the development of a circular supply chain. Flexibility and adaptive governance are essential in keeping circular practices sustainable during global disruptions, as suggested by (Dwivedi et al., 2023). On the whole, despite the importance of global supply chains to facilitate the models of the circular economy, which is proven in the existing literature, the literature is still weak. Integrative studies on the joint development of the circular economy adoption and performance by global supply chains, digital technologies, governance, and resilience are few, which suggests a lucrative opportunity to conduct research on the topic.

III. Materials and Methods

Research Design

The research design is a quantitative, explanatory one that will be used in this study to investigate how global supply chains can facilitate circular economy models. An empirical methodology is applied in a cross-sectional analysis of the links between global supply chain integration, practices of the circular economy, and sustainability performance. A structural equation modeling (SEM) framework is used to test the conceptual relationships and enables the estimation of the measurement and structural relationships at the same time among the latent constructs. The structural model can be stated as:

$$\eta = B\eta + \Gamma\xi + \zeta \qquad (1)$$

In equation (1), ξ is a latent exogenous construct (Global Supply Chain Integration), η is the latent endogenous construct (Circular Economy Practices and Sustainability Performance), B and Γ are the matrices of structural coefficients, and ζ are the structural error terms. The design allows testing hypotheses and drawing causal conclusions based on the existing literature on supply chain management and the circular economy.

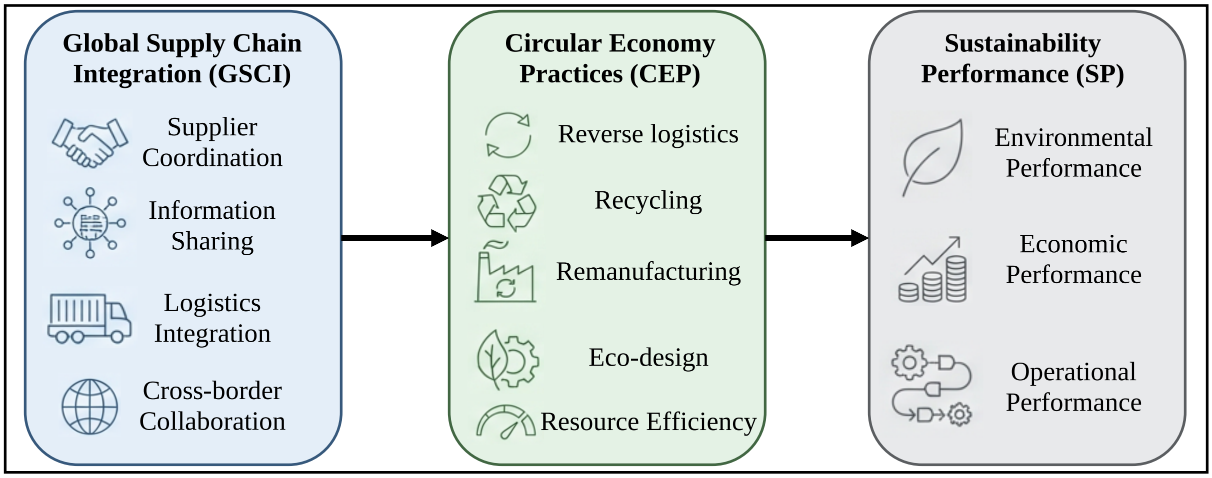

Figure 1: Conceptual Framework Linking Global Supply Chain Integration, Circular Economy Practices, and Sustainability Performance

In Figure 1, there are three major constructs of the study: Global Supply Chain Integration (GSCI), Circular Economy Practices (CEP), and Sustainability Performance (SP). GSCI is focusing on the coordination of suppliers, the sharing of information, integrating logistics, and cross-border collaboration. CEP emphasizes recent logistics, recycling, remanufacturing, eco-design, and resource efficiency. SP records the results of environmental, economic, and operational performance, showing the impact of integrated supply chain and circular practices on general sustainability.

Data Collection and Sample

The primary data were gathered using a structured survey that was conducted on the sustainability officers, operations executives, and the sustainability managers who are involved in global sourcing, manufacturing, or distribution operations. The companies to be considered in the research are in the industries where the global supply chain and the approaches of the circular economy are becoming more applicable, such as automotive, electronics, textiles, and consumer goods. A stratified random sampling approach was applied to achieve diversity in the size of firms, level of operations, and geographical locations. The final sample, after the elimination of responses that were not completed or inconsistent, included X firms that discussed the various regions, and it ensured that the data represented views of the world on the integration of supply chains and the practice of a circular economy.

