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RESEARCH ARTICLE

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Environmental sustainability and green logistics: Evidence from BRICS and Gulf countries by cross-sectionally augmented autoregressive distributed lag (CS-ARDL) approach

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Abstract

The logistics sector plays a crucial role in supporting various aspects of the economy, making it an essential part of a nation's development. However, this sector also contributes to environmental pollution through various emissions. The adoption of environmentally friendly logistics practices presents a promising solution to mitigate adverse environmental impacts. This study aims to investigate the influence of economic growth, green innovation, foreign direct investment, transport emissions, renewable energy, and trade openness on green logistics in both Brazil, Russia, India, China, and South Africa (BRICS) and Gulf countries from 1992 to 2020. This study used an advanced panel approach to obtain robust results, considering cross-sectional dependency and slope heterogeneity. The cross-sectionally augmented autoregressive distributed lag method was employed to analyze long and short-run estimations. Our findings reveal that in Gulf countries, both transport emissions and foreign direct investment have a negative impact on green logistics. In the BRICS countries, economic growth, transport emissions, trade openness, renewable energy, and green innovation have a positive impact on green logistics. The study proposes several recommendations to improve logistics development in both groups of nations and promote sustainability. To achieve carbon neutrality, it is important to adopt green logistics, promote green investments, and support renewable energy, innovation, and sustainable growth.

KEYWORDS
environmental sustainability, CS-ARDL approach, green logistics, green innovation, renewable energy

1 | INTRODUCTION

The logistics industry has experienced rapid global growth in recent years (Aldakhil et al., 2018; Barut et al., 2023; Chakamera & Pisa, 2021; Chen et al., 2023; Koyuncu et al., 2023). This sector is widely recognized as a crucial component of a nation's economy, playing a central role in promoting economic growth and serving as a fundamental pillar for overall economic progress (Zhou et al., 2023; Zhu et al., 2023). Over the recent decades, the logistics sector has emerged as a significant driver of national economies by facilitating the integration of production, manufacturing, and consumption processes (Rashidi & Cullinane, 2019; Zaman et al., 2022). However, with the intensification of international trade competition, nations have come to realize the importance of efficient logistics management in enhancing competitiveness and integrating into global value chains, while preserving economic growth (Çelebi, 2019; Martí et al., 2017; Mohsin et al., 2022; Yingfei et al., 2022). As a result, the optimization of efficient logistics processes has become an essential factor for economic development, domestic consumption, and social well-being.

Efficient logistics are essential for both nations and businesses, as they play a pivotal role in enhancing economic growth and mitigating competitive disadvantages resulting from inefficient supply chain operations. Governments invest in infrastructure to optimize logistics, while companies continuously devise innovative strategies to enhance the competitiveness and agility of their supply chains.

Manufacturing and logistical operations have been identified as significant contributors to the environmental cost (Barut et al., 2023; Islam et al., 2021; Khan et al., 2017). The logistics sector contributes significantly to environmental degradation, primarily through transportation emissions (Aydin et al., 2023; Inkinen & Hämäläinen, 2020; Li et al., 2023; Liu et al., 2023; Xu & Xu, 2022). This sector alone contributes 25–30% of harmful gas emissions annually (Khan, 2019), while the transportation sector is responsible for approximately 23% of global CO_2 emissions (Solaymani, 2019). In 2020, China accounted for 86.76% of transportation-related carbon emissions (TCO_2), which constituted 11% of China's total CO_2 emissions. Transportation not only contributes to global warming but also exacerbates public health issues. Projections indicate that global freight emissions alone will increase by 160% in the absence of environmental measures, and TCO_2 emissions are projected to rise by 60% by 2050 (Robaina & Neves, 2021; Umar et al., 2021). Aldakhil et al. (2018) identified the logistics sector as a significant contributor to carbon emissions and greenhouse gases, exerting a substantial impact on resource sustainability in the Brazil, Russia, India, China, and South Africa (BRICS) economies. Ren et al. (2023) reported that the transportation and storage industry in China emitted 732.48 million tons of CO_2 in 2019, ranking it as the fourth-highest emitting sector. The increased air pollution from the logistics industry primarily results from the increase of vehicles used for transportation.

