UNIVERSITY OF NIS FACULTY OF MECHANICAL ENGINEERING

THE TENTH INTERNATIONAL CONFERENCE
TRANSPORT AND LOGISTICS
https://doi.org/10.46793/TIL2025.063A

GREEN LOGISTICS AND THE CIRCULAR ECONOMY: DYNAMIC IMPACTS ON LOGISTICS SYSTEM PERFORMANCE AND ENVIRONMENTAL FOOTPRINT

Aleksandra ANDJELKOVIĆ [1]

[1)]*Faculty of Economics, University of Niš, Serbia*

ORCID iDs:Aleksandra ANDJELKOVIĆ https://orcid.org/0000-0002-7053-1830

Abstract

The efficiency of logistics systems plays a crucial role in economic development, enabling the smooth flow of goods and services. However, traditional logistics practices often generate significant environmental impacts, including greenhouse gas emissions and resource depletion. This study investigates the relationship between the implementation of green logistics practices and their effects on environmental sustainability and operational efficiency at the macro level. A panel analysis was conducted for selected European Union countries over the period 2019–2023, examining how the use of renewable energy—as an indicator of green logistics practices—affects CO_2 *emissions per capita and economic performance indicators, such as the share of exports and imports in GDP. The findings indicate that green logistics practices, based on the principles of a circular economy, are associated with improvements in environmental performance, but not with the efficiency of logistics operations.*

Keywords: *green logistics, supply chain, circular economy, efficiency, environment.*

1 INTRODUCTION

Global economic development largely depends on the efficiency of logistics systems. Logistics performance is often used as an indicator of a country's overall productivity; however, logistics activities also have a significant environmental footprint, contributing to greenhouse gas emissions and environmental degradation [6, 12]. Given these challenges, growing attention is being focused on the development of sustainable and green logistics practices that minimize negative environmental impacts while simultaneously enhancing supply chain performance and overall economic efficiency. In parallel, the concept of the circular economy provides a framework for advancing sustainability by applying principles of material loop closure through reuse, recycling, and remanufacturing. This approach reduces resource consumption and waste generation while supporting economic growth. Logistics plays a key role in implementing circular economy principles, as it involves the integrated management of forward and reverse material flows throughout the entire product life cycle, facilitating efficient resource redistribution and the closure of material loops [1, 7].

Integrating green logistics practices with circular economy principles is becoming an increasingly important research and practical challenge. Such integration not only mitigates negative environmental impacts but can also serve as a source of competitive advantage for companies and economies that recognize the potential of sustainable business in a timely manner. Therefore, understanding the interconnections between logistics performance, sustainable practices, and circular models is a crucial step in shaping future economic development strategies grounded in sustainability principles. This paper aims to examine the relationship between the implementation of green logistics practices and their role in enhancing environmental sustainability and operational efficiency of logistics systems at the macro level.

2 LITERATURE REVIEW

The effectiveness of logistics systems is vital to economic growth, as it supports the smooth flow of goods and services throughout supply chains. However, logistics activities also exert significant environmental impacts [6, 8]. They are responsible for generating substantial greenhouse gas emissions, and logistics operations are estimated to contribute approximately 22% of global pollution—a figure expected to increase in the future [2]. Furthermore, logistics infrastructure, including distribution centers and warehouses, negatively affects environmental quality through land use and threats to biodiversity [5]. Addressing these challenges underscores the need to implement green and sustainable practices in logistics and supply chains, transitioning toward green/sustainable logistics models. Green logistics encompasses practices and strategies in supply chains that minimize the environmental and energy footprint of transportation, warehousing, material handling, and packaging [13, 1]. These practices aim to reduce negative environmental impacts while, in some cases, providing competitive advantages by aligning with regulatory requirements and rising consumer awareness regarding sustainability [14]. The adoption of green logistics practices also enhances circularity within supply chains and the broader economy.

The circular economy (CE) emerged as a response to unsustainable production and consumption patterns, seeking to close the loop of the linear "take–make–use–dispose" economic model [3]. CE strategies aim to extend the product life cycle and ensure that products at the end of their life are reused or recycled in new forms [4]. This approach not only mitigates environmental impacts but also reduces production costs [3].

