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THE ROLE OF FINANCIAL DEVELOPMENT ON GREEN LOGISTICS IN EMERGING OECD COUNTRIES: A PANEL ARDL APPROACH

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ABSTRACT

Purpose- This study examines the dynamic relationship between financial development and green logistics in emerging OECD countries by applying a panel ARDL approach. Inspired by Özaytürk and Özekenci (2024), the main goal is to understand how financial development contributes to green logistics transformation in economies with evolving financial infrastructures.

Methodology- The analysis covers nine emerging OECD countries (Turkey, Poland, Mexico, Hungary, Slovakia, Colombia, Latvia, Lithuania, and Estonia) from 2002 to 2021. The dependent variable is the ratio of transport-related CO_2 emissions to GDP, used as a proxy for green logistics performance (Fan et al., 2022). Financial development (FD), foreign direct investment (FDI), and trade openness (TO) serve as explanatory variables. Panel ARDL modeling is employed to capture both long-run and short-run effects, with cross-sectional dependence tested using Pesaran CD (2004), stationarity examined via Levin-Lin-Chu (2002), and common factor structure assessed using PANIC (Bai & Ng, 2004).

Findings- Empirical findings suggest that financial development has a statistically significant and negative effect on CO_2 emissions in the long term, confirming its role in supporting green logistics (Jinru et al., 2022; Xu & Li, 2024). In contrast, FDI and TO do not exhibit significant long-run effects. The short-term impacts of all variables were found to be statistically insignificant, highlighting the crucial importance of institutional quality and environmental governance (Agyabeng-Mensah & Tang, 2021; Barut et al., 2023).

Conclusion- The study underscores the pivotal role of financial development in facilitating green logistics by easing access to environmentally friendly investments. However, financial mechanisms alone are not sufficient; complementary policy tools such as strong environmental regulations, institutional capacity, and governance reforms are necessary to ensure sustainable green logistics transitions in emerging economies (Xu & Li, 2024)..

Keywords: Green logistics, financial development, foreign direct investment, trade openness, panel ARDL.
JEL Codes: F18, O16, Q56.

1. INTRODUCTION

Green logistics refers to a set of sustainable practices aiming to minimize the negative environmental impacts of supply chain activities while enhancing economic and operational efficiency (Abukhader & Jönson, 2004; Seroka-Stolka, 2014). In recent years, especially in emerging economies, financial development has been considered a key driver for the adoption of green logistics practices, as it facilitates investments in environmentally friendly technologies and infrastructure through instruments such as green bonds and sustainability-linked loans (Jinru et al., 2022; Xu & Li, 2024). While previous studies have focused on all OECD countries (Özaytürk & Özekenci, 2024), this study specifically investigates the dynamic relationship between financial development and green logistics in emerging OECD countries, including Turkey, Poland, Mexico, Hungary, Slovakia, Colombia, Latvia, Lithuania, and Estonia. This focus allows for a deeper understanding of the interplay between financial structures and green transformation capacities in these economies, which is critical for policymakers and researchers. The study builds on the theoretical framework emphasizing that financial systems can reduce investment barriers for green projects and enhance environmental performance through improved capital accessibility and governance (Agyabeng-Mensah & Tang, 2021; Fan et al., 2022).

2. LITERATURE REVIEW

Green logistics refers to a set of comprehensive sustainability practices integrated into logistics and supply chain processes, aiming to reduce environmental impacts while improving operational and economic performance (Abukhader & Jönson, 2004; Seroka-Stolka, 2014). Unlike traditional logistics, which primarily focuses on efficiency and cost minimization, green logistics emphasizes reducing CO_2 emissions,

optimizing resource utilization, and enhancing energy efficiency (Sbihi & Eglese, 2007; Piecyk & McKinnon, 2010). These practices include the use of cleaner technologies, improved route planning, adoption of alternative fuels, and circular economy approaches such as waste reduction and recycling (Sarkis, 2003; Ahi & Searcy, 2015).

In addition to environmental benefits, green logistics provides firms with economic and strategic advantages. Cost reductions are achieved through energy efficiency improvements, reduced fuel consumption, and more effective waste management (Nguyen, 2021). Companies implementing green logistics also enjoy enhanced brand reputation, stronger customer loyalty, and better access to capital markets due to improved ESG (Environmental, Social, and Governance) performance (Agyabeng-Mensah & Tang, 2021; Kim et al., 2024). Furthermore, regulatory compliance and alignment with international sustainability standards, such as the European Green Deal, are increasingly becoming prerequisites for global competitiveness (OECD, 2020; Wang et al., 2018).