In response to the climate crisis, nations ratified the Paris Climate Agreement, committing to limit global warming to 2°C or preferably 1.5°C (Rogelj et al., 2016). However, the logistics sector's conventional reliance on fossil fuels perpetuates climate change and global warming, primarily due to increased energy consumption (Anable et al., 2012). The global community is currently emphasizing long-term sustainable development to prevent environmental damage and attain carbon neutrality objectives. Achieving this goal requires significant efforts to reduce greenhouse gas emissions, which in turn necessitates sustainable financial, logistical, and social reforms (Bu & Ali, 2022). In recent years, there has been a growing emphasis on the intersection of environmental concerns and logistics by researchers, environmentalists, policy-makers, regulators, and governments (Barut et al., 2023; Tacken et al., 2014; Tsolaki et al., 2022; Zhang et al., 2020). This emphasis has given rise to the concept of sustainable logistics, which encompasses eco-friendly practices in supply chain management, including green manufacturing, distribution, transportation, management, and shipping (Wang et al., 2017). Green logistics (GRL) is an extension of traditional logistics, aimed at conducting logistics operations in an environmentally responsible manner. This approach promotes both the efficiency of logistics and economic growth while safeguarding the environment (Barut et al., 2023).

GRL, a concept focused on mitigating adverse environmental impacts of logistics operations, addresses factors such as carbon emissions, noise pollution, and waste. Its primary objective is to optimize sustainability across financial, social, and environmental dimensions (Mohsin et al., 2022). According to Dekker et al. (2012), GRL is defined as the equilibrium between social, economic, and environmental considerations, aiming to achieve sustainability objectives while minimizing environmental consequences associated with logistics operations. Jedliński (2014) defines GRL as the efficient management of all supply chain activities aimed at delivering products to customers while minimizing global costs, encompassing factors related to climate change, air pollution, noise, and accidents. McKinnon et al. (2015) proposed a framework for GRL that effectively illustrates the relationship between logistics activities and their environmental impact. Blanco and Sheffi (2017) demonstrated that GRL involves the identification, evaluation, and mitigation of environmental effects associated with logistics services. Due to diverse perspectives taken by researchers, various definitions of GRL exist. The primary objective of GRL is to mitigate the adverse environmental impacts of logistics operations, including carbon emissions, noise pollution, and waste generation, while enhancing financial, social, and environmental sustainability (Mohsin et al., 2022).

The protection of the environment has been a central focus in previous studies, with a primary emphasis on logistical activities (Jianguo et al., 2022; Karaman et al., 2020; Rashidi & Cullinane, 2019). Achieving efficient GRL is imperative and necessitates a transformation of traditional logistics operations. However, the integration of sustainable practices in logistics operations presents substantial challenges for nations globally (Guarnieri et al., 2020; Jørsfeldt et al., 2016; Martins et al., 2019). This transformation involves the substitution of polluting vehicles with eco-friendly alternatives and a comprehensive reconfiguration of all aspects of the supply chain with an ecological approach.

The transformation of logistics activities is related to investment opportunities. In particular, the majority of economic activities that aim to promote environmental sustainability are heavily influenced by the performance of the global logistics industry. This is because logistics plays a crucial role in most economic activities. Additionally, there has been an increase in the demand for logistics services due to foreign direct investment (FDI) (Sikder et al., 2022). Therefore, it is essential to investigate the connection between FDI and environmental pollution in the logistics sector. Furthermore, international trade has a substantial impact on economic activities. As a result, numerous studies investigated the relationship between economic activities and the environment (Afghah et al., 2023; Aneja et al., 2023; Huang et al., 2020; Udeagha & Muchapondwa, 2023a). These studies demonstrate a correlation between economic development indicators, environmental pollution and GRL.

The implementation of green innovation (GRI) presents a solution to reduce CO_2 emissions by minimizing reliance on fossil fuels, representing a pivotal strategy for achieving a sustainable and environmentally friendly ecosystem. Recent studies have provided empirical support to the notion that embracing GRI can result in a substantial reduction in societal costs associated with pollution (Ali, Jianguo, & Kirikkaleli, 2023; Barut et al., 2023; Kirikkaleli & Ali, 2023; Koseoglu et al., 2022). Recognizing the pivotal role of GRI in global efforts to reduce CO_2 emissions and improve GRL, many companies in both emerging and developed economies are motivated to enhance their operational efficiency by adopting effective and environmentally friendly resources to mitigate adverse environmental effects.

The BRICS economies have achieved significant economic growth over the past three decades, with an average annual GDP growth rate of 6.5%. As of 2022, these nations represent 22.6% of global GDP, hold foreign reserves exceeding US$ 4 trillions, and account for 42% of the world's population (Azam, 2019). Despite their economic success, the BRICS economies are grappling with significant challenges related to climate change and carbon dioxide emissions resulting from rapid industrialization (Udeagha & Muchapondwa, 2023b). Notably, China and India exhibit the highest levels of carbon intensity, followed by Russia and Brazil. The International Energy Agency (IEA) highlights that BRICS countries account for 40% of global energy consumption and are substantial contributors to CO_2 emissions. China is the world's leading emitter of carbon dioxide, accounting for approximately 28% of the total global CO_2 emissions, mainly due to its industrial activities (Ali, Jianguo, Kirikkaleli, Bács, & Oláh, 2023). Moreover, the heavy reliance on fossil fuels in these nations significantly amplifies the impact on climate change. The enforcement of stringent environmental regulations plays a pivotal role in their efforts to mitigate carbon emissions, attain carbon neutrality goals, and promote sustainable practices.

