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Financing Circularity for Sustainable Indian MSMEs: A PLS-SEM–ANN Approach

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Abstract

This study empirically investigates the impact of circular economy practices on economic and environmental sustainability performance, examining the mediating effect of green finance through the lens of ecological modernization theory. A structured questionnaire was employed to gather data from two hundred MSMEs. This study employed a sequential structured equation modelling -artificial neural network (SEM-ANN) model to understand the complex relationships and relative importance of the predictors in influencing the endogenous construct. The findings revealed that CEP and GF have a significant positive influence on Economic sustainability performance (ECSP) and Environmental sustainability performance (ENSP). In addition to that, the findings also confirmed the partial complementary mediating impact of GF in enhancing the ECSP and ENSP of the MSMEs sector. Addressing the limited primary data-supported investigations, the current study fills the existing research gaps in the CEP, GF, and sustainability literature and delivers valuable insights for academic theory and managerial applications.

Keywords

Circular economy practices (CEP), Green finance (GF), Economic sustainability performance (ECSP) and Environmental sustainability performance (ENSP), Ecological modernization theory (EMT).

1.Introduction

Contemporary climate change, rapid industrial expansion, heavy dependence on resources and environmental pressure pose a significant transformation globally, particularly in developing countries, which experience greater risk exposure (Al-Hakimi et al., 2022; Mohammed et al., 2025). Indian MSMEs, which are the primary driver of India's economic growth engine, contributing 30% of GDP, 45% of its exports, second largest employer, contributing one-fourth of its total industrial emissions (Government of India, Ministry of MSME, 2025), making it a significant contributor to environmental degradation (Gani et al., 2022).

Due to the above adverse environmental impact, firms have been compelled to incorporate sustainable business practices as a core segment of their strategies (Onu & Mbohwa, 2019; Yadav et al., 2018). CEP is a modern, regenerative, and sustainable practice over the traditional linear model, which emphasizes "procure, manufacture, discard". CEP also fosters sustainable development, generate employment opportunities, and minimizes adverse environmental impact (Ellen MacArthur Foundation, 2015). GF refers to funds specifically allocated to activities aimed at enhancing ENSP (Almaqtari et al., 2025). Despite the significant research on CEP and GF enhancing the overall sustainability of firms, there is a paucity of research that focuses on MSMEs sector with special reference to emerging economies such as India, as most of the studies have been taken in the context of developed economies. The present research advances a substantial opportunity to explore how CEP and GF stimulate the ECSP and ENSP by answering the following research questions/objectives.

1.1. Objectives

RQ1: Does CEP stimulate ECSP and ENSP of the Indian MSMEs sector?
RQ2: Do GF mediates the CEP effect on ECSP and ENSP?
RQ3: To what extent do the CEP and GF improve ECSP and ENSP?
The present research contributes fourfold significant contributions to the available scholarly work. Firstly, the research demonstrates empirical support concerning the linkage between CEP, GF and sustain-able performance within Indian MSMEs segment, which remains greatly essential yet comparatively under-researched. Secondly, the research utilizes EMT to justify the harmony among economic, environmental outcomes via eco-friendly strategies. Thirdly, a sequential PLS-SEM and ANN method is employed, linking linear and non-linear statistical method to strengthen both explanatory and predictive capability. Finally, the results present important managerial and policy implications for improving circularity via reinforced organizational facilitation and relevant financial instruments.

2. Literature Review

This study utilizes the "ecological modernization theory (EMT)" as an appropriate theoretical lens to critically explore the complex interplay of CEP, GF, ECSP, and ENSP.EMT posits that the adverse environmental impact of economic growth can be offset through resource optimization using technological innovations (Murphy & Gouldson, 2000).The EMT overrides the customary perception of zero-sum economic framing by the modern framework, which emphasizes integration of industrial advancement with environmental protection (Anderson et al., 2008). Guided by the EMT, the study advances the CEP and GF as a strong theoretical foundation to de-align economic growth from ecological attrition.