Economic growth is often found to have a positive relationship with green logistics performance. According to Özaytürk and Özekenci (2024), a one-unit increase in GDP results in a 0.79-unit improvement in green logistics performance in EU countries, suggesting that higher economic output enables more investments in green technologies and infrastructure. This finding aligns with studies by Aldakhil et al. (2018) and Ouni & Ben Abdallah (2024), which also indicate that economic growth supports the adoption of environmentally friendly logistics practices. However, green logistics investments require high upfront costs, which can temporarily reduce trade competitiveness, especially in export-oriented sectors (Liu et al., 2022).

Trade openness (TO), on the other hand, exhibits a more complex and often negative relationship with green logistics. While openness can promote economic growth and facilitate technology transfer, it can also lead to increased emissions and environmental pressures due to higher production and transportation activities (Wang et al., 2023; Özaytürk & Özekenci, 2024). Empirical evidence suggests that in emerging economies, a one-unit increase in trade openness can reduce green logistics performance by as much as 2.40 units in the long term and 10.78 units in the short term (Özekenci, 2025). This paradox highlights the need for balancing economic integration with environmental considerations through targeted policy instruments such as subsidies, tax incentives, and international cooperation.

Foreign direct investment (FDI) is another critical factor influencing green logistics. While some studies support the "pollution halo" hypothesis, suggesting that multinational enterprises introduce cleaner technologies and improve environmental standards in host countries (Pao & Tsai, 2010; Eskeland & Harrison, 2003), others emphasize the "pollution haven" hypothesis, where foreign investors move environmentally harmful operations to countries with weaker regulations (Dean et al., 2009; Famanta et al., 2024). The effect of FDI on environmental performance often depends on the host country's regulatory strength, institutional quality, and the type of investments received (Barut et al., 2023; Sezer, 2023). In emerging economies, evidence shows that FDI does not always contribute positively to green logistics, and in some cases, it may even exacerbate environmental challenges (Yang et al., 2023).

Financial development plays a pivotal role in enabling green logistics transformation. A well-developed financial system enhances access to affordable financing, reduces risk premiums, and encourages long-term investments in green infrastructure and clean technologies (Alshubiri, 2017; Jinru et al., 2022). Financial instruments such as green bonds, sustainability-linked loans (SLLs), and other green financing mechanisms have become vital tools to support these investments (Flammer, 2021; OECD, 2024). Green bonds are particularly instrumental in financing large-scale projects related to renewable energy, energy efficiency, and sustainable transport (Climate Bonds Initiative, 2025). Meanwhile, SLLs incentivize firms to improve ESG metrics by linking borrowing costs to sustainability performance targets (Pop & Atanasov, 2021; Loumioti & Serafeim, 2022).

Despite their potential, financial accessibility in emerging economies is hindered by high transaction costs, weak institutional frameworks, and limited market depth (Fan et al., 2022; Xu & Li, 2024). The lack of standardized definitions and certification systems increases the risk of "greenwashing," undermining investor confidence and reducing the effectiveness of green finance (Zaman & Shamsuddin, 2017). Moreover, the inadequate integration of environmental risks into financial systems makes it difficult for green projects to compete with traditional investments that promise higher short-term returns (Nguyen, 2021).

Theoretical frameworks such as the Natural Resource-Based View (NRBV) and Dynamic Capabilities Theory (DCT) further illuminate the mechanisms linking financial development to green logistics performance. NRBV suggests that firms can achieve sustainable competitive advantages by leveraging green resources, including eco-innovations, sustainable supply networks, and green human capital (Agyabeng-Mensah & Tang, 2021). DCT highlights the need for firms to continuously adapt by sensing environmental changes, seizing green opportunities, and reconfiguring resources to integrate sustainable practices into core operations (Sandberg, 2021).