Measurement of Variables

The measurement model describes the connections between the latent constructs and their indicators that were observed and was tested through confirmatory factor analysis (CFA). The measurement equations are defined as:

$$X = \Lambda_x \xi + \delta \tag{2}$$

$$Y = \Lambda_x \eta + \varepsilon \tag{3}$$

In equations (2) and (3), X and Y denote observed indicators, Λx and Λy represent factor loading matrices, δ and ε are measurement error terms, ξ corresponds to global supply chain integration, and η represents circular economy practices and sustainability performance.

Multi-item scales that quantified global supply chain integration were through integration of supplier, information, logistics, and cross-border integration. Indicators that were used to operationalize circular economy practices are connected to reverse logistics, recycling, remanufacturing, eco-design, and resource efficiency. The sustainability performance has been evaluated based on the three aspects: environmental, economic, and operational aspects, such as reduction of waste, cost effectiveness, utilization of resources, and flexibility in processes. All constructs were measured using five-point Likert scales adapted from validated instruments in prior research.

Data Analysis Techniques

Data analysis was conducted in two stages. First, descriptive statistics and Pearson's correlation analysis were employed to examine data distribution and preliminary associations among the constructs. In the second stage, SEM was applied to test the hypothesized relationships. The structural relationships were specified as:

$$CEP = \beta_1 GSCI + \zeta_1 \quad (4)$$

$$SP = \beta_2 CEP + \beta_3 GSCI + \zeta_2 \quad (5)$$

In equations (4) and (5), GSCI denotes global supply chain integration, CEP represents circular economy practices, SP refers to sustainability performance, β indicates standardized path coefficients, and ζ represents error terms. The standard indices such as CFI, TLI, RMSEA, and SRMR were used to evaluate model fit. Multigroup analysis was also done to investigate the differences by industry, region, and size of firms.

Reliability and Validity

Internal consistency was evaluated using Cronbach's alpha and composite reliability (CR), calculated as:

$$CR = \frac{(\sum \lambda_i)^2}{(\sum \lambda_i)^2 + \sum \theta_i} \quad (6)$$

Convergent validity was assessed using average variance extracted (AVE):

$$AVE = \frac{\sum \lambda_i^2}{\sum \lambda_i^2 + \sum \theta_i} \quad (7)$$

In equations (6) and (7), λ_i represents standardized factor loadings, and θ_i denotes error variances. Discriminant validity was confirmed using the Fornell–Larcker criterion. Procedural remedies like anonymity of respondents were implemented to overcome the common method bias, and Harman's single-factor test was administered.

Ethical Considerations

Ethics were followed strictly in the research process. The research was done on an academic level, and the involvement of the participants was voluntary. Informed consent was taken, and respondents were assured of their confidentiality and anonymity. The data collected did not include any personally identifiable information, ensuring that participants' privacy was protected. The integrity of the research was ensured by the adherence of all the research procedures to the institutional ethical standards and national data protection laws.

IV. Results

Descriptive Statistics and Correlation Analysis

The descriptive statistics and inter-construct correlation of global supply chain integration (GSCI), circular economy practices (CEP), and sustainability performance (SP) have been presented in Table 1. The average scores show that global supply chain integration processes and circular economy practices are moderately or highly adopted by sampled companies. Sustainability performance is characterized by a relatively high variance, which is the case of heterogeneity of environmental and operational performances in industries and regions.

The correlation coefficients of Pearson indicate significant positive correlations between all constructs, which are statistically significant. GSCI is positively related to CEP, which indicates that the greater the cross-border coordination, information sharing, and logistic integration, the more circular economy practices are adopted. CEP also verifies positively with SP, which means that companies that have adopted the concept of circularity are likely to have better sustainability results. There are no correlation coefficients that are higher than the recommended value of 0.85, and this aspect means that there is no issue of multicollinearity.

