International Journal of Management and Sustainability
2026 Vol. 15, No. 3, pp. 532-546
ISSN(e): 2306-0662
ISSN(p): 2306-9856
DOI: 10.18488/11.v15i3.5113

Determinants of circular economy performance: Empirical evidence from agrifood small and medium-sized enterprises in Vietnam

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Article History
Received: 19 February 2026
Revised: 15 June 2026
Accepted: 31 July 2026
Published: 21 August 2026

Keywords
Agrifood sector
Circular economy index
Small and medium-sized enterprises
Sustainable development
Vietnam.

ABSTRACT

The circular economy has become crucial, especially for developing countries whose sustainable development process has been confronted with resource scarcity, growing environmental pressures, and rapid urbanization. This study develops a circular economy index (CEI) to evaluate circular economy (CE) performance at the firm level and investigates its determinants for small and medium-sized enterprises (SMEs) in Vietnam's agrifood sector. The study employs a Principal Component Analysis approach for the CEI construction and an Ordinary Least Squares regression for examining significant drivers of CE performance with a focus on firms' human capital, business strategies, infrastructure, institutional incentives, and the engagement of consumers and communities. The empirical outcomes highlight the importance of human capital development and demand-side mechanisms in advancing the CE transition in the agrifood sector. Most influentially, managerial awareness and technical competence of employees are significant predictors of higher CEI among agrifood SMEs. Consumer concerns and engagement exert a positive influence, underscoring the critical role of societal pressure in fostering CE performance in the agrifood industry. Government support and business strategy show positive effects, while firm size, location, and infrastructure variables are not statistically significant. Advancing CE practices among SMEs in Vietnam's agrifood sector necessitates a multifaceted strategy encompassing investment in human capital development at both managerial and operational levels, the enhancement of governmental incentives and regulatory frameworks, and the incorporation of corporate social responsibility and community engagement within business strategies.

Contribution/Originality: The paper contributes to the existing literature by presenting the first construction of a CEI for SMEs in the agrifood sector and by extending the existing models with consumer and community engagement, alongside infrastructure, as additional dimensions for analyzing the determinants of CE performance.

1. INTRODUCTION

The circular economy is defined as an economic system replacing the *end-of-life* concept through transforming waste into a resource, prolonging product lifespans, maximizing ecosystem functioning, and promoting environmental quality and sustainability (Alhawari, Awan, Bhutta, & Ülkü, 2021; Saidani, Yannou, Leroy, Cluzel, & Kendall, 2019). It has become a crucial global approach for aligning economic growth with environmental sustainability and a priority for developing countries facing resource scarcity, rapid urbanization, and growing environmental pressures (Islam & Zheng, 2025; Khajuria et al., 2022). Its implementation has been diversified at the macro level of nations, regions, or cities; at the meso level, such as industrial parks; and at the micro level of products,

production, and consumption. The CE models have directly promoted the achievement of Sustainable Development Goals (SDGs), especially SDG 8, SDG 12, SDG 13, SDG 14, and SDG 15 (United Nations Department of Economic and Social Affairs, 2026).

At the micro level, particularly in the agrifood sector, the CE offers a transformative framework to improve resource efficiency, to minimize waste, and to lead the sector towards sustainable development (Scandurra, Salomone, Caeiro, & Gulotta, 2023; Shebanin, Shebanina, Kormyshkin, Drobitko, & Potryvaieva, 2024). This sector incorporates the full value chain of plantation, production, processing, distribution, supplying food, and linking agriculture with food manufacturing and related services (FAO, 2023). The CE models facilitate food security and reduce environmental degradation by closing nutrient loops, handling the use and disposal of resources, and strengthening the resilience and sustainability of agrifood systems. While developed countries have advanced the CE through strong policy frameworks and sustainable standards, the developing nations have challenged legal and financial barriers (Bleischwitz et al., 2022; Mazur-Wierzbicka, 2021). This emphasizes the necessity of empirical studies, capacity building, and national policy incentives, especially in emerging countries.

Regarding the Vietnamese agrifood sector, it has contributed 26.4% of employment in agriculture, and the food processing achieved 7.1% annual growth rate in the period from 2020 to 2024 (National Statistics Office, 2026). The sector has a pivotal role in the country's economic growth and the rural livelihoods aligned with the SMEs serving as the backbone of the value chains, employment, and structural transformation towards sustainability. The CE models have been emphasized in the recent Vietnamese policies as a pathway toward resource efficiency, net zero carbon goal, and inclusive growth (Government of Vietnam, 2022, 2025). Particularly in the agrifood sector, the CE practices are potentially adopted through the whole value chain from organic farming, bioresources utilization, sustainable processing, and the food supply chain (Silvestri, Silvestri, Piccarozzi, & Ruggieri, 2024). Despite these possibilities, the Vietnamese SMEs' capacity and performance in CE practices have remained underexplored, even though they are central to driving sustainability transitions. Emerging evidence indicated that environmental intention enhances consumer engagement with circular behaviors, yet it has been unclear how such societal and market-driven pressures translate into operational adoption within SMEs. Understanding the determinants of CE performance is therefore critical to shaping a resilient, competitive, and sustainable circular economy for the agrifood sector in Vietnam.