The circular economy denotes a transition from the customary linear model of "buy, manufacture, discard" to a closed-loop, regenerative, and sustainable model (Ellen MacArthur Foundation,2015).CEP aids firms in enhancing their economic benefits through reduction of productive cost, enhancement of revenue proceeds, and strengthening brand loyalty, minimizing energy overhead through re-using and re-cycling (Todeschini et al., 2017).CEP augments the ENSP of the firms by minimizing the utilisation of virgin materials, resource recovery, and closed-loop resource circulation (Jabbour et al., 2019;Bai et al., 2020). Bandeira et al. (2025) proposed the Circular Economy Maturity Framework (CEMAF) to facilitate SMEs assess and enhance their CEP. It strengthens the firms in improving resource productivity, lowering ecological impact, and implementing eco-friendly operational distribution activities throughout supply chain network.

GF implies monetary activities and investments specifically assigned to augment ENSP (Almaqtari et al., 2025). Accessibility of GF to firms will increase economic benefits through reallocating their resources in reducing energy and material consumption, lowering the cost of waste management, and input resources consumption (Siddik, Rahman, et al., 2023).GF market mechanism aids in restoration of the environment from degradation by advancing carbon trading and through issuance of green credit instruments such as eco-friendly investment funds, weather-indexed hedging funds, environment outcome-linked bonds, environment-indexed derivative options, etc. (Y. Wang & Zhi, 2016**).** GF demonstrate a substantial influence towards strengthening the sustainability performance through directing financial resources towards eco-friendly initiatives, that supports mitigate both eco-logical risks as well as financial investment risk (Xu et al., 2020) (p. 1).

Gf Acts as a Significant Mediator Between CEP And Long Run ECSP By easing the capital bottlenecks and internalizing environmental value (Dangelico, 2010; Chen & Wang, 2022). GF advances Financial and Working capital Support to CEP Such as green energy, eco-friendly sustainable industrial practices, and waste re-cycling aimed at promoting ENSP (Y. Wang & Zhi, 2016; J. Chen et Al., 2022).

Contemporary literature underscores the emerging importance of sustainability initiatives among MSMSEs, notably in developing countries where resources scarcity and eco-logical challenges are more evident. The prior studies demonstrate that the implementation of CEP increases resources efficiency, waste minimization and strengthens sustained environmental outcomes of the MSMEs (Chakraborty et al., 2025; Gallego-Schmid et al., 2025). Existing literature indicates that GF functions as a major enabler in empowering MSMEs to support investment in eco-friendly innovation, low-emission technologies, and green business models, thereby enhancing sustainability disclosure and eco-friendly performance outcome (Appiah-Kubi et al., 2024).

Although extensive literature on CEP, GF, their economic and environmental impacts remain under-researched in Indian MSMEs, a sector with high growth and emissions, which this study seeks to address with the theoretical lens of EMT, the following hypotheses have been developed.
H1: CEP has a substantial impact on ECSP.
H2: CEP has a significant impact ON ENSP.
H3: GF significantly enhances the ECSP.
H4: GF has a substantial effect on ENSP.
H5:GF mediates the association between CEP and ECSP.
H6: GF mediates the relationship between CEP and ENSP.

3. Research methods

3.1 Study context

The Indian MSMEs sector is contributing around 30% of the overall GDP, 45% of the total exports, and second largest employer, while it is also contributing one-fourth of the total industrial emissions (Small Industries Development Bank of India [SIDBI], 2023), making it salient research context that couples the CEP and GF to concurrently enhance the ECSP and ENSP**.**

3.2 Data and Sample

A structured questionnaire in google-forms was used to gather data from two hundred MSMEs. The questionnaire is divided into two parts. Part A consists of 8 questions on demographics, while part-B consists of 15 questions on CEP, GF, ECSP, and ENSP, with each indicator anchored on a five-point Likert scale. A non-probability judgemental sampling was utilized to select the respondents.