Table 1: Descriptive Statistics and Pearson Correlation Matrix of Global Supply Chain Integration, Circular Economy Practices, and Sustainability Performance

Variable	Mean	Std. Dev.	1	2	3
1. GSCI	3.72	0.64	1.00		
2. CEP	3.58	0.69	0.62**	1.00	
3. SP	3.81	0.71	0.54**	0.68**	1.00

Note: $p < 0.01$

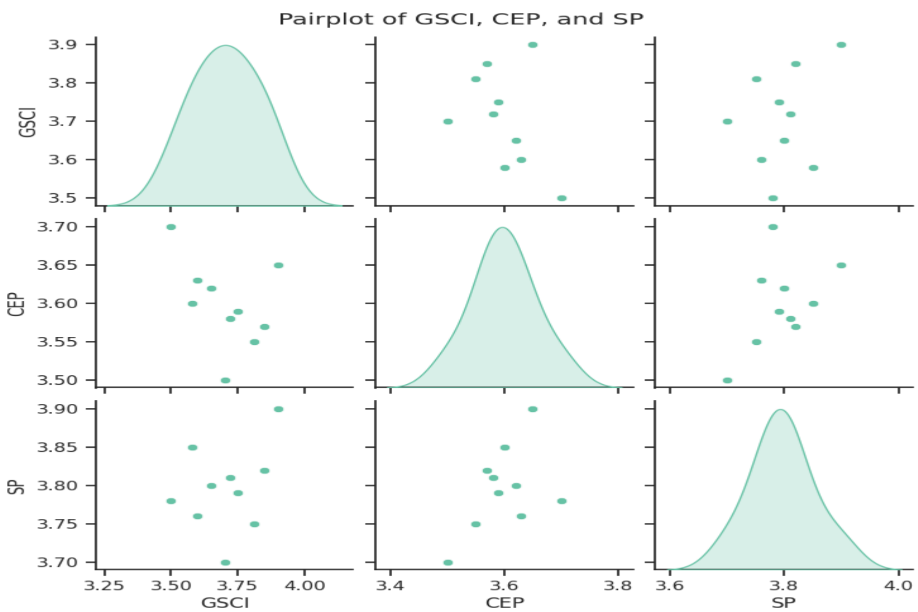

Figure 2: Pairwise Relationships Between Global Supply Chain Integration (GSCI), Circular Economy Practices (CEP), and Sustainability Performance (SP)

Figure 2 visualizes the relationships among GSCI, CEP, and SP. The off-diagonal scatter plots indicate the pairwise relationship between the variables, whereas the diagonal scatter plots demonstrate the distribution of each variable using a series of kernel density estimates. The positive relationships between GSCI and CEP, GSCI and SP, and CEP and SP indicated by the plot are that when the global supply chains are more integrated, the global supply chain will be more circular in practice and perform better.

Measurement Model Assessment

The measurement model was evaluated using confirmatory factor analysis (CFA). All the indicators observed loaded in a significant manner on their corresponding latent constructs, with standardized factor loadings being above the recommended standard factor of 0.70 in the majority of the cases, which supports indicator reliability.

Composite reliability (CR) and average variance extracted (AVE) values for all constructs exceeded the minimum criteria of 0.70 and 0.50, respectively, confirming internal consistency and convergent validity. Discriminant validity was established using the Fornell–Larcker criterion, as the square root of AVE for each construct was greater than its correlations with other constructs.

Table 2: Reliability and Convergent Validity of the Measurement Model

Construct	CR	AVE	√AVE
GSCI	0.89	0.62	0.79
CEP	0.91	0.65	0.81
SP	0.93	0.68	0.82

Table 2 reports composite reliability (CR), average variance extracted (AVE), and the square root of AVE (√AVE) for each latent construct, demonstrating satisfactory internal consistency and convergent validity in the measurement model. Adequacy of the measurement model gives a sound basis for the test of the structural relationships.

Structural Model Fit

The structural equation model showed that there was an adequate overall fit to the data. All the comparative fit index (CFI) and Tucker-Lewis's index (TLI) were above the suggested value of 0.90, and root mean square error of approximation (RMSEA) and standardized root mean square residual (SRMR) were below 0.08. Such results demonstrate that the proposed model can be used to describe the observed covariance pattern.