Although the literature has introduced various CE indices at national and regional scales, existing efforts have heavily concentrated on the macro level with indicators such as waste recycling rates, resource productivity, and emissions (Brando & Ardi, 2026; Heshmati & Rashidghalam, 2021). As a result, these are not appropriate to capture micro-level performance of SMEs, particularly in the agrifood sector, where practices such as farm biomass valorization, integration of crop and livestock, and water-use efficiency play a critical role in circular performance. This gap has limited the formulation of policy incentives for enterprises to push their circular practices. Moreover, the previous models to investigate the determinants of CE performance have primarily focused on institutional pressures and internal resources, with the lack of market factors, e.g., consumer and community engagement, influential in agrifood systems where food safety, traceability, and sustainability shape production decisions (Ahmed, Mahmud, & Acet, 2022). Similarly, the existing studies have overlooked key determinants at the firm level, including managerial awareness, enterprise size, and infrastructural capacity, thereby constraining understanding of how SMEs translate CE principles into practice (Ahmed et al., 2022; De Oliveira & Oliveira, 2023; Murali, Kayal, & Maiti, 2025). Addressing this research gap, this study incorporates consumer and community engagement as well as infrastructure factors into its analytical framework, aiming to provide a more comprehensive assessment of CE performance and to strengthen the evidence base for CE policy interventions for Vietnamese SMEs.

The objective of this study is to construct the CE Index (CEI) and empirically investigate the determinants of CE performance among SMEs, particularly in the agrifood sector in Vietnam. Accordingly, policies are recommended for promoting CE practices in the sector toward sustainable development. The novel contributions of this study are

twofold. First, it develops a CEI for the SMEs in the agrifood sector. Secondly, it incorporates consumer engagement and infrastructure support as additional elements in identifying the determinants of CE performance.

The paper has four main sections as follows. After this introduction, Sections 2 and 3 present the literature review, hypothesis development, and research methodology. Section 4 discusses the results of CE performance and its determinants among the agrifood SMEs in Vietnam, while Section 5 concludes the study.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1. Circular Economy Index and Principal Component Analysis Approach

The circular economy operates at four alternative levels of macro, meso, micro, and nano, which respectively focus on the nation, region or cities; industry; consumers, enterprises; and product and materials (Ahmed et al., 2022). However, most existing frameworks and measurements of CE indices have focused on the macro level with the assessment of national or regional performance, and at the nano level with the circularity indicators for products (De Oliveira & Oliveira, 2023; Murali et al., 2025). This has revealed a critical research gap in analyzing the CE practices at the micro level, especially among the enterprises as inevitable participants during CE transitions in emerging countries. Assessing the enterprises' CE performance has been highly necessary for implementing the policy incentives and determining the challenges during their circular transitions. To date, the methodology and comprehensive frameworks for this assessment or a CEI have been missing in existing literature.

In agricultural production, as the first stage of the agrifood value chain sector, the improvement of resource efficiency can be deployed through composting crop residues, waste reuse, biomass utilization, biogas derived from livestock waste as a renewable energy source, and organic farming (Ahmed et al., 2022; Martínez-Moreno, Buitrago, Yñiguez, & Puig-Cabrera, 2024; Peng, Baležentis, Streimikiene, Dabkiene, & Agnusdei, 2025; Velasco-Muñoz, Mendoza, Aznar-Sánchez, & Gallego-Schmid, 2021). In the processing and distribution stages, there are numerous opportunities to practice circular economy principles through the reuse of processing waste or sustainable packaging (Silvestri et al., 2024). However, most studies have relied on Life Cycle Assessment (LCA) approaches and/or employed single indicators, e.g., carbon footprint or ecosystem damage, environmental indicators, rather than an integrated perspective to capture the multidimensional nature of circularity (Colley, Birkved, Olsen, & Hauschild, 2020; Heshmati & Rashidghalam, 2021). Until now, the lack of a multidimensional CE index for the micro level in the literature continues to hinder empirical analyses and policy incentives for promoting CE practice among enterprises.

The principal component analysis (PCA) process transforms a set of correlated variables into a smaller set of uncorrelated variables known as principal components, which are linear combinations of the original data designed to maximize variance and retain as much variability as possible (Jolliffe & Cadima, 2016). Equivalently, it finds the best-fitting axis with the largest variance of data after projection, retaining the most essential information known as the first principal component (PC1) of the data. Once PC1 is obtained, orthogonal projection can be used to map coordinates onto this new axis to discover the subsequent principal components. This PC1 is a linear combination attaining the maximum variation in the dataset, and the second principal component (PC2) is the next independent linear combination explaining as much of the remaining variability as possible. Additional components are sequentially added, each new component being independent of the preceding one. This approach ensures that variables within the same principal component are highly correlated, while correlations between principal components are minimized. This procedure highlights PCA's advantage in synthesizing representative indices for complex multidimensional variables with fewer principal components (Heshmati & Rashidghalam, 2021; Wang & Wang, 2015).

As the representative vectors for the principal components are identified, only principal components with eigenvalues exceeding one are retained to ensure significant components contributing to overall variance (Heshmati & Rashidghalam, 2020). The percentage of total variance is used as weights in synthesizing the principal components,

ensuring the incorporation of all indices with a contribution vector over 0.30 in the composite index (Heshmati & Rashidghalam, 2020). The contribution to total variance serves as a weighting factor in constructing the composite index. To formulate the CEI for agrifood enterprises, this study follows the PCA approach of Heshmati and Rashidghalam (2021) and Heshmati and Rashidghalam (2020).