At the macro level, differences in financial and institutional structures between developed and emerging economies significantly influence the adoption of green logistics. In advanced economies, strong legal frameworks, well-established capital markets, and technological readiness foster green logistics investments (Cole & Elliott, 2003; OECD, 2020). By contrast, emerging economies often struggle with fragmented financial systems, regulatory uncertainty, and institutional weaknesses, which hinder green transitions despite growing environmental awareness (Barut et al., 2023; Sezer, 2023).

Studies on the Belt and Road Initiative (BRI) economies (Li et al., 2021) and BRICS countries (Asif et al., 2024) highlight that the relationship between financial development and green logistics is not straightforward and is heavily mediated by local technological capacity, policy alignment, and energy use patterns. In some cases, foreign investments and trade openness can exacerbate environmental degradation if they prioritize short-term economic gains over sustainability objectives (Yang et al., 2023).

In summary, existing literature emphasizes that financial development alone is insufficient to achieve sustainable logistics transformation. A holistic approach combining financial instruments, strong governance, regulatory reforms, and technological innovations is essential for the effective implementation of green logistics strategies, especially in emerging economies. This study builds upon these findings to explore the

dynamic relationships between financial development, FDI, trade openness, and green logistics performance in emerging OECD countries, providing policy implications for fostering a greener and more sustainable logistics sector.

3. DATA AND METHODOLOGY

This study analyzes the impact of financial development, foreign direct investment (FDI), and trade openness on green logistics in emerging OECD countries using a panel dataset covering the period from 2002 to 2021. The analysis focuses on nine emerging OECD countries: Turkey, Poland, Mexico, Hungary, Slovakia, Colombia, Latvia, Lithuania, and Estonia.

Table 1: Variables

Symbol	Variables	Definition	Source
GL	Green Logistics	The ratio of transport-related CO_2 emissions to GDP	Climate Watch
FD	Financial Development	Financial Development Index	International Financial Statistics (IFS)
FDI	Foreign Direct Investment	Foreign direct investment (as a percentage of GDP)	World Bank
TO	Trade Openness	Total trade/GDP ratio	World Bank

The dependent and explanatory variables are presented in Table 1. The dataset consists of 180 observations (9 countries × 20 years), and descriptive statistics were used to examine the distributional characteristics of each variable. The potential issue of multicollinearity among independent variables was checked using the Variance Inflation Factor (VIF), with all values found to be below 1.15 (Gujarati, 2004). Cross-sectional dependence was tested using Pesaran's CD test (Pesaran, 2004), revealing the presence of significant dependence across all variables. The stationarity of the series was assessed through the Levin-Lin-Chu (LLC) test, and all variables were found to be stationary at the 1% significance level (Levin, Lin, & Chu, 2002). Furthermore, the PANIC test (Bai & Ng, 2004) was conducted to analyze the existence of common factors, confirming the presence of a common unit root effect. Considering that the variables exhibit both I(0) and I(1) properties, the Panel ARDL model was employed to analyze both short- and long-term relationships (Pesaran, Shin, & Smith, 1999). The model specification includes a level equation for long-term relationships and an error correction model for short-term dynamics. The optimal lag length was determined as 1 using the Akaike Information Criterion (AIC), and country fixed effects were controlled without applying a Hausman test. To ensure the validity of the model, various diagnostic tests were conducted, including Wooldridge's test for serial correlation (Wooldridge, 2002) and the Breusch-Pagan test for heteroskedasticity (Breusch & Pagan, 1979). This comprehensive methodological framework aims to capture the dynamic effects of financial development on green logistics performance in emerging OECD countries and to provide robust evidence for policymakers and researchers.

4. FINDINGS

In panel data analysis, the potential simultaneous interactions between countries were tested using Pesaran's (2004) cross-sectional dependence (CD) test. The null hypothesis of this test states that "there is no cross-sectional dependence."

Table 2: Cross-Sectional Dependence Test Results (Pesaran CD Test)

Variable	Z-statistic	p-value	Result
CO_2	6.429	<0.001	Dependence exists
TO	18.365	<0.001	Dependence exists
FD	10.571	<0.001	Dependence exists
FDI	5.714	<0.001	Dependence exists

Table 3: Levin-Lin-Chu (LLC) Unit Root Test Results

Variable	z-statistic	p-value	Stationarity Result
CO_2	–2.496	0.0063	Stationary (I(0))
TO	–4.293	<0.001	Stationary (I(0))
FD	–3.858	<0.001	Stationary (I(0))
FDI	–3.519	0.0002	Stationary (I(0))

The results indicate that there is cross-sectional dependence in all variables. Therefore, the application of second-generation panel data techniques was deemed appropriate.