Table 3: Structural Equation Model Fit Indices

Fit Index	Value	Recommended Threshold
CFI	0.94	≥ 0.90
TLI	0.93	≥ 0.90
RMSEA	0.056	≤ 0.08
SRMR	0.047	≤ 0.08

In Table 3, the goodness-of-fit statistics of the structural equation model were displayed with an indication that the proposed model has an acceptable to good fit with the observed data according to the generally accepted threshold criteria.

Hypothesis Testing and Structural Path Estimates

The hypothesized relationships are supported with the help of the estimated structural paths. The impact of global supply chains integration on circular economy practices is pronounced and positive, which means that the better industrial companies are integrated in their supply chain, the more they will use recycling, remanufacturing, and eco-design as their strategies. Circular economy practices, in their turn, have a solid positive impact on the sustainability performance, which implies that circular initiatives have a direct impact on better environmental and operational results.

Along with the indirect route, global supply chain integration also has a pronounced direct impact on the sustainability performance, which means that the supply chain integrations increase sustainability performance both directly and indirectly due to the use of the circular economy.

The structural relationships are expressed by the already explained equations (4) and (5) :

$$CEP = \beta_1 GSCI + \zeta_1 \tag{4}$$

$$SP = \beta_2 CEP + \beta_3 GSCI + \zeta_2 \tag{5}$$

Table 4: Structural Path Coefficients and Hypothesis Testing Results

Path	Standardized Coefficient (β)	t-value	p-value
GSCI → CEP	0.61	9.84	<0.001
CEP → SP	0.55	8.97	<0.001
GSCI → SP	0.28	4.12	<0.001

Table 4 reports the standardized path coefficients, t-values, and significance levels from the structural equation model, demonstrating the direct effects of global supply chain integration and circular economy practices on sustainability performance. These findings indicate partial mediation, where circular economy practices transmit a substantial portion of the effect of global supply chain integration on sustainability performance.

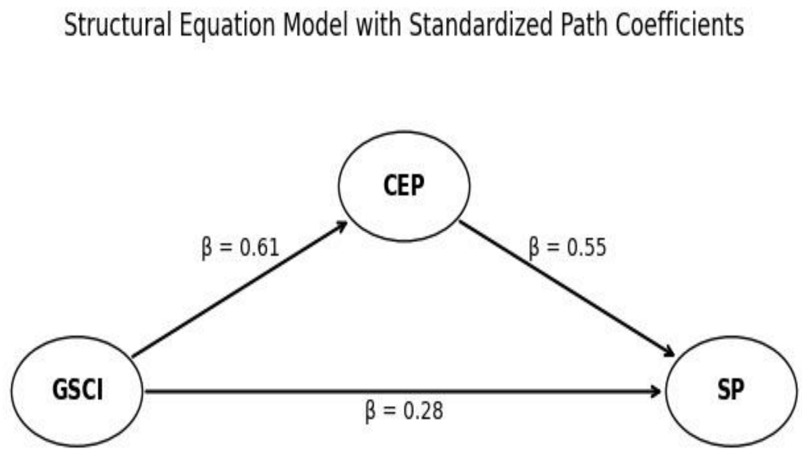

Figure 3: Structural Equation Model Path Diagram with Standardized Coefficients

Figure 3 demonstrates the hypothesized relationships between global supply chain integration (GSCI), circular economy practices (CEP), and sustainability performance (SP), and the standardized coefficients of the path are annotated on each of the major paths. This figure brings to light the direct and indirect impacts, which is a confirmation of the mediating role of CEP in relaying the influence of GSCI on sustainability outcomes.

Mediation Effects of Circular Economy Practices

In order to understand mediation further, the indirect impact of global supply chain integration on sustainability performance through the practice of the circular economy was investigated. The mediating effect was found to be statistically significant, which proved the role of CEP in the relationship between GSCI and SP. This outcome highlights the strategic significance of the concept of circular practices as one of the ways in which globally integrated supply chains turn into sustainability benefits.

Table 5: Direct, Indirect, and Total Effects of Global Supply Chain Integration on Sustainability Performance

Effect Type	**Coefficient**	**p-value**
Direct (GSCI → SP)	0.28	<0.001
Indirect (GSCI → CEP → SP)	0.34	<0.001
Total Effect	0.62	<0.001

Table 5 is a synthesis of the results of the mediation analysis, which details the direct, indirect, and overall impact of the integration of the global supply chain on sustainability performance, and the mediating variable of the global supply chain integration was the circular economy practices.