In CE systems, materials are reused or recycled at the end of their life cycle, reducing waste and the demand for virgin resources. Reuse, particularly in logistics packaging, enhances efficiency and lowers costs [15]. Recycling transforms waste into materials suitable for reuse, contributing to pollution reduction and more sustainable logistics processes [4].

Traditional logistics systems follow linear material flows that end in product disposal, leading to significant material loss and environmental pollution. Logistics is generally divided into two main components [3]: forward logistics, which supports procurement, production, and distribution of new products, and reverse logistics, which manages end-of-life processes. The product usage phase, occurring between forward and reverse logistics, represents an intermediate stage where ownership changes and information flows are often interrupted. This disruption hinders efficient recycling. Integrating recyclers (suppliers of secondary raw materials and components) with manufacturers who reuse components and provide repair services facilitates the transition to a circular economy. Previous research identifies logistics as a critical factor in shifting from linear to circular economic models [16, 6].

Beames et al. (2021) identify green logistics as a prerequisite for implementing circular models, as it enables "closing the loop" in value chains, integrates all actors, and manages product returns efficiently [13]. They highlight three strategic dilemmas in adopting green logistics: the degree of centralization of logistics networks, the extent of product servitization (offering functions or services instead of selling products), and the level of coordination among supply chain members [1]. Cheng et al. (2024), analyzing 43 economies from 2010 to 2016, show that higher Logistics Performance Index (LPI) scores—indicating better logistics performance—are associated with a lower environmental footprint, demonstrating the positive environmental effects of improved logistics efficiency. Similarly, Shah et al. (2021) note that green logistics practices reduce emissions, energy consumption, and waste; however, the impact depends on industry type and the level of integration within supply chains [14, 4].

Liu and Ma (2022) highlight the role of green logistics and sustainable supply chains in promoting circularity, particularly through the Internet of Things (IoT). They demonstrate that e-commerce growth and global logistics expansion significantly increase CO_2 emissions and resource consumption. Their integrated IoT-based model links logistics processes with digital sensors, smart warehouses, and vehicle tracking systems, reducing transport emissions by approximately 27% and improving information efficiency in supply chains by nearly 46% [7]. This approach illustrates how digitalization can enhance circularity, optimize flows, and improve resource utilization, partially addressing previous challenges related to integrating actors in reverse logistics.

Considering prior research and practice, logistics has a dual role: it significantly contributes to economic efficiency and development through smooth product flows and integration into international supply chains, yet it also poses substantial environmental challenges. This study examines the relationship between the degree of green logistics implementation and its impact on environmental and operational performance. The following hypotheses guide this research:

H1: There is a positive correlation between the implementation of green logistics practices and the reduction of environmental impacts.

H2: There is a positive correlation between the implementation of green logistics practices and improvements in operational logistics efficiency.

3 METHODOLOGY AND RESULTS ANALYSIS

The aim of this study is to examine the relationship between the implementation of green logistics practices and environmental performance, as well as the effects of these practices on the economic efficiency of logistics systems. Accordingly, the research is based on a panel analysis of selected European Union countries[1] for the period 2019–2023, using data from available international databases. Focusing on European Union countries is justified because developed economies generally adopt green logistics technologies and policies more rapidly. Therefore, they provide a suitable basis for assessing the real effects of transitioning to more sustainable logistics models.

