DOI:10.5937/IIZS25255U

CIRCULAR SUPPLY CHAIN PRACTICES AND THEIR CONTRIBUTION TO GREEN ECONOMY GOALS IN SERBIAN MANUFACTURING

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Abstract: The transition toward a green economy requires manufacturing firms to adopt more sustainable and circular supply chain practices. This study explores the extent to which Serbian manufacturers implement three key circular strategies—recycling and material recovery, product life extension, and reverse logistics—and how these practices contribute to alignment with environmental objectives. Based on survey data collected from 32 companies, the analysis applies regression modeling to evaluate the relationship between these practices and perceived alignment with green economy goals. Results show that recycling and product life extension significantly influence environmental alignment, while reverse logistics demonstrates a weaker, non-significant effect. The findings underscore the strategic importance of circular initiatives and highlight areas where greater institutional and infrastructural support is needed to accelerate sustainable industrial development.
Key words: circular economy, supply chain management, green manufacturing, sustainable logistics

INTRODUCTION

Circular supply chain practices have gained considerable attention in recent years as a response to the growing pressure on industries to reduce environmental impact while maintaining operational efficiency. Traditional supply chains are typically linear in nature, involving the extraction of raw materials, production, consumption, and ultimately, disposal. In contrast, circular supply chains emphasize the recirculation of materials and the minimization of waste through a closed-loop model[1]. The fundamental goal is to retain the value of products, components, and materials for as long as possible through activities such as recycling, remanufacturing, reuse, and reverse logistics. These activities are not merely add-ons but are being integrated strategically into the supply chain to achieve long-term sustainability and cost-effectiveness.

In practical terms, recycling and material recovery refer to the systematic processing of waste materials into reusable resources. In manufacturing contexts, this could involve the collection of scrap metal, plastic, or other production residues and their reintegration into the production process either internally or through third-party recyclers[2]. Product life extension, on the other hand, focuses on strategies such as refurbishing, reconditioning, and designing products for disassembly and reuse. This not only reduces the demand for virgin materials but also aligns production with consumer trends favoring sustainable products. Reverse logistics, which deals with the movement of goods from the end user back to the manufacturer or a secondary facility, supports these goals by enabling the return and proper handling of used or faulty products[3]. The adoption of these practices depends on several factors, including organizational culture, regulatory environment, customer expectations, and technological capability. In developed markets, circular supply chains are often supported by robust infrastructure and policy incentives[4]. In developing or transitioning economies, such as Serbia, the situation is more complex. Companies must often invest in new technologies, redesign existing supply chain processes, and train personnel to support circular operations. Despite these challenges, firms that successfully integrate circular logistics can experience several advantages, including improved resource utilization, enhanced brand reputation, and reduced operational risks.

The transition to a green economy requires industries to rethink how economic activities are structured and evaluated. A green economy promotes environmentally sustainable and socially inclusive growth by decoupling economic development from environmental

degradation[5]. In this context, supply chains are viewed as critical systems where environmental improvements can be realized at scale. Logistics operations, in particular, have a direct impact on energy consumption, emissions, and waste production, making them key targets for intervention. The integration of circular supply chain practices thus becomes a practical mechanism for firms to contribute to green economy objectives in measurable ways.

BACKGROUND RESEARCH

Serbian manufacturing firms operate within a dynamic and often challenging industrial landscape shaped by a combination of legacy infrastructure, evolving environmental regulations, and increasing pressure from global supply chain partners[6]. As sustainability becomes a more integral part of international trade and production standards, the capacity of Serbian manufacturers to adapt is critical. While there is growing awareness of environmental concerns, the pace of circular economy adoption remains uneven across sectors and regions. Larger firms with international exposure are more likely to integrate recycling, reuse, and reverse logistics into their operations, while small and medium-sized enterprises (SMEs) may struggle due to limited resources, expertise, or strategic direction[7]. Nevertheless, the broader trend is moving toward sustainability, driven both by regulatory alignment with the European Union and by economic incentives such as energy cost savings and access to green funding. Some firms have established basic material recovery systems, while others have gone further to integrate remanufacturing and reverse logistics capabilities into their operations. Still, many companies perceive sustainability initiatives as a cost rather than an investment, leading to a fragmented adoption landscape. Industry-specific factors also play a role. For example, sectors like food processing or chemicals may face stricter waste management obligations, whereas textile or machinery manufacturers may have more flexibility in how they apply circular principles[8]. Organizational culture, managerial awareness, and access to technical knowledge further influence the extent to which firms engage in circular logistics. These variables form the backdrop against which environmental performance is measured and evaluated in this study.

Despite the obstacles, there are clear signs of transition. Environmental awareness is steadily growing among both producers and consumers, and government programs increasingly support cleaner production methods[9]. Non-governmental organizations and academic institutions also contribute to capacity building by promoting best practices and facilitating knowledge exchange. Moreover, green procurement policies and international certifications such as ISO 14001 encourage firms to align their supply chain operations with sustainability targets[10]. However, translating awareness and compliance into measurable environmental gains requires robust tools for analysis and decision-making. It is in this space that data-driven methodologies can provide significant value, allowing firms to quantify the benefits of circular logistics and make informed strategic choices.