3.3 Statistical analysis techniques

A sequential Structured Equation Modelling- Artificial Neural Network was employed to analyse the data. A PLS-SEM was employed due to the following benefits. First, a small sample size faces fewer identification problems. Second, less sensitive to normality constraints. Third, the potential to handle complex relationships within a model (Hair et al., 2022). The G*power with 2 predictors, power level of 0.80 (Siddik et al., 2023), an alpha value of 0.05 and effect size of 0.05 reveals the minimum sample size 159. The sample size employed for this study is 200, which is above the minimum sample size requirement.

4.Results

The research employed dual-staged SEM-ANN approach, where PLS-SEM was initially executed to assess the associations among constructs, succeeded by ANN to assess the predictive relevance of the independent variable on dependent variable. Ahead of analysis, initial multivariate assessment such as ANOVA for linearity (depicted in Table.1), kolmogorow-Smirnow for normality were executed to establish dataset acceptability (Urbach & Ahlemann, 2010; Lee et al., 2020). The findings demonstrated non-normal distribution and the existence of the linear associations (Depicted in Table.1). ANN is robust in predicting linkages between constructs and it can be employed when the associations are linear as it is effective in in determining both simple and non-linear functional relationships and typically offers enhanced predictive accuracy (Zhou et al., 2023).This research utilized the two-staged PLS-SEM-ANN approach to identify complicated associations and strengthen the model's predictive power (Hew et al., 2017;Hidayat-ur-Rehman et al., 2022).

4.1 Common method Bias (CMB)

Before analysing the measurement model, the data should be verified for CMB using the full collinearity test (Kock & Lynn, 2012; Kock, 2015; Podsakoff et al., 2024). The inner variance inflation factor (VIF) values for all indicators are less than 3.3, indicates absence of CMB (Kock, 2015).

4.2 Assessment of Measurement Model

Table.2 depict the results of the measurement model. The outer loadings of all the items are above 0.708 (Min. 0.81; Max. 0.921), indicates indicators reliability (Hair et al., 2019). The reliability and internal consistency of the constructs were confirmed as the Cronbach's alpha (CA) and composite reliability (CR) values are within the recommended range of 0.70 and 0.95 (Hair et al., 2019; Hair et al., 2022). The convergent validity of the model is established as the AVE (average variance extracted) of all constructs is above 0.5 (ranges from 0.621 to 0.681). The discriminant validity (HTMT) of all constructs is less than 0.85, confirming discriminant validity (Henseler et al., 2015) as depicted in Table.3.

Table.1 ANOVA Summary

ANOVA Summary		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Linear/Non-linear**
ECSP * GF	Deviation-from-Linearity	45.198	52	0.869	1.213	0.186	Yes
ECSP * CEP	Deviation-from-Linearity	44.231	73	0.606	0.909	0.668	Yes
ENSP * GF	Deviation-from-Linearity	38.450	52	0.739	1.042	0.414	Yes
ENSP * CEP	Deviation-from-Linearity	63.894	73	0.875	1.265	0.124	Yes

Table.2 Reliability and Validity Results

Constructs	Outer loadings	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Circular Economy Prcatice		0.881	0.884	0.918	0.736
CEP1	0.845				
CEP2	0.874				
CEP3	0.863				
CEP4	0.85				
Economic Sustainability performance		0.884	0.885	0.92	0.741
ECSP1	0.844				
ECSP2	0.87				
ECSP3	0.871				
ECSP4	0.859				
Environmental Sustainability Performance		0.836	0.837	0.89	0.67
ENSP2	0.821				
ENSP3	0.814				
ENSP4	0.81				
ENSP5	0.83				
Green Finance		0.881	0.885	0.927	0.808
GF1	0.891				
GF2	0.921				
GF4	0.884				

Table.3 HTMT results for Discriminant Validity

	CEP	ECSP	ENSP	GF
CEP				
ECSP	0.681			
ENSP	0.572	0.629		
GF	0.397	0.566	0.627	

Table.4 Inner Model-VIF results

	CEP	**ECSP**	**ENSP**	**GF**
CEP		1.147	1.147	1
ECSP				
ENSP				
GF		1.147	1.147	

Table.5 effect size f^2

	CEP	**ECSP**	**ENSP**	**GF**
CEP		0.376	0.177	0.147
ECSP				
ENSP				
GF		0.172	0.246	

Table.6 Explanatory power and model fit

	R-square	**R-square adjusted**
ECSP	0.456	0.45
ENSP	0.397	0.391
GF	0.128	0.124
SRMR	0.07	