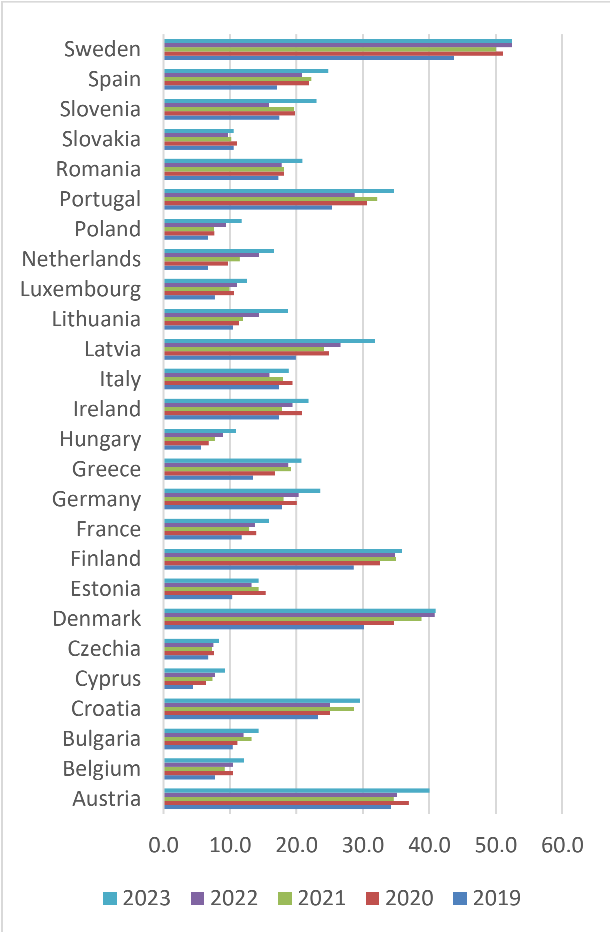

Fig. 1 Renewables (% equivalent primary energy) by country from 2019 to 2023[9]

The research model assumes that the adoption of sustainable energy solutions and the transition to renewable

[1] Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden

energy sources positively influence the reduction of CO_2 emissions, while simultaneously contributing to greater economic openness and competitiveness through increased trade activity.

One of the most suitable and commonly used indicators of logistics operational efficiency is the LPI. However, since this index is not published annually, it is difficult to use it for continuous efficiency evaluation. Therefore, the share of exports and imports in GDP was used as an indicator of economy-wide logistics efficiency [5, 11]. A higher share of exports and imports in GDP indicates more advanced logistics infrastructure and greater international integration, making it a valid proxy for macro-level logistics performance. Similarly, although the Environmental Performance Index (EPI) would be the most appropriate measure of environmental performance, its biennial publication limits its applicability in year-to-year analyses. For this reason, CO_2 emissions per capita (in tons) were used as the environmental performance indicator. While the EPI provides a broader environmental assessment, CO_2 emissions per capita represent a more direct measure of the environmental impact of economic and logistics activities, with annual data available for almost all countries [2, 14].

The share of renewable energy use (%) was employed as an indicator of the degree of implementation of green logistics practices or sustainable policies. This measure is widely used as an indicator of the green transformation of logistics or the transition to sustainable energy sources [5]. Table 1 presents the variables included in the study, their labels, units of measurement, and data sources.

Table 1 Variables

Type of variable	Indicator	Label	Unit of measurement	Source
Dependent variables	CO_2 emissions per capita (ton)	CO_2	t per capita	Our World in Data [9]
	Exports of goods and services (% of GDP)	EX	%	World Bank [17, 18]
	Imports of goods and services (% of GDP)	IM		
Independent variable	Renewables (% equivalent primary energy)	RE	%	Our World in Data [10]

Source: Author

To evaluate the proposed hypotheses, regression analysis was conducted using the SPSS software package. The results show that, in most of the observed countries, there is generally a negative relationship between the use of renewable energy (RE) and carbon dioxide (CO_2) emissions, although it is not always statistically significant. This indicates that a higher share of renewable energy tends to reduce CO_2 emissions, as expected. However, the significance level (Sig.) shows that this relationship is not significant in all countries. The relationship is strong and significant only in some countries, where changes in renewable energy use clearly affect emissions. In Belgium, Bulgaria, Croatia, Estonia, Finland ($p = 0.053$, borderline significance), Greece, Latvia, Lithuania, Poland, Portugal, Romania, Slovakia, Slovenia, and Spain, p-values are high, indicating that an increase in RE cannot be conclusively associated with a decrease in CO_2 emissions. Table 2 presents the countries where H1 is supported.

