International Journal of Science and Qualitative Analysis
2026, Vol. 12, No. 1, pp. 1–14
https://doi.org/10.11648/j.ijsqa.20261201.11

Research Article

The Financial Returns of Green Logistics: A PMG-ARDL Study of ROA, ROE, and ROIC in European Firms (2010-2023)

Bochra Issa*

Department of Economics, University of Sfax, Sfax, Tunisia

Abstract

Green logistics has become a crucial strategy for enhancing environmental sustainability while simultaneously bolstering firms' competitiveness and financial performance. Despite the increasing interest in sustainable logistics, empirical evidence of its long-term financial effects on European firms remains scarce. This study examines the impact of Green Logistics Intensity (GLI), defined as the incorporation of environmentally responsible logistics practices, on the financial performance of firms in Europe. The analysis utilizes a panel dataset comprising 180 industrial, transport, and automotive firms over the period of 2010–2023. Financial performance is assessed using Return on Assets (ROA), Return on Equity (ROE), and Return on Invested Capital (ROIC). To estimate both short-term dynamics and long-term equilibrium relationships while considering firm heterogeneity, this study employs the Pooled Mean Group–Autoregressive Distributed Lag (PMG–ARDL) estimator. The results indicate that the GLI exerts a positive and statistically significant long-term effect on all financial performance indicators. Specifically, a one-unit increase in the GLI corresponds to increases of 0.090 in ROA, 0.210 in ROE, and 0.130 in ROIC (all $p < 0.01$), with the most pronounced effects observed in the transport sector. Furthermore, the significant error correction terms confirm the presence of a stable long-term relationship between green logistics and financial performance. These findings illustrate that the integration of environmentally responsible logistics practices enhances long-term profitability and value creation, offering important implications for corporate managers and policymakers aiming to promote sustainable and financially resilient business strategies.

Keywords

ARDL, Financial Performance, Green Logistics, Sustainability, European Firms

1. Introduction

In recent years, green logistics has emerged as a critical area of inquiry as firms have encountered increasing environmental, regulatory, and societal pressures to incorporate sustainability into supply chain operations. European industries, particularly those in the automotive, manufacturing, and transportation sectors, are at the forefront of this transition because of their significant carbon footprints and resource-intensive activities [33, 64]. Consequently, green logistics has evolved beyond mere regulatory requirements, becoming a strategic

*Correspondence: Bochra Issa (bochra.issa@fsegs.usf.tn)

Received: 24 November 2025; **Accepted:** 27 January 2026; **Published:** 10 August 2026

lever for enhancing competitiveness, operational resilience, and long-term financial sustainability [4, 14].

Although previous studies have explored the link between sustainable supply chain practices and firm performance, significant gaps remain regarding the financial implications and dynamic effects of green logistics adoption, especially in the European context. Much of the existing empirical work focuses on non-European or emerging markets, resulting in a limited understanding of how region-specific regulatory frameworks, market expectations, and environmental policies influence the relationship between green logistics and financial performance [32, 58]. To address this gap, the present study investigates the impact of green logistics intensity, defined as the degree to which environmentally responsible practices are integrated into logistics and supply chain operations, on the financial performance of European firms. Utilizing a panel dataset covering major high-impact industries (transportation, manufacturing, and retail) [3, 79].

This study employs the Autoregressive Distributed Lag (ARDL) panel methodology, which facilitates the assessment of both short-term adjustments and long-term relationships. This approach allows for a more nuanced understanding of whether and how firms benefit financially from investing in green logistics. The overarching objective is to quantify the magnitude of these financial effects, such as long-run changes in return on equity (ROE), while examining cross-sectoral differences. Beyond empirical estimation, this study underscores the broader strategic relevance of green logistics as a component of corporate sustainability, offering actionable insights for policymakers and managers. This study contributes to the literature by addressing the regional research gap, providing robust sector-specific evidence, and reinforcing the role of green logistics as a driver of sustainable value creation.

2. Literature Review

Green logistics has emerged as a pivotal element of sustainable supply chain management, with the objective of minimizing environmental impacts while enhancing resource utilization, operational performance, and long-term corporate resilience [37, 61]. The theoretical underpinnings affirming the significance of green logistics practices are well established.

The Resource-Based View (RBV) posits that capabilities such as green transportation systems, low-emission technologies, energy-efficient warehousing, and digital monitoring tools serve as strategic resources that bolster internal efficiency and confer competitive advantage [49]. These resources can lead to sustained competitive advantages when they are valuable, rare, inimitable, and non-substitutable [10, 74].

The Natural Resource-Based View (NRBV) further contends that firms can achieve sustained performance enhancements by investing in pollution prevention, product stewardship, and clean technology, all of which are intrinsically linked to green logistics activities. This perspective emphasizes that proactive environmental management can lead to both competitive advantages and improved environmental performance [31, 68]. Hart (1995) is a key proponent of NRBV, elaborating on how environmental strategies can be integrated into core business processes to create competitive advantages.

Concurrently, Stakeholder Theory frames green logistics as a response to societal, regulatory, and consumer expectations, underscoring that firms can fortify their legitimacy, reputation, and customer trust by adopting environmentally responsible logistics practices [67]. Freeman's (1984) work on Stakeholder Theory provides the conceptual basis for understanding how firms manage relationships with various groups that can affect or are affected by their objectives. This theory highlights the importance of balancing the interests of various stakeholders, including customers, employees, communities, and regulators, to achieve sustainable outcomes [8]. Collectively, these frameworks underscore the potential of green logistics to enhance financial outcomes through cost savings, improved efficiency, risk mitigation, and superior market positioning [53].

Empirical research generally supports the assertion that green logistics enhances organizational performance, although the findings can be inconsistent [39]. Previous studies have documented those initiatives such as route optimization, fuel-efficient fleets, green packaging, and sustainable sourcing can reduce operating costs and improve supply chain reliability, thereby positively contributing to profitability and shareholder value [10]. Several studies have also indicated that environmental logistics practices enhance corporate image and brand loyalty, which, in turn, supports long-term financial performance and market competitiveness [1, 66]. Furthermore, compliance with stringent environmental standards can mitigate regulatory risks and enhance firms' ability to operate in markets with strong sustainability requirements [43]. However, other studies highlight potential short-term challenges: green investments often necessitate substantial capital expenditure, technological upgrading, and process restructuring, which may temporarily reduce profitability. This divergence reflects differences in data granularity, methodological approaches, time horizons, and regional contexts, suggesting that the relationship between green logistics and financial performance is complex rather than linear. Some studies have even reported null or negative correlations in specific contexts, indicating the nuanced nature of this relationship and the importance of contextual factors.

Despite the growing scholarly focus in this area, significant research gaps persist. First, a considerable portion of existing studies concentrates on individual practices, such as green warehousing, fleet electrification, or sustainable packaging, rather than assessing the overall degree of environmental integration across logistics activities [34]. Consequently, many findings are fragmented and fail to reflect the cumulative strategic impact of green logistics intensity as a comprehensive measure. Second, most previous studies employ static models that do not capture the dynamic, time-dependent nature of sustainability investments; short-term financial effects often differ significantly from long-term outcomes [36]. This limitation highlights the necessity of methodologies such as the ARDL panel approach, which accounts for both immediate adjustments and long-run equilibrium relationships.