4.3 Assessment of structural model

In the structural model, the inner VIF values of all constructs are less than 3, which phrase-out the problem of multi-collinearity as depicted in the Table.4 (Hair et al., 2019; Hair et al., 2022). The explanatory power of the model is explained by the Coefficient of determination (R^2); the R^2 values of the constructs are more than 0.1, confirms the explanatory power of the dependent variable, demonstrating the capability for prediction as shown in the Table.6 (Falk & Miller, 1992). The f^2 explains the effect of the dependent variable on the independent variable. CEP has a large effect on ECSP and a moderate effect on ENSP, while GF has a moderate effect on ECSP and ENSP, as depicted in

Table.5. Standardized root mean square residual values (SRMR) are the suggested test for model fit; the value of SRMR is 0.07, which is below 0.1, confirming the adequacy of the model fit as depicted in Table.6 (Kock, 2020).

Hypothesis testing was performed through bootstrapping using 10,000 sub-samples to validate the direct as well as indirect impact of the structural model as shown in Table.7 and Figure.1. The analysis exhibits the significant and positive effect of CEP on ECSP (β = 0.485, t = 6.278, p = 0.000) and ENSP (β = 0.35, t = 5.039, p = 0.000), H1 and H2 were confirmed. The GF has a significant positive influence on ECSP (β = 0.327, t = 4.792, p = 0.000) and ENSP (β = 0.413, t = 6.67, p = 0.000), H3 and H4 were confirmed. Furthermore, the GF also acts as a partial complementary mediator in the interplay between CEP and ECSP, as well as between CEP and ENSP., Hence, H5 and H6 were supported.

Table.7 Hypotheses testing results

Direct effect	**Coefficients**	**t-statistics**	**Remarks**
H1: CEP-> ECSP	0.485(0.000)	6.278	H1 supported
H2: CEP-> ENSP	0.350(0.000)	5.039	H2 supported
H3: GF -> ECSP	0.327 (0.000)	4.792	H3 supported
H4: GF -> ENSP	0.413 (0.000)	6.67	H4 supported
Indirect Effect			
H5: CEP -> GF -> ECSP	0.117(0.000)	3.913	H5 supported
H6: CEP -> GF -> ENSP	0.148 (0.000)	4.481	H6 supported