Multigroup Analysis Results

Multigroup SEM analysis shows that the structural relations are strong with respect to both industries and firm sizes, although the GSCI to CEP path is much stronger in manufacturing-intensive industries like automotive and electronics. In the same manner, the magnitude of the relationship between CEP and SP is more significant in the largest companies than in small and medium-sized businesses, indicating the scale effects of adopting a circular economy strategy.

V. Discussion

The paper offers solid empirical data on how the global supply chain integration contributes to the development of circular economy practices and improves the sustainability performance. The results of the descriptive statistics and correlation in Table 1 suggest that the sample firms have moderate to high degrees of supply chain integration and circular economy adoption, and sustainability performance has a relatively higher dispersion. The statistical significance and high correlation between GSCI, CEP, and SP ($r = 0.62$ and $r = 0.68$, $p < 0.01$) are the first indications of the fact that the hypothesized relationships are supported, and integrated supply chains are strongly correlated with the outcomes of circularity and sustainability. The reliability and validity of the constructs are confirmed in the measurement model assessment. According to Table 2, the composite reliability values are between 0.89 and 0.93, and the AVE values are over the AVE=0.50 mark, which means that there is good internal consistency and convergent validity. The validity in the differentiation of the constructs is also enhanced by the discriminant validity that is formed as a result of the Fornell-Larcker criterion. These results ensure that subsequent structural findings are not affected by measurement deficiencies.

The structural model demonstrates a satisfactory fit to the data, with all fit indices meeting recommended thresholds (CFI = 0.94, TLI = 0.93, RMSEA = 0.056, SRMR = 0.047; Table 3). These results are further strengthened by Figure 3, the structural equation model path diagram with standardized coefficients, which graphically depicts the magnitude and direction of the postulated relationships. The significant positive association between GSCI and CEP ($\beta = 0.61$, $p < 0.001$; Table 4) demonstrates the essential role of cross-border coordination, the exchange of information, and logistics integration in facilitating such a phenomenon, which is a circular practice, like recycling, remanufacturing, and eco-design. This fact can be traced back to the theory of supply chain and the theory of the circular economy, which dwell on the notion of integration as a state of resource circularity. CEP also has a significant impact on sustainability performance ($\beta = 0.55$, $p < 0.001$), which proves that the notion of circular initiatives is directly correlated with the improvement of environmental and operational results. Moreover, the subject of GSCI to SP direct path ($\beta = 0.28$, $p < 0.001$) shows a considerable direct impact on sustainability, not only based on circular activities but also in terms of efficiency and coordination advantages. Part of Table 5 indicates that the indirect effect (0.34) is greater than the direct effect, which indicates partial mediation and a significant role of CEP as a transmission channel in the middle.

VI. Conclusion

This paper illustrates that global supply chain integration (GSCI) is a major driver of the circular economy practice (CEP) and improved sustainability performance (SP). According to the structural equation modeling results, the relationship between GSCI and CEP is strong and positive ($\beta = 0.61$, $p < 0.001$), which indicates that successful cross-border coordination and logistics facilitate the implementation of circular strategies, such as recycling and eco-design. Besides, CEP influences SP to a considerable degree ($\beta = 0.55$, $p < 0.001$), which once again highlights that circular projects are associated with improved environmental and operational performance. Also, GSCI positively influences SP ($\beta = 0.28$, $p < 0.001$), which increases sustainability by increasing efficiency and coordination. The result of mediation analysis indicates that the indirect influence of GSCI on SP through CEP (0.34, $p < 0.001$) is more significant than that of the direct one, which could be regarded as the partial mediation and the importance of CEP as an essential transmission process. The results are justified by the good model fit measures (CFI = 0.94, TLI = 0.93, RMSEA = 0.056, SRMR = 0.047), as well as the good reliability and validity levels. The implications suggest that to enhance sustainability performance, companies should focus on the global supply chain integration to apply circular economy practices successfully. The nature of industry and the size of the firms influencing these relationships reveal the need to adopt the most appropriate strategies to use in various situations, particularly with small and medium-sized enterprises. It is advised in future studies to employ longitudinal studies, integrate objective sustainability measures, and examine the mediating effects of digital technologies, policy systems, and institutional environments in support of a better comprehension of the circular and sustainable supply chains.

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