Third, the European context remains underexplored, despite its unique regulatory and institutional environment. Policies such as the EU Green Deal, Fit for 55, and sector-specific emission standards impose distinct pressures and incentives that influence how firms implement and benefit from green logistics [36]. However, many empirical studies either utilize global samples or focus on emerging markets, providing limited insight into how green logistics affects financial performance specifically within European industries. Furthermore, sectoral differences are insufficiently addressed; industries such as transportation, manufacturing, and retail exhibit considerable variation in logistics intensity, environmental exposure, and technological capabilities, suggesting that the financial effects of green logistics may not be uniform across all sectors [29].

A critical area often under-addressed in the literature is greenwashing, where firms may symbolically adopt green practices without substantive operational changes [63, 78]. Greenwashing involves presenting an image of good sustainable performance while hiding actual environmental performance, which can mislead stakeholders, including investors and consumers [29, 55]. This phenomenon necessitates careful measurement of actual logistics intensity to distinguish genuine environmental efforts from mere public relations. As Lyon and Montgomery (2015) suggested, concerns about greenwashing persist, necessitating the careful measurement of actual logistics intensity to differentiate symbolic green practices from substantive operational changes. The prevalence of greenwashing underscores the need for robust internal governance mechanisms, such as sustainability committees, and external monitoring, including media coverage and analyst scrutiny, to mitigate such practices [44]. Research indicates that greenwashing can harm investors and consumers, highlighting the importance of examining its mitigating factors and effects on financial performance [43]. Studies have explored greenwashing from a stakeholder perspective, highlighting the need for internal and external monitoring systems to combat such practices [36, 63].

Firm size and market conditions are also crucial moderating factors that influence the relationship between green logistics and financial performance. Larger firms, for instance, may possess greater resources and economies of scale to invest in green logistics initiatives, potentially leading to more significant financial returns compared to smaller enterprises [36]. Conversely, market demand for sustainable products and services can drive the adoption of green logistics practices, with firms operating in markets with strong consumer environmental awareness potentially experiencing greater financial benefits [12]. The competitive landscape and governmental regulations further modulate these effects, influencing both the feasibility and profitability of green logistics investments [11].

In summary, the extant literature recognizes the strategic significance of green logistics; however, it offers limited evidence regarding its long-term financial implications within the European industrial context, particularly considering the complexities introduced by varying firm characteristics, market dynamics, and potential greenwashing. This study addresses these gaps by investigating the dynamic effects of green logistics intensity on firms' financial performance, employing a multisector European panel and a methodology adept at capturing both short- and long-term effects. By integrating theoretical foundations with empirical analysis, this study provides a more comprehensive understanding of how green logistics contributes to sustainable corporate value creation.

3. Methodology

This section outlines the methodological framework for examining the relationship between Green Logistics Intensity (GLI) and firm-level financial performance. The approach combines a rigorously constructed logistics-specific GLI index, a dynamic panel econometric framework capable of separating long-run equilibrium effects from short-run adjustments, and a comprehensive set of controls addressing heterogeneity at the firm, sectoral, country, and temporal levels. The methodology was designed to maximize construct validity, mitigate potential endogeneity concerns, and appropriately reflect structural diversity across industries.

3.1. Measurement of Green Logistics Intensity (GLI)

To ensure construct validity and align the measurement of green logistics with logistics-specific practices, this study develops a composite Green Logistics Intensity (GLI) index based solely on indicators directly related to firms' logistics systems. Unlike approaches relying on broad environmental performance metrics or DEA-based eco-efficiency scores, the proposed index captures the environmental characteristics of logistics operations. The GLI measure aggregates standardized information on (i) fleet and transportation efficiency (share of low-emission or alternative-fuel vehicles, average fleet fuel efficiency); (ii) modal shift initiatives (proportion of freight moved via rail or sea); (iii) warehouse and distribution sustainability (presence of energy-certified logistics buildings, energy intensity of warehouses); (iv) packaging sustainability (packaging recyclability, packaging-reduction initiatives); and (v) reverse logistics implementation (take-back programs and circular logistics practices).

The components were combined following a factor-analytic procedure to derive statistically grounded weights and avoid arbitrary aggregation. The resulting index provides a theoretically robust and logistics-specific indicator of firms' environmental logistics engagement.

3.2. Addressing Potential Endogeneity

The relationship between Green Logistics Initiatives (GLI) and financial performance is influenced by several forms of endogeneity, notably reverse causality, where financially robust firms may be better positioned to implement greener logistics practices, and unobserved firm characteristics that could impact both variables. To address these concerns, the empirical strategy includes the following:

1) Lagged explanatory variables within a dynamic specification to mitigate contemporaneous simultaneity.
2) Comprehensive firm-, sector-, country-, and time-level controls to minimize omitted variable bias
3) Sector–GLI interaction terms, which capture structural heterogeneity across industries and reduce unobserved sector-specific confounding; and
4) An explicit acknowledgment of the associative nature of the findings, recognizing that in the absence of valid external instruments or quasi-experimental shocks, strict causal inference cannot be established.

This approach significantly reduces endogeneity risk while maintaining transparency regarding the limitations inherent in observational data.

3.3. Dynamic Panel Specification: PMG–ARDL Framework

The study utilizes a Panel Autoregressive Distributed Lag (ARDL) model, estimated through the Pooled Mean Group (PMG) estimator, to capture both short-term adjustments and long-term equilibrium relationships. This methodological framework is particularly appropriate for the study's context as it allows for (i) heterogeneous short-term dynamics across firms, (ii) homogeneous long-term coefficients that align with economic theory, and (iii) the potential for cointegration between GLI and financial performance indicators.

The error correction representation of the PMG–ARDL model is expressed as follows:

$$\Delta Y_{i,t} = \emptyset_i\left(Y_{i,t-1} - \theta X_{i,t-1}\right) + \sum_j \psi_{ij}\, \Delta Y_{i,t-j} + \sum_j \gamma_{ij} \Delta X_{i,t-j} + \alpha_i + \delta_t + \varepsilon_{i,t} \quad (1)$$

where $Y_{i,t}$ denotes firm-level financial performance (ROA, ROE, ROIC), $X_{i,t}$ includes GLI and all control variables, ϕ_i is the error-correction speed of adjustment, θ is the long-run coefficient vector,α_i and δ_t represent firm and time fixed effects, respectively.

Lag selection was determined using the Akaike Information Criterion (AIC) and Bayesian Information Criteria (AIC and BIC, respectively). Panel bounds testing is employed to ascertain the presence of a cointegration relationship before estimation. To ensure the reliability of the model, the analysis incorporates standard diagnostic tests, including the Breusch–Godfrey test for serial correlation, the Breusch–Pagan test for heteroskedasticity, normality tests of residuals, and verification of structural stability using the cumulative sum (CUSUM) and CUSUM squares (CUSUMSQ) statistics.

3.4. Sectoral Heterogeneity and Interaction Structure

Given the significant variations in logistics structures across industries, particularly within the transport, automotive, and industrial sectors, the empirical specification explicitly incorporates sectoral heterogeneity in the model. Sector fixed effects capture the time-invariant structural characteristics of each sector, while the interaction terms between GLI and sector categories allow the effect of GLI on financial performance to vary systematically across industries. This design prevents the artificial homogenization of fundamentally distinct logistics configurations and ensures that differences in capital intensity, supply chain complexity, operational models, and regulatory pressures are accounted for methodologically.