Table 2 Regression analysis (RE & CO2)

Country	Coefficient B	Std. Error	Beta	t	Sig.
Austria	-3.521	0.746	-0.939	-4.719	0.018
Cyprus	-0.723	0.214	-0.890	-3.375	0.043
Czechia	-9.937	1.080	-0.983	-9.201	0.003
France	-10.768	3.340	-0.881	-3.224	0.048
Germany	-2.203	0.394	-0.955	-5.595	0.011
Hungary	-1.615	0.382	-0.925	-4.226	0.024
Ireland	-1.924	0.252	-0.975	-7.626	0.005
Italy	-1.910	0.582	-0.884	-3.283	0.046
Luxembourg	-11.095	1.581	-0.971	-7.016	0.006
Netherlands	-2.027	0.271	-0.974	-7.479	0.005
Sweden	-0.530	0.087	-0.962	-6.109	0.009

Source: Author

Additionally, regression results indicate that in almost all observed countries, exports and imports do not significantly affect renewable energy (RE) use. This implies that the relationship between logistics performance and green logistics practices may not be strictly linear or may be influenced by other macroeconomic factors. Table 3 shows the two countries where H2 is either fully or partially supported.

Table 3 Regression analysis (RE & EX/IM)

Country	**Variable**	**B**	**Std. Error**	**Beta**	**t**	**Sig.**
Estonia	(Constant)	229.830	17.970	—	12.790	0.006
	EX	0.083	0.007	1.410	12.077	0.007
	IM	-0.193	0.027	-0.828	-7.093	0.019
Slovakia	(Constant)	170.761	25.264	—	6.759	0.021
	EX	-0.003	0.005	-0.217	-0.562	0.631
	IM	-0.070	0.024	-1.141	-2.955	0.098

Source: Author

Thus, considering the results from Table 3, Estonia stands out, where both relationships are statistically significant ($p < 0.05$). Exports (EX) positively influence renewable energy (RE) use, whereas imports (IM) have a negative effect, indicating a strong link between economic performance and foreign trade dynamics. In Slovakia, a borderline significant negative relationship between IM and RE was observed, while in the other countries the coefficients were not statistically significant, although they exhibited varying directions of influence. These results suggest that the relationship between logistics efficiency (measured via EX and IM) and RE use is heterogeneous across countries, depending on their economic structure, competitiveness, and degree of integration into international supply chains.

4 CONCLUSION

This study examined the impact of green logistics practices, based on circular economy principles, on environmental performance and logistics system efficiency at the macro level across selected European Union countries from 2019 to 2023. The findings indicate that the adoption of renewable energy as a key indicator of green logistics practices generally contributes to the reduction of CO_2 emissions, although the magnitude and statistical significance of this effect differ across countries. Also, these findings are consistent with previous studies that have highlighted the importance of factors other than the adoption of green logistics practices in reducing the environmental footprint, such as a higher degree of integration among supply chain participants or the implementation of information technologies [4, 7, 14].

The analysis shows that the implementation of green logistics practices, measured by the use of renewable energy (RE), generally does not affect logistics efficiency, as measured by exports (EX) and imports (IM), in most of the observed countries. The only exception is Estonia, where exports (EX) positively and imports (IM) negatively influence renewable energy use, confirming H2 only in this case. This suggests that the impact of green logistics practices on operational efficiency depends on specific macroeconomic and structural factors. In most countries, the adoption of green logistics practices does not lead to improvements in logistics efficiency. These results indicate that policies and strategies promoting green logistics practices should be tailored to the specific economic and infrastructural context, as gains in operational efficiency do not automatically accompany ecological benefits.

This study has several limitations. First, logistics efficiency and environmental performance were proxied by exports/imports and CO_2 emissions per capita, which may not fully capture all relevant aspects. Second, the analysis covers a limited set of EU countries over a relatively short period (2019–2023), restricting generalizability. Finally, the regression models identify correlations but cannot establish causality, and the use of renewable energy as a proxy represents only one dimension of green logistics practices.