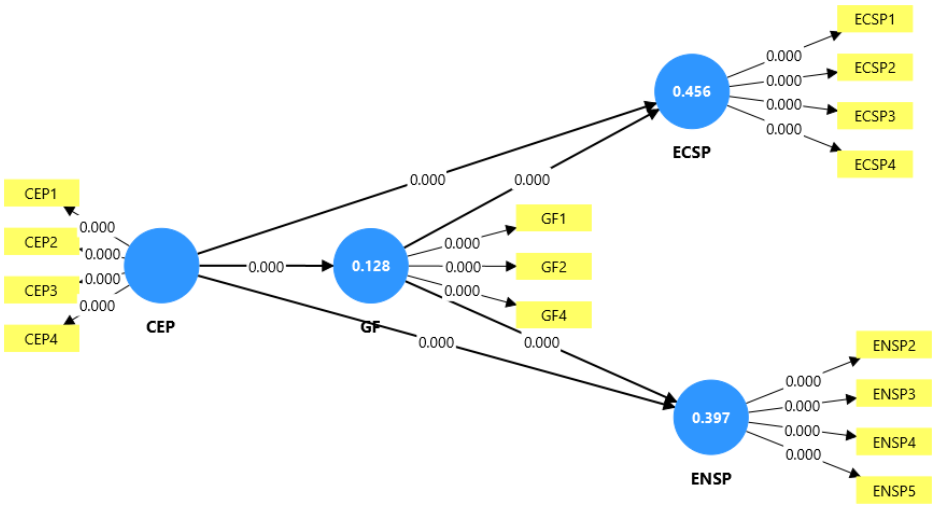

Figure 1. Structural Model

4.4 Second stage: Artificial Neural Network

Figure. 1 portrays the structural model demonstrating the linkages among CEP, GF, ENSP and ECSP of MSMEs. The primary reason for incorporating ANN is to examine the linear and non-linear relationship between exogeneous and endogenous variable, without being sensitive to normality constraint (Leong et al., 2013). The predictive performance of the ANN model has been rigorously analysed through the processing of the RMSE scores derived from both testing and training throughout repeated iterations**.** The problem of over-fitting of data has been avoided by utilizing ten-fold cross validation, dividing 90% of the data for training and remaining 10% of the data for testing purpose (Ooi & Tan, 2016). Two ANN models have been created. Model 1, in which ECSP is taken as output, CEP and GF are taken as input, while in model.2, ENSP is taken as output, CEP and GF are taken. Root mean square error (RMSE) mean values

of ECSP for training and testing data were 0.557 and 0.452, while for ENSP, the values are 0.560 and 0.498 as depicted in the Table.8. The analysis of both models indicates a reliable estimate (Siddik et al., 2023).

After analysing the predictive power of the ANN model, a sensitivity analysis has been undertaken. This present study concentrated on analyzing the predictive capabilities of the input nodes, providing an insight of the relative importance of the exogeneous constructs and ascertaining their influence in determining their ENSP and ECSP within Indian MSMEs (Leong et al., 2019) as depicted in Table.9. For ECSP, CEP (100%) is the significant predictor, followed by GF (82%), whereas for ENSP, GF (100%) is the significant predictor, followed by CEP (97%).

Table 8. RMSE Values of ANN

	Model.1		**Model.2**	
	ECSP		**ENSP**	
Network	**Training**	**Testing**	**Training**	**Testing**
1	0.588	0.361	0.549	0.497
2	0.622	0.510	0.572	0.376
3	0.556	0.388	0.533	0.625
4	0.525	0.557	0.551	0.475
5	0.572	0.348	0.561	0.523
6	0.534	0.475	0.556	0.472
7	0.536	0.415	0.564	0.531
8	0.542	0.427	0.567	0.386
9	0.550	0.489	0.575	0.486
10	0.545	0.551	0.570	0.611
Mean	**0.557**	**0.452**	**0.560**	**0.498**
S.D	**0.029**	**0.076**	**0.013**	**0.081**

Table. 9 Sensitivity Analysis

5	**ECSP**		**ENSP**	
Neural Network	**CEP**	**GF**	**CEP**	**GF**
NN (i)	0.8	1.0	0.8	1.0
NN (ii)	0.8	1.0	0.6	1.0
NN (ii)	1.0	0.7	0.9	1.0
NN (iv)	1.0	0.7	1.0	0.9
NN (v)	0.7	1.0	1.0	0.9
NN (vi)	1.0	0.6	0.9	1.0
NN (vii)	1.0	0.6	1.0	0.8
NN (viii)	1.0	0.5	0.9	1.0
NN (ix)	0.9	1.0	1.0	0.8
NN (x)	1.0	0.4	0.9	1.0
Average importance	0.9	0.8	0.9	0.9
Normalised importance	100%	82%	97%	100%

5. Discussions and Validation

RQ1: Does CEP stimulate ECSP and ENSP of the Indian MSMEs sector?

CEP has a positive substantial influence on the ECSP, which is consistent with the existing literature that reveals that CEP fosters ECSP through its capability of materials savings, resource optimization, unintended external impacts, energy efficiency and waste reduction (Jabbour et al., 2019; Ellen MacArthur Foundation,2015) (H1 was supported). CEP also enhances the ENSP of MSMEs, which is supported by existing literature that underscores the importance of CEP in stimulating the ENSP through sustainable techniques, reduced energy losses, and minimizing carbon emissions (Jabbour et al., 2019; Bai et al., 2020).

RQ2: Does GF mediate the CEP effect on ECSP and ENSP?