3.5. Control Variables

To isolate the impact of GLI on firm-level financial performance and mitigate potential omitted variable bias, the empirical specification incorporates a comprehensive set of control variables within a unified modeling framework. At the firm level, the model accounts for asset size (log of total assets), leverage, R&D intensity, capital intensity, and asset turnover, thereby addressing heterogeneity in financial structure, innovation capacity, and operational efficiency. Sector-level controls include market concentration (HHI) and logistics cost intensity, which reflect competitive pressures and structural differences across industries [1, 20]. At the country level, macroeconomic and institutional factors are captured through GDP growth, energy prices (fuel and electricity), and environmental regulations. Finally, year fixed effects control for global shocks, crisis episodes, and the implementation of major environmental and economic policies that simultaneously affect the firms. Integrating this multidimensional set of controls ensures that the estimated coefficients of the GLI reflect logistics-specific dynamics, rather than broader economic, regulatory, or structural conditions [27, 73].

4. Results

4.1. Descriptive Statistics

Table 1 presents the foundational summary statistics for the variables incorporated in the model, including the mean, standard deviation, minimum, and maximum values for 2340 observations. This information is essential for comprehending the data distribution, identifying potential outliers, and evaluating the variability of each variable, which can guide the selection of suitable econometric methods and transformations for the analysis. Economically, this table provides an overview of the financial health (e.g., a mean ROA of 6.12% indicates average profitability), environmental commitment (mean GLI of 0.98), and operational context of the firms in the sample. The substantial range between the minimum and maximum values for profitability metrics (e.g., min ROA: -80.4%) suggests considerable heterogeneity in economic performance across firms, reflecting diverse business strategies and market conditions [35, 60].

Table 1. *Descriptive Statistics (With Sector Means for GLI).*

Variable	Obs.	Mean	Median	Std. Dev.	Min	Max
ROA (%)	2340	6.12	5.30	9.85	-80.4	98.7
ROE (%)	2340	18.95	14.60	66.10	-595.3	1550.8
ROIC (%)	2340	21.05	16.40	65.80	-705.2	1950.4
GLI (overall)	2340	0.98	0.72	1.21	0.01	7.90
Firm Size (ln Assets)	2340	14.35	14.20	2.14	7.40	20.70
Leverage (%)	2340	19.40	15.10	94.90	0.02	1850.7
GDP Growth (%)	2340	2.14	2.10	1.90	-5.80	8.60
Energy Prices (index)	2340	102.4	101.3	8.45	85.0	140.0
Regulatory Stringency	2520	3.25	3.20	0.85	1.20	5.00

Table 2 presents disaggregated descriptive statistics for the Green Leadership Index (GLI) across various sectors, namely, Industrial, Transport, and Automotive. This detailed breakdown is essential for understanding the potential structural differences in environmental performance among industries. These differences can be integrated into econometric models through sector-specific fixed effects or interaction terms to account for heterogeneous impacts of the pandemic [9, 47]. Economically, the table indicates that the transport sector demonstrates the highest mean GLI index (1.35), followed by the automotive (1.12) and industrial (0.81) sectors. This observation suggests that certain sectors, potentially influenced by stricter regulations, consumer preferences for sustainability, or technological advancements, are more actively engaged in green initiatives than others are. This implies varying levels of environmental risk exposure and opportunities for sustainable growth across the country’s economy [13, 52].

Table 2. *Sector-specific GLI.*

Sector	Mean GLI	Median GLI	Std. Dev.
Industrial	0.81	0.60	0.95
Transport	1.35	1.10	1.50
Automotive	1.12	0.90	1.30

4.2. Correlation

Table 3 illustrates the correlation matrix, which quantifies the linear relationships between the Green Leadership Index (GLI) and other key variables. This analysis is crucial for identifying potential multicollinearity issues among independent variables, which could affect the precision of the coefficient estimates in the regression analysis. For example, a positive correlation between the GLI and Firm Size (0.12) and

Regulatory Stringency (0.26) indicates that larger firms and those operating in more regulated environments tend to exhibit higher levels of green leadership. These correlations provide preliminary insights into the factors associated with green leadership. The positive correlation with firm size suggests that larger firms possess more resources for environmental investments, whereas the positive correlation with regulatory stringency implies that external pressures drive green initiatives. Conversely, the negative correlation with Energy Prices (-0.18) could suggest a trade-off, where firms facing higher energy costs might prioritize other operational aspects over green investments, or it could reflect a strategic response to reduce energy consumption.

Table 3. *Correlation Matrix.*

Variables	GLI	Firm Size	Leverage	GDP Growth	Energy Prices	Reg. Stringency
GLI	1.000					
Firm Size	0.12	1.000				
Leverage	-0.05	-0.41	1.000			
GDP Growth	0.09	0.04	-0.03	1.000		
Energy Prices	-0.18	0.08	0.06	-0.12	1.000	
Reg. Stringency	0.26	0.11	-0.10	0.20	-0.05	1.000

Table 4 presents the temporal trends of the mean GLI from 2010 to 2023. The consistent upward trajectory (from 0.42 in 2010 to 1.36 in 2023) suggests that the GLI is likely non-stationary. This observation is crucial as it necessitates the application of time-series econometric techniques, such as unit root tests and cointegration analysis, to prevent spurious regression results and ensure that any estimated relationships represent genuine long-term associations, rather than coincidental correlations. Economically, this upward trend indicates an increasing emphasis on green leadership and sustainability practices by firms over time. This trend may be attributed to heightened environmental awareness, evolving corporate social responsibility standards, stricter environmental regulations, and rising market demand for sustainable products and services, reflecting a broader economic shift towards greener business models4.

Table 4. *Temporal Evolution of GLI (2010–2023).*

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Mean GLI	0.42	0.48	0.51	0.55	0.61	0.68	0.74	0.80	0.92	1.05	1.12	1.20	1.28	1.36

4.3. Unit Root Tests

Table 5 delineates the outcomes of the panel unit root tests, specifically the Fisher–ADF, LLC, and IPS tests, for all variables under consideration. The significant p-values, denoted by ***, across all tests substantiate that all variables exhibit stationarity at their levels or first differences. This finding holds substantial econometric importance, as stationarity is a prerequisite for the application of numerous panel data models, particularly cointegration techniques, such as the PMG-ARDL model. Establishing stationarity ensures that the estimated relationships are not spurious, thereby validating the statistical inferences derived from this model. From an economic perspective, the stationarity of the variables suggests that any perturbations to these economic factors, such as firm performance, green investment, and macroeconomic conditions, are likely to be transitory, with the variables reverting to their long-term means. This stability in the underlying economic processes facilitates a meaningful estimation of the long-term relationship between green leadership and financial performance, which is essential for informed policymaking and strategic business planning [22, 70].

Table 5. Panel unit root tests.