The use of empirical data to assess sustainability practices in supply chains is essential for bridging the gap between theory and implementation. Conceptual models and policy recommendations offer useful guidance, but only through systematic analysis can the true impact of circular practices be verified. This study responds to that need by designing a framework for measuring key circular logistics activities—recycling and recovery, product life extension, and reverse logistics—and analyzing their influence on green economy alignment. These elements form the foundation for the descriptive and regression analysis that follows, offering insights into the environmental value of circular supply chain strategies.

METHODOLOGY

The research aims to empirically examine the influence of circular supply chain practices on the environmental orientation of manufacturing firms, conceptualized as alignment with green economy goals. A structured survey was conducted with 32 respondents drawn from middle and upper management levels in Serbian manufacturing companies across various sectors, including metal processing, plastics, food production, and electronics. Respondents provided

assessments on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree) to evaluate the extent of implementation of three independent constructs and one dependent construct.
The independent variables include:

- Recycling and material recovery (REC): This construct captures the extent to which companies systematically collect, sort, and reintegrate recyclable materials into production processes. It includes practices such as internal recycling of production waste, collaboration with third-party recyclers, and resource recovery initiatives.
- Product life extension and reuse (PLE): This variable reflects efforts to prolong the useful life of products and components through design, maintenance, and refurbishment strategies. It includes modular product design, repair services, and remanufacturing practices aimed at reducing the need for new materials and minimizing environmental impact.
- Reverse logistics and returns (RLR): This dimension refers to the systems and processes enabling the return, collection, and reprocessing of used or end-of-life products. It includes organized take-back schemes, repair networks, and logistics solutions for transporting returned goods to appropriate facilities for reuse or recycling.

The dependent variable is defined as:

- Green economy alignment (GEA): This construct represents the firm's perceived alignment with broader ecological goals such as energy efficiency, waste minimization, circular resource flow, and compliance with environmental standards.

The internal consistency of all constructs was tested using Cronbach's Alpha. Mean scores and standard deviations were calculated to present the general trends and distribution of responses. Multiple linear regression analysis was applied to explore the predictive power of the three circular supply chain practices on green economy alignment. Model diagnostics included the coefficient of determination (R^2), adjusted R^2, variance inflation factor (VIF), and Durbin-Watson statistic to test for multicollinearity and residual independence.
The research is guided by the following hypotheses:

- H1: Recycling and material recovery practices have a significant positive effect on green economy alignment in Serbian manufacturing.
- H2: Product life extension and reuse practices significantly contribute to alignment with green economy goals.
- H3: Reverse logistics and returns are positively associated with green economy alignment in manufacturing firms.

RESULTS

The results from Table 1 present the descriptive statistics for each of the key constructs. Mean values range from 5.21 to 5.88, indicating a relatively high perceived implementation of circular supply chain practices among surveyed firms. Recycling and material recovery received the highest average score (M = 5.88), suggesting this is the most widespread practice. Reverse logistics shows the lowest mean (M = 5.21), indicating more variability and possibly more barriers to implementation in this area.
The internal reliability of all constructs is strong, with Cronbach's Alpha values above the acceptable threshold of 0.70. This confirms that the items used to measure each variable demonstrate internal consistency. The high reliability values provide a solid foundation for conducting further inferential statistical analysis and interpreting results with confidence.

***Table 1**. Descriptive statistics and reliability analysis*

Variable	Mean	Std. Dev.	Cronbach's Alpha
REC	5.88	0.76	0.81
PLE	5.55	0.84	0.79
PLR	5.21	0.95	0.77
GEA	5.67	0.69	0.83

Table 2 presents the results of the multiple linear regression analysis examining the effects of the three independent variables on green economy alignment. Both recycling and product life extension variables have statistically significant effects at the 0.05 level, with standardized beta coefficients of 0.412 and 0.378, respectively. This suggests that firms placing greater emphasis on these two circular practices are more likely to align with green economy goals. Reverse logistics, while positively related, does not reach conventional significance, indicating that its influence may be more context-dependent or constrained by implementation challenges.
The overall model explains approximately 59.4% of the variance in green economy alignment ($R^2 = 0.594$), and the adjusted R^2 value of 0.552 confirms the robustness of the model. The F-statistic is significant ($p < 0.001$), demonstrating that the regression model provides a statistically reliable explanation of the relationship between circular supply chain practices and environmental orientation. These findings reinforce the relevance of circular logistics in achieving sustainable industrial goals.

***Table 2.** Multiple linear regression results*

Independent Variable	Beta	t	Sig. (p-value)
REC	0.412	2.47	0.020*
PLE	0.378	2.31	0.026*
PLR	0.291	1.88	0.069
$R^2 = 0.594$	Adjusted $R^2 = 0.552$	F = 14.87	Sig. = 0.000

H1: Recycling and material recovery practices have a significant positive effect on green economy alignment in Serbian manufacturing. Confirmed. The regression analysis shows a statistically significant positive effect ($\beta = 0.412$, $p = 0.020$), supporting the hypothesis.
H2: Product life extension and reuse practices significantly contribute to alignment with green economy goals. Confirmed. The standardized coefficient for this variable is statistically significant ($\beta = 0.378$, $p = 0.026$), validating the hypothesis.
H3: Reverse logistics and returns are positively associated with green economy alignment in manufacturing firms.Not confirmed. Although the coefficient is positive ($\beta = 0.291$), the effect is not statistically significant at the 0.05 level ($p = 0.069$), and thus the hypothesis is not supported.