2.2. Circular Economy Index for Agrifood Companies

The circular economy index at the firm level has not been missing in the existing literature, particularly for the agrifood sector. This study has extended analytical assessments of CE performance in the agrifood sector and synthesizes indicators from Ahmed et al. (2022); Poponi, Arcese, Pacchera, and Martucci (2022), and Velasco-Muñoz et al. (2021) to further develop a CEI. Accordingly, the CEI for agrifood companies is developed based on seventeen indicators grouped into five sub-indices. First, the Efficient consumption sub-index involves energy-saving activities (EC1), use of renewable energy (EC2), and energy-saving products and services (EC3) (Table 1). Second, the use of raw materials sub-index includes using biological and biodegradable materials (RM1), reusing and reducing plastic packaging (RM2), and classifying and managing waste in a circular manner (RM3). Third, the Environmental activities and human health sub-index covers supervising environmental activities (EA1), improving soil quality and biodiversity (EA2), and reducing emissions (EA3). Fourth, the community and social activities sub-index includes achieving environmental certifications (CS1), performing product LCA (CS2), considering environmental criteria for inputs (CS3), and implementing incentive programs to recover old products (CS4). Finally, recycling waste into raw materials for production involves using recycled materials in the production process (RW1), replacing chemicals with safe ingredients (RW2), and reusing wastewater (RW3). All 17 indicators used to construct the five sub-indices for the agricultural firms have been aggregated into the overall Circular Economy Composite Index (CEI) for agrifood enterprises.

Table 1. Indicators for the circular economy index for agrifood companies.

Categories	Indicators	Label	Mean	Std. Dev.
Efficient consumption	- Conduct energy-saving activities	EC_1	3.27	1.40
	- Use renewable energy	EC_2	2.94	1.44
	- Use energy-saving products and services	EC_3	2.65	1.37
Use of raw materials	- Use biological and biodegradable materials	RM_1	2.76	2.76
	- Reuse and reduce plastic packaging	RM_2	3.11	1.31
	- Classify and manage waste in a circular manner	RM_3	3.77	1.22
Environmental activities and human health	- Supervise activities related to the environment	EA_1	3.34	1.44
	- Improve soil quality, biodiversity, and landscape	EA_2	2.90	1.46
	- Perform greenhouse gas and other emission reduction activities	EA_3	3.13	1.47
Community and social activities	- Achieve environmental certification or standards	CS_1	2.86	1.24
	- Conduct life cycle assessments	CS_2	2.41	1.08
	- Consider environmental criteria when using electricity, gas, and other inputs	CS_3	3.15	1.32
	- Implement incentives to recover the old product	CS_4	2.23	1.15
Recycling waste into raw materials	- Use recycled materials	RW_1	2.77	1.45
	- Replace chemicals with environmentally friendly ingredients	RW_2	2.48	1.08
	- Reuse wastewater and rainwater	RW_3	2.66	1.43
	- Conduct an evaluation of waste circulation	RW_4	2.59	1.36

The five sub-indices in Table 1 are used to calculate the CE index using the PCA approach, yielding a result with only one PC for each sub-index based on the condition of an eigenvalue greater than 1 (Appendix 1). This indicates that the data for the Agricultural sector may exhibit homogeneity and similar influencing factors toward the overall outcome. Despite having only one PC, the contributions of each PC are all above 0.62, signifying their importance

and significant influence on the dataset and enhancing the efficiency of analysis and understanding the dataset structure. Having only one PC might imply a loss of diversity in the dataset. However, since each sub-index is based on a relatively small number of indicators from 2 to 4, the PCA result with only one PC does not significantly diminish dataset diversity. Furthermore, all 17 indicators employed to estimate the five sub-indices have been synthesized for a comprehensive CE performance in the agrifood sector.

For the composite CE index, four PC have eigenvalues greater than one, collectively explaining 69% of the total variance (Appendix 1). Among these four PCs, the contribution of the first principal component is 47%, gradually decreasing to 6% for the final principal component. The composite CEI for the agrifood sector is constructed from four PCs, which together explain 69% of the total variance in CE activities.

In this study, the CEI is utilized as the dependent variable in the regression model to identify the significant determinants among explanatory variables. The choice of independent variables is based on previous studies on CE performance reflecting characteristics of firms and human resources, strategies, and market contexts in the agrifood sector (Ahmed et al., 2022; Heshmati & Rashidghalam, 2021; Silvestri et al., 2024). The PCA method is also employed to synthesize the indices for the four independent variables of government and regulation, consumer and community, infrastructure, and business using the indicators in Table 2. By synthesizing multidimensional indicators into a CEI, the study provides a robust and nuanced proxy for CE performance, offering valuable insights for policymakers aiming to enhance CE practices in the agrifood sector in Vietnam.

2.3. Theoretical Background and Literature Review

This study follows the resource-based view (RBV), stakeholder theory, and institutional theory. While the first emphasizes the enterprises' internal capabilities such as technology adoption, financial resources, and human capital to enable circular practices, the second theory underscores the expectations of the firms' stakeholders, including consumers, suppliers, local communities, and other stakeholders in the supply chain. Their demands for sustainability change are critically engaged in the firms' transition (Barney, Wright, & Ketchen, 2001; Osei, Agyemang, & Cobbinah, 2026). Finally, the institutional theory highlights the influence of external pressures, particularly government policies and regulatory frameworks, that shape the operational environment for SMEs (Yin, Jiang, Chen, & Jia, 2024). Together, these theoretical backgrounds support the understanding of internal factors, external enablers, and institutional and stakeholder pressures for the analysis of CE performance determinants in the agrifood sector.