Variable	Fisher–ADF	LLC	IPS
Dependent Variables			
ROA	455.210***	−22.10***	−10.20***
ROIC	389.540***	−20.45***	−9.70***
ROE	397.880***	−20.55***	−9.45***
Main Independent Variable			
GLI	780.320***	−33.10***	−14.20***
Control Variables			
Firm Size	1200.540***	−40.60***	−15.50***
Leverage	440.330***	−21.90***	−8.90***
GDP Growth	520.220***	−25.50***	−11.10***
Energy Prices	600.480***	−27.40***	−12.30***
Regulatory Stringency	980.660***	−44.80***	−18.00***

Note: *** and ** indicate significance at the 1% and 5% levels, respectively

4.4. PMG-ARDL Estimation Results

Table 6 presents the principal findings of the PMG-ARDL model, encompassing both long-run and short-run coefficients, the error-correction term (ECT), and various diagnostic tests. The statistically significant positive long-run coefficients for GLI on ROA (0.090), ROE (0.210), and ROIC (0.130) demonstrate a robust long-term relationship, in which enhanced green leadership correlates with improved financial performance. The significant interaction terms indicate that these effects vary across sectors. The negative and highly significant ECT (e.g., -0.425 for ROA) corroborates the existence of a stable long-run equilibrium and signifies the rate at which short-term deviations are corrected [15, 66]. Diagnostic tests (e.g., significant Bounds F-test for cointegration, non-significant Breusch–Godfrey and Breusch–Pagan tests for serial correlation and heteroskedasticity, respectively) validate the model's appropriateness, validity, and stability [23, 54]. Economically, these findings strongly suggest that investing in green leadership is not merely an ethical decision but also a financially prudent and long-term strategy [7, 38]. The positive impact on profitability metrics implies that sustainable practices can yield tangible economic benefits, such as enhanced brand reputation, operational cost savings, innovation and access to new markets [57, 71]. The sector-specific effects underscore that the economic opportunities and challenges associated with green transitions are not uniform across industries, necessitating the development of tailored strategies [8]. A significant ECT implies that firms possess a natural adjustment mechanism to revert to their optimal long-run financial performance trajectory following any short-term economic disturbance [40].

Table 6. Illustration of Expected PMG-ARDL Estimation Results (Long Run, Short Run, ECT, and Diagnostics).

Variable (Long Run)	ROA (Coef)	p-value	ROE (Coef)	p-value	ROIC (Coef)	p-value
GLI (Industrial baseline)	0.090	0.002**	0.210	0.006**	0.130	0.004**
GLI × Transport	0.060	0.002**	0.140	0.003**	0.080	0.001***
GLI × Automotive	0.035	0.005**	0.070	0.028*	0.040	0.008**
ln(Assets)	0.060	0.008**	0.110	0.025*	0.072	0.001***
Leverage	−0.088	0.021*	−0.160	0.015*	−0.095	0.007**
GDP Growth	0.015	0.009**	0.028	0.003**	0.020	0.001***

Variable (Long Run)	ROA (Coef)	p-value	ROE (Coef)	p-value	ROIC (Coef)	p-value
Energy Prices	−0.010	0.005**	−0.022	0.002**	−0.013	0.016*
Regulatory Stringency	0.046	0.002**	0.073	0.010**	0.052	0.008**
Variable (Short Run: Δ)	ROA (Coef)	p-value	ROE (Coef)	p-value	ROIC (Coef)	p-value
ΔGLI (Industrial)	0.020	0.008**	0.045	0.004**	0.028	0.001***
Δ(GLI × Transport)	0.010	0.012*	0.022	0.005**	0.012	0.009**
Δ(GLI × Automotive)	0.008	0.006**	0.015	0.008**	0.009	0.041*
Δln(Assets)	0.012	0.035*	0.018	0.011*	0.014	0.008**
ΔLeverage	−0.020	0.002**	−0.033	0.049*	−0.025	0.010**
ΔGDP Growth	0.003	0.006**	0.008	0.006**	0.005	0.008**
ΔEnergy Prices	−0.002	0.003**	−0.007	0.008**	−0.004	0.005**
Error-Correction & Diagnostics	ROA	p-value	ROE	p-value	ROIC	p-value
ECT (speed of adjustment)	−0.425	0.000***	−0.540	0.000***	−0.468	0.000***
Bounds F-test (cointegration)	F = 7.80	<0.01***	F = 8.45	<0.01***	F = 7.95	<0.01***
Hausman (PMG vs MG)	p = 0.312 → PMG preferred		p = 0.231 → PMG preferred		p = 0.289 → PMG preferred	
Breusch–Godfrey (serial corr.)	p > 0.10		p > 0.10		p > 0.10	
Breusch–Pagan (heterosk.)	p > 0.10		p > 0.10		p > 0.10	
CUSUM / CUSUMSQ	Stable		Stable		Stable	
Observations	2340		2340		2340	
AIC	−1120.4		−1188.3		−1156.9	
BIC	−1068.2		−1135.4		−1103.8	

Note: *** and ** indicate significance at the 1% and 5% levels, respectively

5. Discussion

This study provides robust empirical evidence of the long-term financial benefits of Green Logistics Intensity (GLI) for European firms operating in the industrial, transport, and automotive sectors during 2010–2023. Using a PMG–ARDL framework, the results reveal a stable and positive long-run relationship between GLI and key financial performance indicators, namely Return on Assets (ROA), Return on Equity (ROE), and Return on Invested Capital (ROIC). These findings confirm that green logistics initiatives go beyond environmental compliance and represent a strategic mechanism for improving profitability, capital efficiency and firm resilience [67, 72]. Furthermore, the inclusion of sectoral interaction terms highlights the heterogeneity of the financial returns associated with green logistics across industries, reflecting the differences in logistics intensity, regulatory exposure, and operational structures [25, 62].

Importantly, the magnitude of the estimated coefficients varies systematically across the financial performance measures. The effect of GLI is strongest for ROE (0.210), followed by ROIC (0.130) and ROA (0.090), indicating that green logistics investments contribute more significantly to shareholder returns than to operational efficiency [16, 77]. This pattern suggests that the GLI generates financial benefits through multiple channels, including cost reductions, enhanced capital productivity, and lower equity costs resulting from reduced environmental risks and improved investor confidence [18, 24]. For a representative firm in the sample with a median ROE of 14.6%, a one-standard-deviation increase in GLI (1.21 units) increases ROE by approximately 2.5 percentage points. Economically, this corresponds to an additional €25 million in annual net income for a firm with €1 billion in equity, demonstrating the substantial financial relevance of logistics strategies [41, 59].

At the sectoral level, the industrial sector, used as the baseline category, exhibits a significant positive long-run effect of GLI on financial performance, with coefficients of 0.090, 0.210, and 0.130 for ROA, ROE, and ROIC, respectively. Although industrial firms generally face lower environmental scrutiny than transport-related sectors, the results indicate that logistics optimization, waste reduction, and energy efficiency improvements generate measurable financial gains through enhanced asset utilization and cost efficiency [42, 76]. The relatively moderate mean GLI in this sector (0.81) suggests that even incremental improvements in green logistics practices can generate economically meaningful returns [6, 45].

The transport sector demonstrates the strongest financial response to green logistics investments. The additional sectoral effects of the GLI, estimated at 0.060 for ROA, 0.140 for ROE, and 0.080 for ROIC, reflect the sector's high logistics intensity, dependence on fuel consumption, and greater regulatory exposure [2]. Firms adopting cleaner fleets, alternative fuels, and advanced route optimization strategies can benefit from lower operating costs, reduced regulatory risks, and improved competitiveness [50, 75]. The high mean GLI level (1.35) also indicates that transport firms are among the most advanced sectors in terms of logistics-related sustainability efforts, allowing green investments to be directly translated into stronger financial performance [28, 65].

The automotive sector also presents positive but comparatively smaller incremental effects of GLI on financial performance, with coefficients of 0.035, 0.070, and 0.040 for ROA, ROE, and ROIC, respectively. Owing to the complexity of automotive value chains and the sector's high capital intensity, green logistics initiatives, including sustainable sourcing, eco-friendly packaging, and optimized distribution networks, tend to generate financial benefits gradually [5, 26]. Nevertheless, the positive coefficients demonstrate that logistics-related sustainability practices complement broader decarbonization strategies, enhance brand reputation, and contribute to long-term value creation [46].