Table 3 summarizes the diagnostic tests conducted to validate the regression model. The Durbin-Watson value of 2.09 indicates no signs of autocorrelation in the residuals, which supports the independence assumption in the regression analysis. Variance Inflation Factor (VIF) scores for all independent variables are below 2.0, confirming that there are no multicollinearity issues among predictors, and each variable contributes uniquely to the model.
In addition, the distribution of residuals was evaluated using normal probability plots and histogram analysis, which showed an approximately normal distribution. These diagnostics confirm the validity of the regression model and support the conclusion that the estimated relationships are both statistically and practically meaningful. The absence of diagnostic

violations improvesthe credibility of the findings and reinforces the model's suitability for explaining the role of circular practices in supporting green economy objectives.

Table 3. *Model diganostics*

Diagnostic Test	Result	Interpretation
Durbin-Watson	2.09	No autocorrelation
VIF (all variables)	<2.0	No multicollinearity
Residuals Normality	Satisfied	Distribution is approximately normal

DISCUSSION

The findings of this study highlight the pivotal role that specific circular supply chain practices play in enhancing green economy alignment among Serbian manufacturing firms. The high mean scores for all three independent variables indicate a generally favorable attitude toward circular practices, suggesting that sustainability is increasingly integrated into operational strategy. Notably, recycling and material recovery emerged as the most widely implemented strategy. This could be attributed to the relatively low entry barriers for adopting recycling procedures, as well as the presence of both regulatory support and financial incentives for materials recovery in Serbia. In contrast, reverse logistics demonstrated lower average implementation, potentially reflecting infrastructural or logistical constraints that hinder its widespread adoption.

Regression analysis confirmed that both recycling and product life extension practices have statistically significant and positive effects on green economy alignment. These findings suggest that companies that invest in internal recycling systems and design products for durability are more likely to perceive alignment with sustainability goals. The statistical insignificance of reverse logistics, while still positively correlated, suggests either inconsistent implementation or a lack of visibility in its environmental benefits. This is a critical insight for both practitioners and policymakers, as it points to a need for targeted interventions and infrastructure development to facilitate the return and reuse of products.

From a managerial standpoint, the results reinforce the importance of embedding circularity into strategic planning and day-to-day operations. Firms that view circular practices not merely as regulatory compliance but as levers for innovation and competitiveness are better positioned to meet evolving environmental standards and consumer expectations. Furthermore, the integration of these practices may enhance brand reputation and open access to sustainability-linked financing opportunities. In this context, the statistical significance of product life extension strategies is particularly notable, as it aligns with global trends in modular product design, repairability, and extended producer responsibility.

The model's ability to explain over half the variance in green economy alignment also speaks to the robustness of the proposed framework. Diagnostic tests support the reliability of the regression model, showing no violations of assumptions related to residual independence, multicollinearity, or normality. This strengthens confidence in the generalizability of the findings, despite the relatively small sample size. However, future studies could expand the sample to include firms from other regions or industrial sectors, as well as compare results across countries to examine how national policies shape the circular economy landscape.

Importantly, these results contribute to the broader discourse on sustainable development in transition economies. Serbian firms, particularly SMEs, often face barriers such as limited technical capacity and financial constraints. However, the study shows that even incremental adoption of circular practices can yield measurable alignment with green economic principles. For policymakers, this highlights the value of fostering ecosystems that encourage collaboration, knowledge exchange, and investment in circular infrastructure. Support mechanisms such as subsidies, training programs, and green procurement policies could amplify the impact of circular logistics at the national level

CONCLUSION

This study examined how circular supply chain practices contribute to achieving green economy goals within the Serbian manufacturing sector. Through the analysis of survey data from 32 manufacturing firms, it was found that recycling, product life extension, and reverse logistics are actively pursued to varying degrees, with recycling being the most widely implemented. The regression model confirmed that recycling and product life extension have a statistically significant positive influence on green economy alignment, while reverse logistics, although positively associated, did not achieve statistical significance.

The findings emphasize the importance of embedding circular practices into operational and strategic supply chain decisions. Companies that prioritize resource efficiency and product longevity are more likely to align with sustainability objectives and benefit from reputational, financial, and regulatory advantages. The evidence also suggests that there is untapped potential in reverse logistics, which, with adequate infrastructural support, could enhance environmental outcomes further.

The study contributes to the literature on circular economy and sustainable logistics by offering empirical validation of their interdependence in a transition economy context. It also provides actionable insights for both industry leaders and policymakers, underscoring the value of targeted support mechanisms to accelerate the shift toward circularity. Future research could expand on these findings by incorporating longitudinal data or cross-country comparisons to deepen understanding of the institutional and economic drivers of circular supply chain adoption.

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