Key determinants of CE performance at the enterprise level are adapted from the existing literature, specifically relevant to agriculture and food processing (Khue et al., 2024; Silvestri et al., 2024; Zuofa, Ochieng, & Ode-Ichakpa, 2023). The internal factors include the firm's size, organizational awareness, technology application, and financial capacity (Khue et al., 2024). Heshmati and Rashidghalam (2021); Mura, Longo, and Zanni (2020), and Mishra, Singh, and Govindan (2022) proposed external factors driving the CE performance encompassing government policies and incentives, infrastructure, market demand, and community engagement. Importantly, consumer concerns for environmentally friendly processed foods have now become a powerful market driver, compelling the SMEs to transition to circularity for certification standards and brand reputation in a competitive market (Luthra, Kumar, Sharma, Garza-Reyes, & Kumar, 2022). Unlike industries with less public visibility, the agrifood firms are inevitably sensitive to health concerns and environmental feedback in the community, making stakeholder engagement a pivotal determinant of their CE performance. As for the Vietnamese agrifood industry, Khue et al. (2024) indicated that the financial factor and technological application, awareness of staff, and production scale are the predominant drivers of CE adoption.

2.4. Hypothesis Development

In compliance with the RBV theory, firm size reflects its capacity to access and deploy resources that facilitate CE practices. The agrifood enterprises often benefit from economies of scale. Larger agrifood ones typically have

stronger financial and organizational capabilities, enabling investments in advanced waste-treatment technologies, closed-loop models, biowaste valorization, and circular supply-chain processes (Khue et al., 2024; Mura et al., 2020). Khue et al. (2024) and Levický, Fiľa, Maroš, and Korenková (2022) indicated that production scale significantly enhances CE adoption and active participation in CE initiatives due to superior access to capital, technology, and managerial expertise. Particularly for the agrifood sector, the advantages of firm size enable the adoption of such capital-intensive circular practices as precision farming, biogas systems, and nutrient recycling. Based on these aforementioned premises, the first hypothesis is as follows:

H_1: Firm size has a positive impact on CE performance.

A broader understanding of sustainability principles beyond the CE framework positively induces an enterprise's manager to operationalize circular practices. Managers equipped with the knowledge of organic production, LCA methodology, and environmental management standards such as ISO 14001 are more likely to pursue CE implementation within their agrifood operations (Ahmed et al., 2022; Zuofa et al., 2023). An awareness of such sustainability mechanisms, soil health, biodiversity protection, and carbon sequestration further enables the managers to design their circular strategies to foster innovation and sustainable application in the agrifood sector that aligns with environmental goals in the long run (Pham, Truong, & Tran, 2025; Sharma, Mangla, Patil, & Liu, 2019). The second hypothesis on human capital impact on CE performance is proposed as follows:

H_2: Employers' sustainable development awareness has a positive impact on CE performance.

Workforce awareness and technical competencies also greatly contribute to the effective execution of CE performance at the operational level. Practitioners in the agrifood sector are required to have knowledge and skills for such activities as waste segregation, composting, biomass utilization, minimizing chemical inputs, reutilization of byproducts, e.g., rice husk, bagasse, and water recycling, and integrated pest management (Zuofa et al., 2023). The workers' awareness and training initiatives enhance operational readiness and the CE performance in the agrifood sector (Luthra et al., 2022). Khue et al. (2024) additionally demonstrated that the CE knowledge attainment of employees results in better coordination in teamwork, greater consistency in implementation, and better CE performance as a result. Building on this rationale, the third hypothesis is proposed:

H_3: Employees' knowledge positively contributes to CE performance.

According to the Institutional theory, the government shapes the institutional environment to promote the firms' CE practices by providing legitimacy, regulatory guidance, policies, and incentives. The incentives and policies enhance the firms' sustainable operations and certifications like organic certification, using renewable energy, and, more recently, support them in managing their financial and operational barriers to engage in CE models (Heshmati & Rashidghalam, 2021; Mishra et al., 2022; Sharma et al., 2019). In the study site of Vietnam, national initiatives include the Circular Economy Action Plan to 2030 and provincial programs promoting CE adoption (Government of Vietnam, 2022, 2025). These interventions signal government commitment and further support to the SMEs during the CE transition. Building on this rationale, the fourth hypothesis is proposed as follows:

H_4: Government policy and regulation positively influence CE performance.

The RBV theory indicates that business practices such as planning and operational routines, technology adoption, and resource utilization can constitute essential capabilities for effective CE implementation. Business CE practices in the agrifood sector may involve designing a product to prolong its lifespan, adopting techniques for resource efficiency, e.g., drip irrigation, integrated nutrient management, transforming waste into a resource, engaging in circular procurement, environmentally certified inputs, and collaborating with supply chain partners (Luthra et al., 2022; Mishra et al., 2022; Mura et al., 2020). The more advanced practices an enterprise conducts, the better achievement of material efficiency and environmental performance it attains. These capabilities collectively strengthen a firm's competence to integrate CE practices into its daily operations. Based on this reasoning, the following hypothesis is proposed:

H_5: Business practices have a positive impact on CE performance.