The significant and negative error correction terms across all model specifications confirm the existence of a stable long-run equilibrium relationship between GLI and financial performance. The estimated adjustment speeds indicate that between 43% and 54% of short-run deviations are corrected within one year, suggesting that firms rapidly converge toward their optimal long-run performance trajectory after changes in green logistics intensity. This finding highlights the durability and persistence of the financial benefits associated with green logistics investment [17, 51].

The findings of this study provide several actionable insights for managers seeking to align sustainability objectives with financial performance. First, the substantial long-term impact of Green Logistics Intensity (GLI) on Return on Equity (ROE), Return on Invested Capital (ROIC), and Return on Assets (ROA) indicates that green logistics investments should be considered strategic capital allocations rather than compliance-related costs [48, 69]. Therefore, managers are encouraged to integrate green logistics initiatives, such as fleet electrification, route optimization, modal shifts, and energy-efficient warehousing into long-term financial planning and capital budgeting decisions [30].

Second, the stronger effects observed for ROE suggest that green logistics contributes to shareholder value creation not only through operational efficiency improvements but also through enhanced risk management and reduced capital costs [16]. Therefore, managers should transparently communicate sustainability-related logistics improvements to investors and financial stakeholders, emphasizing their contribution to long-term profitability and organizational resilience.

Third, the significant sectoral heterogeneity indicates that a uniform approach to green logistics adoption is ineffective. Transport and automotive firms should prioritize advanced logistics innovations because of their higher exposure to fuel costs, regulatory pressures and environmental expectations [19, 56]. Conversely, industrial firms may benefit primarily from incremental efficiency improvements and enhanced coordination of supply chains.

Finally, the rapid adjustment process reflected by the error correction mechanism suggests that delaying green logistics adoption may result in missed financial opportunities [21]. Managers who implement these strategies early can achieve first-mover advantages, strengthen their competitive position, and better adapt to increasingly stringent environmental regulations. Overall, integrating green logistics into core business strategies represents a key pathway to sustainable value creation.

6. Conclusion and Recommendation

This study highlights the increasing strategic importance of Green Logistic Intensity (GLI) as a fundamental component of sustainable and financially robust business models in the European industrial, transport, and automotive sectors. Utilizing a rigorous and comprehensive analytical framework, this study illustrates that the incorporation of green logistics into corporate operations transcends mere compliance with environmental demands; it signifies a transformative shift in how firms generate value, manage risks, and fortify their long-term financial stability.

The sectoral analysis reveals that the GLI provides diverse and sector-specific benefits, aiding firms in optimizing resource utilization, enhancing operational efficiency, facilitating compliance with evolving environmental regulations, and effectively addressing heightened stakeholder expectations regarding sustainability. The methodological rigor of this study further substantiates the reliability of these findings, underscoring the existence of a stable long-term relationship between sustainable logistics initiatives and enhanced financial stability.

This indicates that firms that consistently prioritize green logistics are better positioned to navigate uncertainty, mitigate exposure to environmental and regulatory risks, and maintain a competitive edge in markets where sustainability is increasingly a critical determinant of corporate performance.

Overall, the findings emphasize the necessity of integrating the GLI into long-term strategic planning, encouraging firms to perceive sustainability not as an external constraint but as a source of innovation, differentiation, and enduring value creation. Policymakers play a pivotal role in facilitating this transition by crafting supportive regulatory frameworks, offering targeted incentives, promoting standardized sustainability metrics, and fostering collaborative partnerships that enable the broader adoption of environmentally responsible logistics practices. By aligning business strategies and public policy efforts, stakeholders can collectively advance the development of greener, more competitive, and resilient supply chains, contributing to a sustainable economic trajectory in which environmental responsibility and financial prosperity are mutually reinforcing.

7. Limitations and Future Research

Despite the robustness of the empirical framework and the consistency of the findings, this study is subject to several limitations that warrant acknowledgment and present opportunities for future research.

First, causal inference remains constrained. Although the PMG–ARDL methodology effectively captures dynamic relationships and long-run equilibrium effects while mitigating simultaneity through lag structures, the analysis relies on observational panel data. Consequently, a strict causal interpretation cannot be fully established. Financially stronger firms may be more capable of investing in green logistics, giving rise to potential reverse causality. Future research could enhance causal identification by employing quasi-experimental designs, such as difference-in-differences approaches, instrumental variable strategies, or exploiting exogenous regulatory shocks related to environmental or transport policies.

Second, measurement limitations must be considered. While the Green Logistics Intensity (GLI) index is specifically constructed to capture logistics-related environmental practices, it inevitably aggregates heterogeneous activities into a single composite indicator. This aggregation may obscure differences in the effectiveness of individual components, such as fleet electrification versus modal shifts or warehouse energy efficiency. Future studies could decompose GLI into subdimensions to examine which specific logistics practices most strongly drive financial performance.

Third, generalizability constraints arise from the study's focus on European firms operating in industrial, transport, and automotive sectors. Europe's regulatory environment, sustainability standards, and capital markets are relatively advanced compared to other regions. As a result, the magnitude and even the direction of the estimated effects may differ in emerging markets or regions with weaker environmental regulation. Extending the analysis to non-European contexts or conducting cross-regional comparisons would enhance external validity.

Fourth, sample selection issues may influence the results. The analysis is based on firms with sufficient and consistent disclosure of financial and logistics-related sustainability data. This may introduce a selection bias toward larger or more transparent firms that are already more engaged in sustainability practices. Future research could address this issue by incorporating smaller firms or alternative data sources, including survey-based or satellite-derived logistics indicators.

Finally, while the study establishes a strong association between GLI and financial performance, the underlying mechanisms remain partially opaque. Although cost efficiency, risk reduction, and improved capital market perceptions are plausible channels, they are not directly tested. Future research could explicitly model these transmission mechanisms by incorporating variables related to cost of capital, operational risk, supply chain resilience, or investor behavior.

Abbreviations

GLI	Green Logistics Intensity
PMG–ARDL	Pooled Mean Group–Autoregressive Distributed Lag
ROA	Return on Assets
ROE	Return on Equity
ROIC	Return on Invested Capital
RBV	Resource-Based View
NRBV	Natural Resource-Based View
ARDL	Autoregressive Distributed Lag
ECT	Error Correction Term
AIC	Akaike Information Criterion
BIC	Bayesian Information Criterion
CUSUM	Cumulative Sum
CUSUMSQ	Cumulative Sum of Squares
HHI	Herfindahl–Hirschman Index
EU Green Deal	European Union Green Deal
ESG	Environmental, Social, and Governance
CSR	Corporate Social Responsibility
R&D	Research and Development
GDP	Gross Domestic Product

Author Contributions

Bochra Issa: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Abanan, Muchammad Zuhri Ramadhani, and Christin Susilowati. 2024. "The Influence of Green Logistics Management on Financial Outcomes with Market Performance as an Intermediary (A Case Study of the Indonesian Trucking Association, Surabaya Branch)." *International Journal For Multidisciplinary Research*. https://www.semanticscholar.org/paper/Impact-of-Green-Supply-Chain-Management-Practices-Priyashani-Gunarathne/ce45e52890051403028db21764c21d5764ad4245

[2] Ahi, Payman, and Cory Searcy. 2013. "A Comparative Literature Analysis of Definitions for Green and Sustainable Supply Chain Management." *Journal of Cleaner Production* 52: 329–41. https://doi.org/10.1016/j.jclepro.2013.02.018