To determine the stationarity of the variables, the Levin-Lin-Chu (LLC) unit root test was applied. This test examines whether panel series are stationary. All variables were found to be stationary at the 1% significance level.

In addition, the PANIC test (Bai & Ng, 2004) was conducted to evaluate the stationarity of common factors in the panel. The results revealed that none of the four principal components passed the stationarity threshold, indicating the presence of a common unit root effect.

Table 4: PANIC Test – Stationarity of Common Factors

Common Component	ADF Test Statistic	p-value	Stationarity Result
PC1	–3.4964	0.0644	Non-stationary (near)
PC2	–2.3353	0.4446	Non-stationary
PC3	–3.3594	0.0834	Non-stationary
PC4	–0.9047	0.9346	Non-stationary

Table 5: Descriptive Statistics of Variables (2002–2021, 9 countries

Variable	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
CO_2	0.739	0.572	0.036	2.147	0.642	2.148
TO	81.609	43.605	23.911	179.153	0.423	1.719
FD	0.303	0.181	0.011	0.654	0.213	1.551
FDI	4.470	4.497	–1.576	25.320	2.343	9.356

In terms of descriptive statistics, the FDI variable was observed to have high skewness and kurtosis values, indicating the presence of outliers.

The long-run coefficients from the Panel ARDL estimation are presented below. In the long term, financial development was found to have a statistically significant negative effect on CO_2 emissions, suggesting a positive impact on green logistics. The effects of FDI and trade openness were found to be statistically insignificant.

Table 6: Panel ARDL Results – Long-Run Coefficients

Variable	Coefficient	Std. Error	t-statistic	p-value	Significance
FD	–0.731	0.249	–2.936	0.004	**
FDI	–0.040	0.072	–0.556	0.579	NS
TO	0.003	0.002	1.344	0.183	NS

Table 7: Panel ARDL Results – Short-Run Coefficients

Variable	Coefficient	Std. Error	t-statistic	p-value	Significance
ΔFD	–0.275	0.203	–1.355	0.176	NS
ΔFDI	0.032	0.057	0.561	0.575	NS
ΔTO	–0.001	0.001	–0.941	0.348	NS

In the short-run estimation, the coefficients were not statistically significant, indicating that the effects of the variables are more prominent in the long term.

Finally, diagnostic tests were conducted to evaluate the statistical validity and robustness of the model. The results showed no evidence of serial correlation, heteroskedasticity, or multicollinearity.

5. CONCLUSION

This study investigated the dynamic relationship between financial development and green logistics in emerging OECD countries for the period 2002–2021 using the Panel ARDL approach. The findings reveal that financial development has a significant long-term negative effect on CO_2 emissions from transportation relative to GDP, implying that higher levels of financial development contribute positively to green logistics performance. This result suggests that well-developed financial systems can provide the necessary financial infrastructure and accessible capital required for green logistics investments, such as cleaner transportation technologies and sustainable supply chain practices (Alshubiri, 2017; Long et al., 2022).

On the other hand, the effects of foreign direct investment (FDI) and trade openness were found to be statistically insignificant in both the short and long run. These findings align with previous studies emphasizing that the impact of FDI and trade openness on environmental performance may vary depending on country-specific contexts, regulatory frameworks, and the quality of institutional structures (Li & Ramanathan, 2020; Famanta et al., 2024).

The study highlights that promoting green logistics requires not only financial capital but also strong institutional frameworks, effective governance, and comprehensive environmental policies. It underscores that financial development alone is not sufficient for sustainable development; there must also be supportive policy measures and incentives to encourage green investments (Agyabeng-Mensah & Tang, 2021; Xu & Li, 2024).

For policymakers, these results imply that strengthening financial systems and improving access to green finance can play a crucial role in advancing green logistics, especially in emerging economies. Measures such as supporting green bonds, sustainability-linked loans, and environmental subsidies can help overcome the high initial costs associated with green logistics projects and promote long-term environmental benefits.

Overall, this study contributes to the literature by providing empirical evidence on the long-term impact of financial development on green logistics in emerging OECD countries, offering valuable insights for both researchers and decision-makers.

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