GF acts as a financial bridge (partial complementary mediator) in the relationship between GF and ECSP as well as between GF and ENSP, which is in line with existing literature that emphasizes that GF channelizes the finance towards sustainable and monetary rewarding practices, which promotes ECSP and ENSP through cost and resource efficiency, a distinct innovative process, and channelizing the finance towards green initiatives (Yuan, 2025; Yang et al., 2021; Hussain et al., 2024).

RQ3: To what extent do the CEP and GF improve ECSP and ENSP?

ANN has been performed to identify the relative importance of the CEP and GF aimed at promoting ECSP and ENSP. In promoting the ECSP, among 2 constructs, the CEP (100%) is the significant predictor, followed by GF (82%). In fostering ENSP, the GF (100%) is the significant predictor, followed by CEP (97%).

6. Theoretical implications

This study makes a substantial contribution to existing literature by exploring the complex relationship among CEP, GF, ECSP, and ENSP, as most studies are limited to large corporations and developed nations, and limited scholarly attention has been paid to MSMEs with special context to emerging economies such as India. ANN further complements the SEM results by revealing that CEP is a significant predictor in determining the ECSP, while GF is a significant predictor in determining the ENSP. The findings reveal that a firm can increase its overall sustainability by adopting the CEP through GF as guided by EMT, which advances eco-logical degradation by economic development can be mitigated by the technological innovations (Murphy & Gouldson, 2000).

7. Managerial and policy Implication

The MSMEs managers have to leverage GF to enhance the overall sustainability performance of the firms, as 65%of MSMEs firms affirmed that availability of funds is the major hindrance in implementing the sustainability initiatives (Small Industries Development Bank of India [SIDBI] & Dun & Bradstreet, 2025).In India, CEP adoption is limited in spite of significant awareness (59% awareness) about government GF schemes such as MSME-GIFT, supporting CEP, therefore MSME managers have to collaborate with Government run financial institutions and lending institutions to enhance accessibility, affordability, and minimize cost and disbursement delays. In order to enhance the GF, the policy makers have to create a single point of clearance and end-to-end mechanism to expedite the flow of finance to MSMEs to promote CEP. MSME managers are encouraged to incorporate the CEP within core organizational strategies rather than considering sustain-ability simply as regulatory compliance and obligation. Measures such as eco-design, green-sourcing, reverse logistics and cradle to grave management strengthen organizational efficiency and facilitate enduring sustain-ability outcomes. Policy makers can also frame laws and regulations such as carbon tax, pollution trading system as well as promotion and development of carbon credit market. Furthermore, policy makers can introduce green subsidies, tax exemptions, GF credit guarantee scheme to implement CEP at the floor level of MSMEs firms.

8. Limitations and Future Scope of the Study

The study has certain limitations. First, Indian MSMEs are heterogeneous in nature, as micro, small and medium enterprises differ significantly in terms of investment capacity, revenue size, resource availability and technological competence as classified by the ministry of MSME. Second, the reliance on cross-sectional data constrains the capability to establish strong causal interpretation among study constructs. thereby, future research may employ longitudinal research design to attain more stronger causal explanation. third, this study incorporates only one mediator, but in practice, there can be many mediators, such organizational culture, leadership style etc., which can influence the relationship between CEP and the sustainability performance of the firms.

9. Conclusion

In order to sustain in the ever-evolving, dynamic, and uncertain environment, a firm has to align the sustainable practice into their core strategy as the findings suggests that CEP and GF significantly enhance the ECSP and ENSP of the MSMEs, which is the backbone of the Indian economy. The present study extends the academic literature by offering empirical evidence to the scholarly work through for the association between CEP, GF and sustainable performance within Indian MSMEs in the context of the theoretical basis related to EMT. The adoption of sequential PLS-SEM and ANN methodology strengthens the reliability of the outcomes through recognizing both linear as well as non-linear linkages. The results additionally provide practical insights for the benefit of managers as well as policy-makers through emphasizing the significance of reinforcing financial and institutional facilitation mechanisms in order promote the uptake of CEP as well as strengthen the sustainability outcomes.

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