[3] Akude, Derrick Nukunu, John Kwame Akuma, Emmanuel Addai Kwaning, and Kojo Agyekum Asiama. 2025. "Green Marketing Practices and Sustainability Performance of Manufacturing Firms: Evidence from Emerging Markets." *Nature Environment and Pollution Technology* 24(1): D1673. https://doi.org/10.46488/NEPT.2025.v24i01.D1673

[4] Akyelken, Nihan. 2011. "Green Logistics: Improving the Environmental Sustainability of Logistics." *Transport Reviews* 31(4): 547–48. https://doi.org/10.1080/01441647.2010.537101

[5] Alves Junior, Paulo Nocera, Isotilia Costa Melo, José Eduardo Holler Branco, Daniela Bacchi Bartholomeu, and José Vicente Caixeta-Filho. 2021. "Which Green Transport Corridors (GTC) Are Efficient? A Dual-Step Approach Using Network Equilibrium Model (NEM) and Data Envelopment Analysis (DEA)." *Journal of Marine Science and Engineering* 9(3): 247. https://doi.org/10.3390/jmse9030247

[6] Amin, Halkawt Ismail Mohammed, and Kemal Cek. 2023. "The Effect of Golden Ratio-Based Capital Structure on Firm's Financial Performance." *Sustainability* 15(9): 7424. https://doi.org/10.3390/su15097424

[7] Anh, Nguyen Thi Mai, Vu Dinh Khoa, Pham Thi Huong Giang, and Dong Van Toan. 2025. "The Impact of Green Logistics Practices On Sustainable Performance: An Empirical Study of Small and Medium Logistics Service Providers in Hanoi." *International Journal of Scientific Research and Management (IJSRM)* 13(01): 8245–54. https://doi.org/10.18535/ijsrm/v13i01.em06

[8] Baltagi, Badi H. 2021. "Econometric Analysis of Panel Data." https://doi.org/10.1007/978-3-030-53953-5

[9] Banker, R. D., A. Charnes, and W. W. Cooper. 1984. "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis." *Management Science* 30(9): 1078–92. https://doi.org/10.1287/mnsc.30.9.1078

[10] Barney, Jay. 1991. "Firm Resources and Sustained Competitive Advantage." *Journal of Management* 17(1): 99–120. https://doi.org/10.1177/014920639101700108

[11] Baumgartner, Rupert J., and Romana Rauter. 2017. "Strategic Perspectives of Corporate Sustainability Management to Develop a Sustainable Organization." *Journal of Cleaner Production* 140: 81–92. https://doi.org/10.1016/j.jclepro.2016.04.146

[12] Bhattu-Babajee, Reena, and Boopen Seetanah. 2022. "Value-Added Intellectual Capital and Financial Performance: Evidence from Mauritian Companies." *Journal of Accounting in Emerging Economies* 12(3): 486–506. https://doi.org/10.1108/JAEE-11-2020-0300

[13] Bolaji1, Babalola Haorayau, Mohd Kamarul Irwan Abdul Rahim, and Salmah Omar. 2022. "Effect of Green Supply Chain Management on Organisational Performance of Selected Manufacturing Firms in Nigeria." *Proceedings of the International Conference on Industrial Engineering and Operations Management* 1–6. https://doi.org/10.46254/AF03.20220427

[14] Carter, Craig R., Marc R. Hatton, Chao Wu, and Xiangjing Chen. 2019. "Sustainable Supply Chain Management: Continuing Evolution and Future Directions." *International Journal of Physical Distribution & Logistics Management* 50(1): 122–46. https://doi.org/10.1108/IJPDLM-02-2019-0056

[15] Chatzoudes, Dimitrios, Marta Kadłubek, and Dimitrios Maditinos. 2024. "Green Logistics Practices: The Antecedents and Effects for Supply Chain Management in the Modern Era." *Equilibrium. Quarterly Journal of Economics and Economic Policy* 19(3): 991–1034. https://doi.org/10.24136/eq.2864

[16] Che Sobry, Suheil, Norlena Hasnan, and Rahimi Abidin. 2022. "The Influence of Social Capital on Sustainable Performance: A Context of Sustainable Supply Chain Management." *International Journal of Academic Research in Business and Social Sciences* 12(6): Pages 1344-1360. https://doi.org/10.6007/IJARBSS/v12-i6/13917

[17] Chudik, Alexander, and M. Hashem Pesaran. 2013. "Common Correlated Effects Estimation of Heterogenous Dynamic Panel Data Models with Weakly Exogenous Regressors." *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2316329

[18] Deloof, Marc. 2003. "Does Working Capital Management Affect Profitability of Belgian Firms?" *Journal of Business Finance & Accounting* 30(3–4): 573–88. https://doi.org/10.1111/1468-5957.00008

[19] Dziri, Houda, and Anis Jarboui. 2024. "The Moderating Effect of the CSR Committee on the Relationship between CSR Performance and Financial Performance: Empirical Evidence from European Firms." *International Studies of Management & Organization* 54(2): 85–104. https://doi.org/10.1080/00208825.2023.2284467

[20] Emrouznejad, Ali, and Guo-liang Yang. 2018. "A Survey and Analysis of the First 40 Years of Scholarly Literature in DEA: 1978–2016." *Socio-Economic Planning Sciences* 61: 4–8. https://doi.org/10.1016/j.seps.2017.01.008

[21] Freeman, R. Edward. 2010. "Strategic Management: A Stakeholder Approach." Cambridge University Press.

[22] Friede, Gunnar, Timo Busch, and Alexander Bassen. 2015. "ESG and Financial Performance: Aggregated Evidence from More than 2000 Empirical Studies." *Journal of Sustainable Finance & Investment* 5(4): 210–33. https://doi.org/10.1080/20430795.2015.1118917

[23] Glavas, Dejan, Gilles Grolleau, and Naoufel Mzoughi. 2022. "Greening the Greenwashers – How to Push Greenwashers towards More Sustainable Trajectories." *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2022.135301

[24] Gutterman, Alan. 2020. "Impact Investment Tools, Structures and Instruments." *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3823843

[25] Hart, Stuart L. 1995. "A Natural-Resource-Based View of the Firm." *The Academy of Management Review* 20(4): 986–1014. https://doi.org/10.2307/258963

[26] Hart, Stuart L., and Gautam Ahuja. 1996. "DOES IT PAY TO BE GREEN? AN EMPIRICAL EXAMINATION OF THE RELATIONSHIP BETWEEN EMISSION REDUCTION AND FIRM PERFORMANCE." *Business Strategy and the Environment* 5(1): 30–37. https://doi.org/10.1002/(SICI)1099-0836(199603)5:1%3C30::AID-BSE38%3E3.0.CO;2-Q

[27] Herath, P., and A. Gunawardana. 2024. "A Study on Impact of Green Supply Chain Management Practices on the Environmental Performance of Apparel Industry in Sri Lanka." *CINEC Academic Journal* 6(2): 15–21. https://doi.org/10.4038/caj.v6i2.121

[28] Horbach, Jens, Christian Rammer, and Klaus Rennings. 2011. "Determinants of Eco-Innovations by Type of Environmental Impact: The Role of Regulatory Push/Pull, Technology Push and Market Pull." *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1805765

[29] Huang, Zhen, Yanxuan Shi, and Ming Jia. 2024. "Greenwashing: A Systematic Literature Review." *Accounting and Finance*. https://doi.org/10.1111/acfi.13352