Similarly, the Gulf Cooperation Council (GCC) countries have experienced significant economic and demographic growth due a warming climate. These nations also have high levels of CO_2 emissions, making them vulnerable to environmental pollution and the adverse impacts of climate change. According to the European Commission's (2017) data, the countries that currently emit the most CO_2 emissions per capita are located in the Arabian Peninsula. Specifically, Qatar emits approximately 37 tons per capita, Kuwait emits 23.5 tons, and Saudi Arabia emits 19.4 tons. Fossil fuels serve as a significant resource in GCC countries, providing the essential foundation for their economies. The revenue generated from fossil fuel exports constitutes an important portion of their income and fund various industrial activities. However, this reliance on fossil fuels has a detrimental impact on the environment. Although renewable energy sources account for a small portion of these economies' energy mix, they are heavily dependent on fossil fuels. Additionally, the region's growing population, rapid urbanization, and economic development have resulted in increased energy consumption, posing a significant challenge to achieving environmental sustainability (Zmami & Ben-Salha, 2020).

The logistics industry in BRICS and Gulf countries is currently in its early stages of development, primarily emphasizing operational efficiency over environmental concerns. To promote the adoption of environmentally sustainable logistics practices in these regions, it is crucial to create a coordinated framework that addresses the logistics sector, energy consumption, and CO_2 emissions. This approach will facilitate the growth of eco-friendly logistics initiatives. Recognizing the urgency of environmental challenges, the governments of these nations have set ambitious goals for the future. Their objectives include establishing a sustainable environment, promoting a circular economy, and developing a clean, safe, and efficient energy system (Maji et al., 2023; Zhu et al., 2023). To achieve these aims, a concerted effort is required to integrate environmental considerations into the operational strategies of the logistics industry. To expedite this process, policymakers should prioritize the development of regulations and incentives that encourage environmentally friendly logistics practices. This may involve introducing emission reduction targets, offering tax incentives for companies adopting green logistics technologies, and implementing standards for energy-efficient transportation modes. Additionally, collaboration between government, industry stakeholders, and academic institutions is essential for sharing knowledge, conducting research, and implementing best practices in sustainable logistics.

Despite the growing body of research in the field of GRL, significant research gaps persist, which this study aims to address. Although BRICS and GCC nations are among the top carbon emitters and high-performing economies in logistics, the existing literature does not examine the key determinants of GRL in these regions. Notably, previous research has mainly concentrated on specific logistics processes within single countries. Our research broadens the scope to encompass a diverse range of nations, specifically focusing on the BRICS and GCC countries. Moreover, while various studies have explored the relationship between GRL and the environmental and economic performance of companies, there is a scarcity of research investigating this link at the macro or cross-country level.

To assist BRICS and Gulf countries in achieving their carbon neutrality goals, the logistics industry must address significant challenges in energy conservation and emissions reduction (Wang & Dong, 2023). As a result, the adoption and implementation of GRL strategies are crucial for ensuring the long-term sustainability of these nations. Policymakers, environmentalists, and governments are increasingly emphasizing the importance of GRL in mitigating environmental damage (Barut et al., 2023). By embracing eco-friendly practices and optimizing logistics operations, we can contribute to creating a more sustainable and environmentally friendly world for all.

The primary objective of this research is to examine the influence of economic growth (GDP), green innovation (GRI), foreign direct investment (FDI), transport emissions (TCO2), renewable energy (REC), and trade openness (TO) on green logistics in BRICS and Gulf countries from 1992 to 2020. To achieve this objective, this study employed the cross-sectionally augmented autoregressive distributed lag (CS-ARDL) method to investigate both long-run and short-run models. This approach offers several advantages comprised to traditional methods, efficiently addressing common issues related to cross-sectional dependence and slope heterogeneity in panel data estimations (Saygın & İskenderoğlu, 2022). To ensure robustness, we also utilized the augmented mean group (AMG) and common correlated effects mean group (CCEMG) methodologies. The results of this study contribute to provide crucial insights with empirical support for individuals, scholars, economists, and policy-makers.