Geographical location decides firms' cost and feasibility to access to resources, infrastructure, and regulatory environments, shaping their competence to engage in CE practices as a result. The Institutional theory reveals that enterprises in urban and peri-urban areas have advantages of advanced infrastructure to enhance the firm's CE performance, e.g., waste collection services, recycling facilities, and stronger regulatory enforcement for producers and consumers. Meanwhile, resource constraints theory highlights that higher costs of land and labor and compliance burdens in urban areas may confine the agrifood SMEs' investment in CE initiatives (Zuofa et al., 2023). Aligned with this argument, rural enterprises have more affordable access to land for composting, waste recycling, and other CE activities. These theoretical premises, in the context of empirical results on spatial effects in the agrifood sectors of developing countries, motivate the following hypothesis:

H_6: Firm location in major urban centers is associated with lower CE performance.

As food safety has been included in the United Nations' SDG 2 on ending hunger, improving food security and nutrition, and promoting sustainable agriculture, and SDG 3 on healthy lives and well-being, this obviously raises the global demand for organic, safe, and sustainable inputs and outputs for the agrifood value chain (United Nations Department of Economic and Social Affairs, 2026). These growing preferences from the consumers and the community have shaped the firms' integration into CE practices and more commitment under their stakeholder pressure (Luthra et al., 2022; Mishra et al., 2022; Mura et al., 2020). While the consumers have highly focused on agrifood products, the community has a critical concern about water quality and management, pesticide use, and other emissions for sustainability desirability in the long run. These all motivate agrifood firms to initiate circular practices. Therefore, the following hypothesis is proposed:

H_7: Consumer and community engagement has a positive impact on CE performance.

The infrastructure availability has been a prerequisite factor to impel the agrifood firms' transition toward CE models (Heshmati & Rashidghalam, 2021; Luthra et al., 2022). While CE infrastructure such as waste collection services, composting facilities, and bioenergy supply chains remains unevenly distributed in the emerging economies, the promotion of such contextual factors enables the firms' CE performance (Khue et al., 2024). Accordingly, the following hypothesis is as follows:

H_8: Infrastructure support has a positive impact on CE performance.

3. METHODOLOGY

This study employs an Ordinary Least Squares regression model to empirically determine the determinants of CE performance among the agrifood SMEs. The CEI is constructed using the PCA approach presented in Section 2.2 and utilized as the dependent variable of the firms' CE performance level. This composite index captures the multidimensionality of circular practices within the agrifood SMEs.

The regression equation is as follows:

$$CEI_i = \beta_0 + \sum_{j=1}^{8} \beta_j X_{ij} + u_i \quad (1)$$

Where CEI_i reflects the extent of CE implementation at the firm i, X_{ij} is determinant j of the firm i (Table 3); β_0, β_j is the regression coefficients and u_i is the unbiased estimate of the error term u.

Appendix 2 presents a variable correlation analysis to examine the potential multicollinearity among independent variables before the model estimation. The correlation coefficient captures the strength and direction of linear relationships, with values below 0.4 being weak, 0.4–0.8 being moderate, and above 0.8 being a strong association (Shi & Conrad, 2009). All independent variables have not been strongly correlated with the coefficient greater than 0.8. The results of post-estimation diagnostics further ensure model reliability. The variance inflation factor (VIF) assesses the extent to which predictor intercorrelations inflate coefficient variance, where elevated VIF values signal multicollinearity concerns. Heteroskedasticity tests are also performed since non-constant error variance violates key OLS assumptions and may compromise estimator efficiency (Astivia & Zumbo, 2019).

3.1. Data Collection

This study utilized the primary data from the survey of agrifood enterprises in the Southeast and Mekong Delta regions, since the agrifood activities have been predominant in these regions in Vietnam. The surveyed entities are diverse in activities of agricultural production for both cultivation and livestock, food processing, and agricultural input trading in 2024 (Figure 1). A structured questionnaire via Google Form was sent to the firms for data collection. The questionnaire captured information on characteristics of firms, employers, and employees, their awareness of CE concepts, CE performance of firms, and indicators for the CEI construction and variables for the regression model. A convenience sampling approach was employed. A total of 120 managers from agrifood companies were invited to participate in the study, resulting in 86 valid responses and yielding a response rate of 72%.

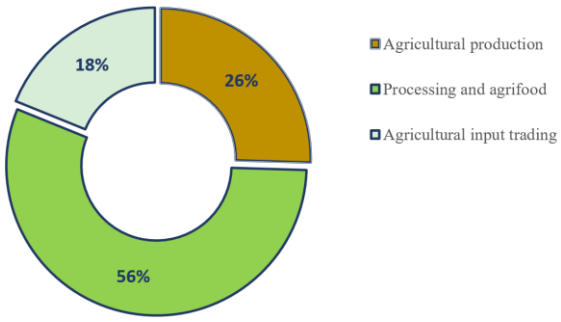

Figure 1. Agrifood enterprises by operational activities.