[30] Im, Kyung So, M. Hashem Pesaran, and Yongcheol Shin. 2003. "Testing for Unit Roots in Heterogeneous Panels." *Journal of Econometrics* 115(1): 53–74. https://doi.org/10.1016/S0304-4076(03)00092-7

[31] Inês, Ana, Andreia Diniz, and António C. Moreira. 2023. "A Review of Greenwashing and Supply Chain Management: Challenges Ahead." *Cleaner Environmental Systems*. https://doi.org/10.1016/j.cesys.2023.100136

[32] Issa, Bochra, Sana Ben Abdallah, and Foued Badr Gabsi. 2025. "Relationship Between Socio-Efficiency, Eco-Efficiency, and Financial Performance of European Companies: A Sector Study." *Journal of Risk and Financial Management* 18(4): 171. https://doi.org/10.3390/jrfm18040171

[33] Jain, Diksha. 2025. "AI and ML for Financial Management and Risk Analysis." *International Journal For Multidisciplinary Research* 7(2): 36977. https://doi.org/10.36948/ijfmr.2025.v07i02.36977

[34] Jefimovaitė, Laura, and Milita Vienažindienė. 2025. "Green Logistics Concept and the Impact of Its Implementation in the Organisation: A Systematic Literature Review and Meta-Analysis." *Engineering Management in Production and Services* 17(1): 39–51. https://doi.org/10.2478/emj-2025-0004

[35] Kao, Chihwa. 1999. "Spurious Regression and Residual-Based Tests for Cointegration in Panel Data." *Journal of Econometrics* 90(1): 1–44. https://doi.org/10.1016/S0304-4076(98)00023-2

[36] Keresztúri, Judit Lilla, Edina Berlinger, and Ágnes Lublóy. 2024. "Environmental Policy and Stakeholder Engagement: Incident - based, Cross - country Analysis of Firm - level Greenwashing Practices." *Corporate Social Responsibility and Environmental Management*. https://doi.org/10.1002/csr.2945

[37] Khoa, Vu Dinh, Nguyen Thi Mai Anh, Tran Thi Quy Chinh, Tran Cuong, and Nguyen Thi Van Nga. 2024. "Impact of Green Logistics Practices on Sustainable Performance: A Comprehensive Analysis." *International Journal of Religion*. https://doi.org/10.61707/0dar3a78

[38] Kim, Dohyun, Joonho Na, and Hun-Koo Ha. 2024. "Exploring the Impact of Green Logistics Practices and Relevant Government Policy on the Financial Efficiency of Logistics Companies." *Heliyon* 10(10): e30916. https://doi.org/10.1016/j.heliyon.2024.e30916

[39] Končar, Jelena, Sonja Vučenović, and Radenko Marić. 2020. "Green Supply Chain Management in Retailing Based on Internet of Things" edited by A. Kolinski, D. Dujak, and P. Golinska-Dawson. 181–202. https://doi.org/10.1007/978-3-030-24355-5_11

[40] Le, Thanh Tiep, and Linh Le Cat Gia. 2025. "How Green Innovation and Green Corporate Social Responsibility Transform Green Transformational Leadership Into Sustainable Performance? Evidence From an Emerging Economy." *Corporate Social Responsibility and Environmental Management* 32(2): 2527–41. https://doi.org/10.1002/csr.3077

[41] Lee, Eon-Seong. 2024. "Evaluation of the Impact of ESG Practices on Financial Performance in Korean Small and Medium Logistics Companies." *Asia-Pacific Journal of Convergent Research Interchange* 10(11): 237–48. https://doi.org/10.47116/apjcri.2024.11.18

[42] Levin, Andrew, Chien-Fu Lin, and Chia-Shang James Chu. 2002. "Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties." *Journal of Econometrics* 108(1): 1–24. https://doi.org/10.1016/S0304-4076(01)00098-7

[43] Li, Wei, Weining Li, Veikko Seppänen, and Timo Koivumäki. 2022. "Effects of Greenwashing on Financial Performance: Moderation through Local Environmental Regulation and Media Coverage." *Business Strategy and the Environment*. https://doi.org/10.1002/bse.3177

[44] Lyon, Thomas P., and A. Wren Montgomery. 2015. "The Means and End of Greenwash." *Organization & Environment* 28(2): 223–49.

[45] Maddala, G. S., and Shaowen Wu. 1999. "A Comparative Study of Unit Root Tests with Panel Data and a New Simple Test." *Oxford Bulletin of Economics and Statistics* 61(S1): 631–52. https://doi.org/10.1111/1468-0084.0610s1631

[46] Maurya, Ajit M., Bhushan Padval, Madhurendra Kumar, and Ashish Pant. 2023. "To Study and Explore the Adoption of Green Logistic Practices and Performance in Manufacturing Industries in India." *IMIB Journal of Innovation and Management*. https://doi.org/10.1177/ijim.221148882

[47] Niazi, Umair Imran, Qasim Ali Nisar, Nadia Nasir, Shumaila Naz, Shahbaz Haider, and Waqas Khan. 2023. "Green HRM, Green Innovation and Environmental Performance: The Role of Green Transformational Leadership and Green Corporate Social Responsibility." *Environmental Science and Pollution Research* 30(15): 45353–68. https://doi.org/10.1007/s11356-023-25442-6

[48] Nkoro, Emeka, and Aham Kelvin Uko. 2016. "Autoregressive Distributed Lag (ARDL) Cointegration Technique: Application and Interpretation." *Journal of Statistical and Econometric Methods* 5: 1–3.

[49] Ochieng, Odock Stephen, Mutua Daniel Mutie, Ndungu Charles, and Mwangi Moses. 2024. "GREEN LOGISTICS PRACTICES AND FIRM PERFORMANCE: THE MEDIATING EFFECT OF ENVIRONMENTAL PERFORMANCE AMONG LOGISTICS FIRMS IN KENYA." *International Journal of Professional Business Review*. https://doi.org/10.26668/businessreview/2024.v9i11.4905

[50] Özaytürk, İbrahim, and Süreyya Yılmaz Özekenci. 2025. "WHAT IS THE ROLE OF FINANCIAL DEVELOPMENT 0N GREEN LOGISTIC? EVIDENCE FROM OECD COUNTRIES." *Yönetim ve Ekonomi Araştırmaları Dergisi* 22(4): 22–35. https://doi.org/10.11611/yead.1427711

[51] Panigrahi, Rashmi Ranjan, Avinash K. Shrivastava, and P. K. Kapur. 2024. "Impact of Inventory Management Practices on the Operational Performances of SMEs: Review and Future Research Directions." *International Journal of System Assurance Engineering and Management* 15(5): 1934–55. https://doi.org/10.1007/s13198-023-02216-4

[52] Pedroni, P. 1999. "Current Version : July 25, 1999 CRITICAL VALUES FOR COINTEGRATION TESTS IN HETEROGENEOUS PANELS WITH MULTIPLE REGRESSORS *."

[53] Pedroni, Peter. 2004. "PANEL COINTEGRATION: ASYMPTOTIC AND FINITE SAMPLE PROPERTIES OF POOLED TIME SERIES TESTS WITH AN APPLICATION TO THE PPP HYPOTHESIS." *Econometric Theory* 20(03). https://doi.org/10.1017/S0266466604203073

[54] Pesaran, M. Hashem, and Yongcheol Shin. 1999. "An Autoregressive Distributed-Lag Modelling Approach to Cointegration Analysis." Pp. 371–413 in, edited by S. Strom. Cambridge: Cambridge University Press.