REFERENCES

1. Beames, A., Claassen, G. D. H., Akkerman, R., 2021, *Logistics in the Circular Economy: Challenges and Opportunities*, in: Rezaei, J. (ed.) Strategic Decision Making for Sustainable Management of Industrial Networks. Greening of Industry Networks Studies, 8., pp. 1-14. Springer, Cham. https://doi.org/10.1007/978-3-030-55385-2_1
1. Cheng, H., Chaudhry, H. R., Kazi, I., Umar, M., 2024, *Unlocking greener supply chains: A global innovative perspective on the role of logistics performance in reducing ecological footprints*, Journal of Innovation & Knowledge, 9(4), No. article 100612. https://doi.org/10.1016/j.jik.2024.100612
2. Jayarathna, Ch. P., Agdas, D., Dawes, L., 2024, *Viability of sustainable logistics practices enabling circular economy: A system dynamics approach*, Business Strategy and the Environment, 33(4), pp. 3422-3439. https://doi.org/10.1002/bse.3655
3. Ji-Hyland, C., White, D., Khaydarov, R., 2025, *The impact of circular economy practices on sustainable logistics performance*, International Journal of Logistics Research and Applications, 28(10), pp. 1220–1246. https://doi.org/10.1080/13675567.2025.2465579
4. Khan, S. A. R., Godil, D. I., Yu Z., Abbas, F., Shamim, M.F. A., 2021, *Adoption of renewable energy sources, low-carbon initiatives, and advanced logistical infrastructure—An step toward integrated global progress,* Sustainable Development, 30(1), pp. 275-288, 10.1002/SD.2243
5. Khan, S.A.R., Jian, C., Zhang, Y., Golpîra, H., Kumar, A., Sharif, A., 2019, *Environmental, social and economic growth indicators spur logistics performance: From the perspective of South Asian Association for Regional Cooperation countries*, Journal of Cleaner Production, 214, pp. 1011-1023, 10.1016/J.JCLEPRO.2018.12.322
6. Liu, Ch., Ma, T., 2022, *Green logistics management and supply chain system construction based on internet of things technology*, Sustainable Computing: Informatics and Systems, 35, Article no. 100773. https://doi.org/10.1016/j.suscom.2022.100773
7. Magazzino, C., Alola, A. A., Schneider, N., 2021, *The trilemma of innovation, logistics performance, and environmental quality in 25 topmost logistics countries: A quantile regression evidence*, Journal of Cleaner Production, 322 (September), Article no. 129050, 10.1016/j.jclepro.2021.129050
8. Our World in Data, CO_2 and Greenhouse Gas Emissions, CO_2 and Greenhouse Gas Emissions - Our World in Data, Accessed, 05.11.2025.
9. Our World in Data, Renewable Energy, Renewable Energy - Our World in Data, Accessed, 05.11.2025.
10. Rahman, M. M., Vu, X. B., 2020, *The Nexus between Renewable Energy, Economic Growth, Trade, Urbanisation and Environmental Quality: A Comparative Study for Australia and Canada*. Renewable Energy, 155, pp. 617-627. https://doi.org/10.1016/j.renene.2020.03.135
11. Rashidi, K., Cullinane, K., 2019, *Evaluating the sustainability of national logistics performance using data envelopment analysis,* Transport Policy, 74, pp. 35-46, 10.1016/J.TRANPOL.2018.11.014
12. Seroka-Stolka, O., Ociepa-Kubicka, A., 2019, *Green logistics and circular economy,* Transportation Research Procedia, 39, pp. 471-479. https://doi.org/10.1016/j.trpro.2019.06.049
13. Shah, K. J., Pan, Sh. Y., Lee, I., Kim, H., You, Z., Zheng, J. M., Chiang, P. Ch., 2021, *Green transportation for sustainability: Review of current barriers, strategies, and innovative technologies*, Journal of Cleaner Production, 326, No. article 129392. https://doi.org/10.1016/j.jclepro.2021.129392

14. Silva, N., Pålsson, H., 2022, *Industrial Packaging and its Impact on Sustainability and Circular Economy: A Systematic Literature Review*, Journal of Cleaner Production 333, Article no. 130165. https://doi.org/10.1016/j.jclepro.2021.130165
15. WHITEPAPER, Future Challenges in Logistics and Supply Chain Management: Moving in Circles: Logistics as Key Enabler for a Circular Economy, Whitepaper Social Networked Industry ganzheitlich entwickeln, Retrieved, 10.10.2025.
16. Wordl Bank(a), Imports of goods and services (% of GDP) | Data, Accessed, 05.11.2025.
17. World Bank, Exports of goods and services (% of GDP) | Data, Accessed, 05.11.2025.

Contact address:
Aleksandra Andjelković
University of Niš
Faculty of Economics
18000 Niš
Trg kralja Aleksandra Ujedinitelja 11
E-mail: aleksandra.andjelkovic@eknfak.ni.ac.rs