3.2. Description of Variables

Following the construction of the CEI for agrifood enterprises in Section 2, regression analysis is conducted to assess the influence of various independent variables on firms' CE performance. These variables include firm location, enterprise size, managerial awareness of CE, and employee knowledge. In addition, several contextual and organizational factors, including government regulation, consumer and community engagement, infrastructure support, and business practices, are hypothesized to shape the firms' CE performance. Definitions and measurement scales for all variables are provided in Table 2 and Table 3.

Table 2. Indicators to aggregate the independent variable indices.

Government and regulation index	
GOV_1	Financial incentive policies for CE transition
GOV_2	Penalties for non-compliance with the CE transition
GOV_3	Support for an innovative market for reuse and repair centers
GOV_4	Lack of guidelines and bureaucratic hurdles in CE legislation application
GOV_5	Coordination of regulations
Consumer and community index	
CON_1	Consumer awareness and knowledge of the CE transition
CON_2	Positive social norms and strong environmental beliefs on the CE transition
CON_3	Consumers perceive CE products as a trade-off between price and performance
CON_4	Limited public awareness hinders progress
Infrastructure index	
INF_1	R&D projects and technical advancements drive enterprise CE transitions.
INF_2	Lack of data banks and standard evaluation hampers recognition of achievements.
INF_3	Limited technology, design, and material options for CE in Vietnam.
INF_4	Complex value chain management and end-of-life material traceability issues.
INF_5	Insufficient collaboration and network support among businesses.
Business index	
BUS_1	Support for sourcing low-impact raw materials and identifying eco-friendly suppliers.
BUS_2	Facilitation of financial access for CE transition.
BUS_3	Potential to reduce raw resource dependence and environmental impacts in CE transition.
BUS_4	Promotion of servitized business models during CE transition.
BUS_5	Profitability uncertainty and perception of CE as a cost, not an investment.
BUS_6	Tools to assess the long-term benefits of CE.

Table 3. Variable description.

Variables	Notation	Unit	Mean	Std. Dev.	Min.	Max.
CE performance	CEI	Index	49.36	24.57	2.71	98.53
Government and regulation	GOV	Index	49.58	18.91	1.26	95.00
Consumer and community	CON	Index	47.43	16.74	12.00	82.10
Infrastructure	INF	Index	39.08	13.04	5.71	83.33
Business	BUS	Index	48.52	15.08	14.18	95.00
Location	LOC	1= Big cities, 0=others	0.34	0.48	0.00	1.00
Firm size	SIZE	No. full-time employees	2.00	1.19	1.00	4.00
Employers' sustainable development awareness	KNO1	1= Yes, 0= No	0.61	0.49	0.00	1.00
Employees' knowledge of CE[2]	KNO2	Likert scale measuring employees' awareness of CE	2.77	1.85	1.00	6.00

Note: 1 = Ha Noi/ Hai Phong/ Da Nang/ Can Tho/ Ho Chi Minh City; 0 = Others; [2]: this variable reflects the percentage of employees with awareness of the CE. 1: below 5% total employees, 2: from 5% to below 10% total employees, 3: from 10% to below 20% total employees, 4: from 20% to below 30% total employees, 5: from 30% to below 50% total employees, and 6: equal or greater than 50% total employees.

4. RESULTS AND DISCUSSION

4.1. Correlation Analysis

The correlation coefficients between the independent variables and the CEI are reported in Appendix 2. Within the agrifood sector, the analysis indicates that three variables of Government and Regulation (GOV), Consumer and Community (CON), and Business Practices (BUS) exhibit statistically significant positive correlations with the CEI, suggesting their potential to enhance the CE performance. Figure 2 implies a potential positive association between GOV, CON, and BUS independent variables and CE performance with the clear upward trends. Differently, the scatter plot of the infrastructure (INF) and CEI showed a dispersed pattern without an identifiable linear relationship, revealing an unlikely significant effect of INF on CE performance.