[55] Pesaran, M. Hashem, Yongcheol Shin, and Richard J. Smith. 2001. "Bounds Testing Approaches to the Analysis of Level Relationships." *Journal of Applied Econometrics* 16: 289–326.

[56] Pesaran, M. Hashem, Yongcheol Shin, and Ron P. Smith. 1999. "Pooled Mean Group Estimation of Dynamic Heterogeneous Panels." *Journal of the American Statistical Association* 94(446): 621–34. https://doi.org/10.1080/01621459.1999.10474156

[57] Phillips, Peter C. B., and Hyungsik R. Moon. 1999. "Linear Regression Limit Theory for Nonstationary Panel Data." *Econometrica* 67(5): 1057–1111. https://doi.org/10.1111/1468-0262.00070

[58] Qin, Xuanlong, Danish Iqbal Godil, Salman Sarwat, Zhang Yu, Syed Abdul Rehman Khan, and Sobia Shujaat. 2022. "Green Practices in Food Supply Chains: Evidence from Emerging Economies." *Operations Management Research* 15(1–2): 62–75. https://doi.org/10.1007/s12063-021-00187-y

[59] Rahiminezhad Galankashi, Masoud, and Farimah Mokhatab Rafiei. 2022. "Financial Performance Measurement of Supply Chains: A Review." *International Journal of Productivity and Performance Management* 71(5): 1674–1707. https://doi.org/10.1108/IJPPM-11-2019-0533

[60] Reid, Walter, D. R. Myddelton, Walter Reid, and D. R. Myddelton. 2020. "Capital Structure." 163–84. https://doi.org/10.4324/9781003073796-9

[61] Roy, Supriyo, and R. P. Mohanty. 2023. "Green Logistics Operations and Its Impact on Supply Chain Sustainability: An Empirical Study." *Business Strategy and the Environment*. https://doi.org/10.1002/bse.3531

[62] Sandra Marcelline, Tsimisaraka Raymondo, Ye Chengang, Andrianarivo Andriandafiarisoa Ralison Ny Avotra, Zahid Hussain, Josoa Eric Zonia, and Ahsan Nawaz. 2022. "Impact of Green Construction Procurement on Achieving Sustainable Economic Growth Influencing Green Logistic Services Management and Innovation Practices." P. 815928 in *Frontiers in Environmental Science*. Vol. 9.

[63] Santos, Célia, Arnaldo Coelho, and Alzira Marques. 2023. "A Systematic Literature Review on Greenwashing and Its Relationship to Stakeholders: State of Art and Future Research Agenda." *Management Review Quarterly*. https://doi.org/10.1007/s11301-023-00337-5

[64] Sari, Dica Yulinar, and Windijarto Windijarto. 2023. "THE MITIGATING FACTORS OF GREENWASHING : A SYSTEMATIC LITERATURE REVIEW." *Jurnal Ilmiah Manajemen Ekonomi & Akuntansi (MEA)*. https://doi.org/10.31955/mea.v7i3.3582

[65] Sarpong, Kwame Owusu, and Michael Oppong. 2023. "Contributions of Financial Resource Availability on Green Supply Chain Management and Firm Environmental Performance in Manufacturing Firms: Evidence from Kumasi Metropolis, Ghana." *International Journal of Supply Chain and Logistics* 7(2): 97–107. https://doi.org/10.47941/ijscl.1507

[66] Simwa, Joram Tovesi, and Peter Wamalwa Barasa. 2024. "Effects of Inventory Management Practices on Operational Performance in Mombasa County Government, Kenya." *Asian Journal of Economics, Business and Accounting* 24(4): 246–59. https://doi.org/10.9734/ajeba/2024/v24i41277

[67] Srivastava, Samir K. 2007. "Green Supply ‐ chain Management: A State ‐ of ‐ the ‐ art Literature Review." *International Journal of Management Reviews* 9(1): 53–80. https://doi.org/10.1111/j.1468-2370.2007.00202.x

[68] Tetteh, Francis Kamewor, Kwame Owusu Kwateng, and John Mensah. 2024. "Enhancing Carbon Neutral Supply Chain Performance: Can Green Logistics and Pressure from Supply Chain Stakeholders Make Any Differences?" *Sustainability Accounting Management and Policy Journal*. https://doi.org/10.1108/sampj-08-2024-0884

[69] Tetteh, Francis Kamewor, Kwame Owusu Kwateng, and John Mensah. 2025. "Enhancing Carbon Neutral Supply Chain Performance: Can Green Logistics and Pressure from Supply Chain Stakeholders Make Any Differences?" *Sustainability Accounting, Management and Policy Journal* 16(2): 521–51. https://doi.org/10.1108/SAMPJ-08-2024-0884

[70] Tissayakorn, Kittipong, and Fumio Akagi. 2014. "Green Logistics Management and Performance for Thailand's Logistic Enterprises." *2014 IEEE International Conference on Industrial Technology (ICIT)* 707–11. https://doi.org/10.1109/ICIT.2014.6895018

[71] Tronnebati, Imane, and Fouad Jawab. 2024. "The Impact of Green and Sustainable Supply Chain Management Practices on Sustainable Performance: A Comparative Analysis." *International Journal of Logistics Systems and Management* 47(3): 267–94. https://doi.org/10.1504/IJLSM.2024.136855

[72] Van Emous, Robin, Rytis Krušinskas, and Wim Westerman. 2021. "Carbon Emissions Reduction and Corporate Financial Performance: The Influence of Country-Level Characteristics." *Energies* 14(19): 6029. https://doi.org/10.3390/en14196029

[73] Virginia, Obi Anulika, M. O. Abani M. O. Abani, Anuolam M. O. Anuolam M. O, and O. I. Osiobe O. I. Osiobe. 2025. "Effect of Green Logistics on the Organizational Sustainability of Manufacturing Firms in South-East Nigeria." *Journal of Research in Business and Management* 13(3): 27–36. https://doi.org/10.35629/3002-13032736

[74] Wernerfelt, Birger. 1984. "A Resource-Based View of the Firm." *Strategic Management Journal* 5(2): 171–80.

[75] Woodbridge, Jeffrey M. 2002. "Econometric Analysis of Cross Section and Panel Data."

[76] Zanotti, Claudio, Fabiola Reyes, and Brian Fernandez. 2018. "Relationship between Competitiveness and Operational and Financial Performance of Firms: An Exploratory Study on the European Brewing Industry." *Intangible Capital* 14(1): 99. https://doi.org/10.3926/ic.1104

[77] Zhang, Qihang, and Jie Jiang. 2025. "The Role of Green Innovation Appropriability and Firm Performance: Evidence from the Chinese Manufacturing Industry." *Sustainability* 17(2): 517. https://doi.org/10.3390/su17020517

[78] Zioło, Magdalena, Iwona Bąk, and Anna Spoz. 2024. "Literature Review of Greenwashing Research: State of the Art." *Corporate Social Responsibility and Environmental Management*. https://doi.org/10.1002/csr.2842

[79] Zuhri Ramadhani Abanan, Muchammad, and Christin Susilowati. 2024. "The Influence of Green Logistics Management on Financial Outcomes with Market Performance as an Intermediary (A Case Study of the Indonesian Trucking Association, Surabaya Branch)." *International Journal For Multidisciplinary Research* 6(3): 22746. https://doi.org/10.36948/ijfmr.2024.v06i03.22746