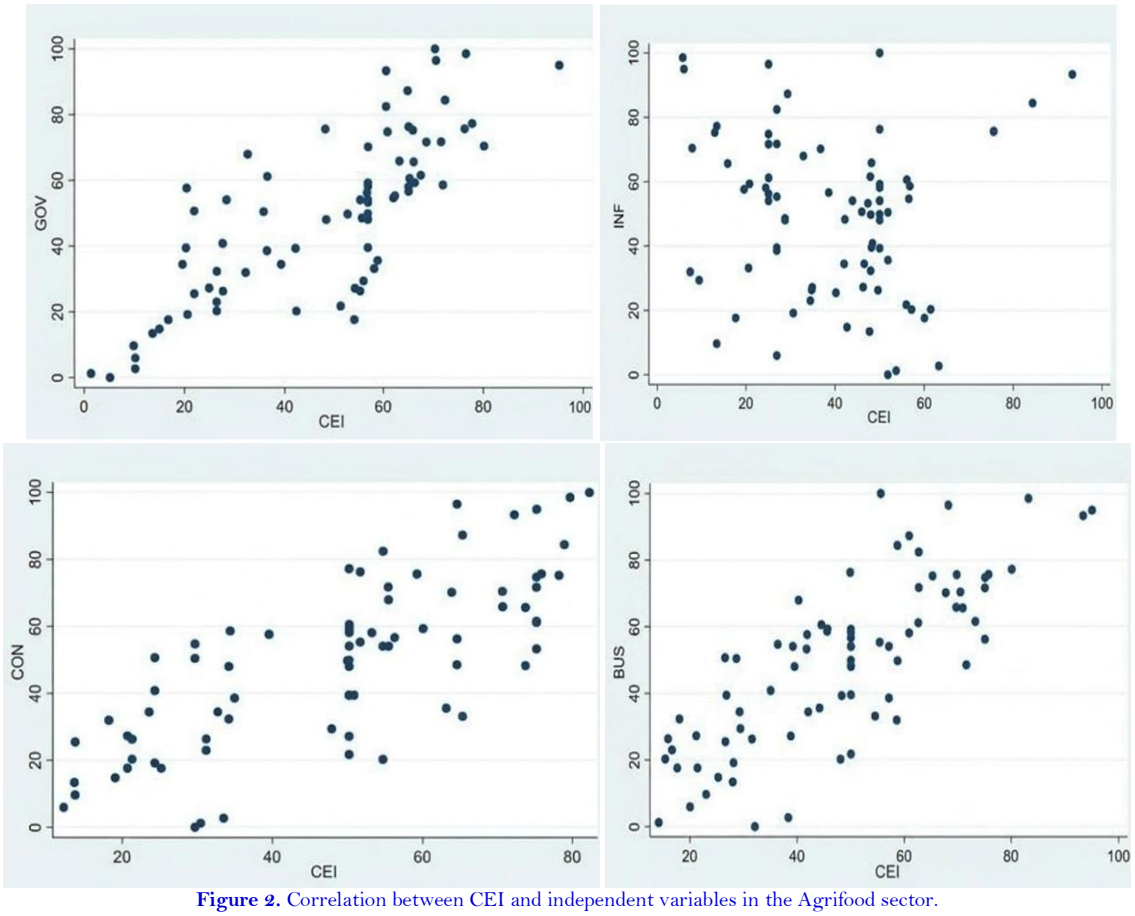

Figure 2. Correlation between CEI and independent variables in the Agrifood sector.

4.2. Determinants of Circular Economy Performance in the Agrifood Sector

The regression model investigates the determinants of CE performance among agrifood enterprises using the dependent variable of CEI and the independent variables of four indices and other characteristics of firms and human resources (Table 5). The model statistics demonstrate a robust fit and suitability in this analysis for the agrifood sector. Before interpreting the model results, two post-estimation diagnostics were employed to assess the adequacy of the model, namely the Variance Inflation Factor (VIF) to evaluate multicollinearity and a heteroskedasticity test to examine the constancy of error variance. They were conducted. The VIF values for all predictors are all lower than the conventional threshold of 5, proving that there is no evidence of multicollinearity (Table 4). The latter test resulted in a p-value of 0.98, substantially higher than the 10% significance level, suggesting the null hypothesis of homoskedasticity cannot be rejected. The two tests confirmed the nonexistence of heteroskedasticity or multicollinearity in the model and supported its statistical robustness. Additionally, the high R-squared value of 0.77 and an adjusted R-squared of 0.74 further demonstrate the model's strong explanatory capacity for identifying the determinants of CE performance in the agrifood sector (Table 5).

Table 4. Post-estimation test.

Variance Inflation Factor (VIF) test	
Variables	**VIF**
Government and regulation	3.30
Consumer and community	3.34
Infrastructure	1.07
Business	3.63
Location	1.17
Firm size	1.14
KNO1	2.55
KNO2	1.47
Heteroskedasticity test	
Prob > chi2	0.98

Table 5. Empirical model results.

Variables	**Notation**	**Coefficient**	**p-value**
Government and regulation	GOV	0.24	0.056*
Consumer and community	CON	0.26	0.051*
Infrastructure	INF	0.04	0.592
Business	BUS	0.30	0.030**
Location	LOC	-0.90	0.777
Firm size	SIZE	0.88	0.486
Employers' sustainable development awareness	KNO1	2.53	0.009***
Employees' knowledge of CE	KNO2	3.24	0.025**
Intercept		-15.06	0.018
RSS	10,718		
R^2	0.77		
$\overline{R^2}$	0.75		
F (8,77)	29.69		
Prob > F = 0.0000			
Observations	86		

Note: *** p<0.01, ** p<0.05, * p<0.1; The coefficients represent percentage point changes in the CEI.

Table 5 presents the effects of organizational, institutional, and contextual factors on CE performance among agrifood SMEs. Among the model predictors, the employers' sustainable development awareness, employees' knowledge of CE, business practices, government and regulation, and consumer and community show statistically significant effects on the dependent variable at various confidence levels (Table 5). Specifically, the hypotheses H2 and H3 are strongly supported. The human capital variables display the strongest impacts, namely the variable of the

managers' awareness of sustainable development with its significant coefficient of 2.53 and p-value of 0.009, and the employees' CE knowledge with its significant coefficient of 3.24 and p-value of 0.025.

In view of organizational capabilities, business practices emerge as a significant predictor with the estimated coefficient β of 0.30, p-value of 0.03, supporting the hypothesis H5 and indicating that the internal management systems, efficient processes, and operational routines contribute significantly to CE performance. Regarding institutional drivers, the results confirm the hypothesis H4, showing that the government and regulation are a key determinant with the coefficient β of 0.24 and a p-value of 0.056. Notably, the consumer and community engagement also show a positive and borderline significant effect with its coefficient of 0.26 and p-value of 0.051. However, contrary to the expectation from the RBV theory for the sector, some contextual factors, particularly firm size, do not show a statistically significant impact, leading to the rejection of H1.

4.3. Discussion and Implication

Among the significant determinants of CE performance in agrifood firms, it is noteworthy that human capital emerges as a critical factor, with KNO1 and KNO2 variables yielding substantial coefficients of 2.53 and 3.24, respectively. The findings of strong positive impacts of human capital variables on the CEI underscore that for agrifood SMEs, internal human resources, both leadership vision and workforce technical skills, are the critical drivers for successful CE implementation. Providing training on the CE practices for employees and updating knowledge on the CE models for managers is essential to successfully scale up and replicate CE practices among agrifood firms. For organizational capabilities, the business strategies and daily practices are crucial for the firm's CE performance. The transformation of business strategies and the integration of CE practices into daily operations require substantial efforts from business managers' awareness, while operational effectiveness depends on investment capacity and various external supporting factors.

Concerning the institutional drivers, the government, regulation, consumer, and community engagement are significantly positive determinants of CE performance. This implies that stronger government policies, incentives, and regulatory frameworks positively encourage agrifood firms to adopt circular practices. The market pressures from consumers demanding safe and/or organic products. Community engagement serves as a vital external driver and motivation for agrifood firms to adopt CE initiatives. Therefore, the CE performance has been enhanced by not only firms' human capital and their strategic and operational practices but also by external factors, namely the government incentives, consumer participation, and community engagement. These factors could interact to create synergistic effects and enhance the effectiveness of CE practices. Besides, the insignificance of the firm's size and infrastructure variables suggests that in Vietnam's agrifood context, CE performance is less dependent on the scale of operation. The data do not provide sufficient evidence to conclude that infrastructure significantly affects CE performance. Similarly, the hypothesis H6 is not supported by the data.

5. CONCLUSIONS

This study contributes to the literature by developing a CEI comprising 17 indicators, extending the drivers of consumer engagement and infrastructure support into the analysis, and providing empirical evidence on the determinants of CE performance among SMEs in Vietnam's agrifood sector. The model has empirically identified the significant determinants of human capital, institutional support, business practices, and stakeholder engagement for shaping the firms' CE performance in the agrifood sector. The most influential factors derived from the model belong to human resources, particularly the awareness of the business manager and the technical competence of the employees. Institutional support further enhances circular performance, while business strategies facilitate the integration of circular principles into daily operations. The statistically significant variable of consumer and community emphasizes the existing market concerns for sustainable agrifood products, subsequently shaping firms' circular practices. In contrast, the agrifood firms have been significantly constrained by scale or spatial factors, but

also by knowledge, governance, and stakeholder dynamics. Based on the model results, policy efforts should prioritize institutional strengthening, consumer awareness initiatives, and especially capacity building for both managers and employees to effectively accelerate the transition toward a circular economy in Vietnam's agrifood sector.

It is acknowledged that the sample size of 86 observations utilized in this study revealed a constraint on the generalizability of the findings. Convenience sampling may introduce selection bias. However, the diagnostic tests for the regression model remain statistically robust at an acceptable level. Furthermore, this sample reflects a diverse range of enterprise types within the agrifood sector, capturing the specific characteristics under consideration. Future research could expand the sample size to enhance the representativeness and generalizability of the results.

Funding: This research was funded by the University of Economics Ho Chi Minh City, Vietnam (UEH).
Institutional Review Board Statement: The Ethical Committee of the University of Economics, Ho Chi Minh City, Vietnam has granted approval for this study with Ref. No. 2026-06-16-3938. Informed verbal consent was obtained from all participants, and all data were anonymized to protect participant confidentiality.
Transparency: The author states that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The author declares that there are no conflicts of interest regarding the publication of this paper.
Acknowledgement: The author acknowledges the data provision partially used in this study from the project on circular economy in Vietnam in the period from 2023 to 2024 between Western Sydney University (WSU) and the University of Economics Ho Chi Minh City (UEH).

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Appendix.

Appendix 1. Principal component analysis CEI in the agrifood sector.

Variable	Eigenvalue	Proportion	Cumulative
Index components			
Efficient consumption			
PC 1	2.17	0.72	0.72
Use of raw materials			
PC 1	1.40	0.70	0.70
Environmental activities and human health			
PC 1	2.66	0.66	0.66
Community and social activities			
PC 1	2.49	0.62	0.62
Recycling waste into raw materials for production			
PC 1	2.83	0.71	0.71
Overall composite CE index			
- PC(1)	7.93	0.47	0.47
- PC(2)	1.43	0.08	0.55
- PC(3)	1.28	0.08	0.63
- PC(4)	1.10	0.06	0.69

Appendix 2. Correlation among the index components for the agrifood sector.

	CEI	GOV	CON	INF	BUS	LOC	SIZE	KNO1	KNO2
CEI	1.00								
GOV	0.78	1.00							
CON	0.76	0.75	1.00						
INF	-0.09	-0.13	-0.07	1.00					
BUS	0.79	0.75	0.79	-0.14	1.00				
LOC	0.17	0.10	0.23	-0.17	0.18	1.00			
SIZE	0.15	0.09	0.12	-0.03	0.02	0.18	1.00		
KNO1	0.74	0.70	0.64	-0.18	0.68	0.24	0.24	1.00	
KNO2	0.61	0.51	0.44	-0.05	0.51	0.16	0.08	0.49	1.00