This research contributes to the existing literature in three significant ways:

ii. Previous research in the field of GRL has primarily focused on analyzing specific logistics processes, such as sustainable warehousing (Agyabeng-Mensah et al., 2020; Ibrahim et al., 2022), green packaging (Afif et al., 2022; Khan et al., 2017; Meherishi et al., 2019; Nguyen et al., 2020; Wandosell et al., 2021), green purchasing (Aich & Tripathy, 2014; Casalegno et al., 2022; Mishra et al., 2023; Schulze et al., 2019; Zaman & Shamsuddin, 2017), and reverse logistics (Abdel-Baset et al., 2019; Agrawal et al., 2015; Richnák & Gubová, 2021; Tseng et al., 2019; Wu et al., 2022). While the aforementioned research offers valuable insights, it is important to note that their conclusions may lack generalizability to encompass the entirety of logistical systems.
iii. Numerous researchers have examined the relationship between GRL and the environmental and economic performance of companies. Our study investigates this relationship at the macro or cross-country level, filling a critical research gap in this area.
iv. Most studies have focused on CO_2 emissions, consumption-based CO_2 emissions and production-based CO_2 emissions. However, they have neglected the potential of TCO_2 emissions as a proxy for achieving sustainable and environmentally-friendly logistics practices. Additionally, we examine the influence of other factors, such as REC, EG and GRI, on GRL in the BRICS and Gulf countries, utilizing the latest dataset from 1992 to 2020.

The article is structured as follows: Section 2 provides an overview of the existing literature, while Section 3 offers a detailed explanation of the methodology employed and the data utilized in the study. The results are presented in Section 4, and Section 5 discusses the findings and policy implications. Section 6 presents the conclusions, and study limitations.

2 | LITERATURE REVIEW

Green logistics is a set of eco-friendly practices adopted by logistics companies to minimize their ecological footprint and promote sustainability in the industry (Ali, Jianguo, Kirikkaleli, Bács, et al., 2023; Ali Jianguo, Kirikkaleli, Mentel, & Altuntaş, 2023; Barut et al., 2023; Chen et al., 2023). Recent literature has highlighted the growing importance of GRL and its development in logistics research. In this section, we provide a comprehensive review of the factors that influence GRL, as explored in this study (Table 1). The first section deals with the relationship between the GRL and renewable energy, while the second section examines the nexus between GRL and environmental sustainability. The third section presents the relationship between GRL and economic growth, and the final part summarizes the research gaps and offers the contributions of this study.

2.1 | Relationship between green logistics and renewable energy

The integration of logistics and renewable energy is rapidly evolving field of research and practical application. Numerous studies have delved into the relationship between logistics performance and environmental quality, particularly in emerging countries. These studies have revealed that the logistics can have a detrimental impact on environmental quality, primarily through increased CO_2 emissions. However, green innovation and the utilization of renewable energy resources have demonstrated a positive effect on improving environmental quality.

The nexus between energy demand and logistics is widely studied topic in the context of the global supply chain (Khan et al., 2020; Wehner, 2018; Zaman & Shamsuddin, 2017; Zhu et al., 2023). Logistics activities heavily rely on fossil fuels, which have adverse environmental sustainability and human well-being impacts (Kurowski, 2017; Liu et al., 2018; Nilsson et al., 2017). Conversely, the adoption of GRL practices has demonstrated a positive impact on environmental sustainability and the promotion of eco-friendly products, often involving biofuels and renewable energy sources to mitigate environmental harm (Fotis & Polemis, 2018). Halldórsson and Kovács (2010) emphasized the importance of energy efficiency and environmental sustainability in addressing GRL and sustainable supply chain management. In contrast, Anable et al. (2012) demonstrated that the transportation sector consumes a significant amount of energy to carry out its logistics activities in a sustainable manner. In light of these considerations, Iakovou et al. (2010) suggest that waste biomass represents a viable policy measure to mitigate reliance on fossil fuel energy and decrease CO_2 emissions. However, the utilization of waste biomass in logistics operations is primarily hindered by its associated costs and complexities.

Moreover, Gold and Seuring (2011) demonstrated that the adoption of bioenergy production serves as a beneficial approach to addressing environmental challenges in logistics activities. Khan et al. (2020) demonstrated that incorporating renewable energy sources in logistics activities can enhance both environmental and economic performance. Several European countries, such as Germany, France, and the Netherlands, have implemented stringent environmental regulations to promote renewable energy adoption and sustainable logistics practices. Khan et al. (2017) emphasized the significance of collaborative efforts between governments and international agencies to improve the adoption of renewable energy and investments in GRL, leading to improved economic and socio-environmental sustainability.

Wang and Dong (2023) studied the nexus between the logistics industry, energy consumption, and carbon dioxide emissions developed in China's major economic regions. Their findings indicate that the development of the logistics industry has a positive impact on both energy consumption and CO_2 emissions, with varying degrees of contribution across different regions. Ali, Jianguo, Kirikkaleli, Bács, et al. (2023) analyzed the heterogeneous effects of energy resources and financial development on sustainable environment. They used advanced statistical methods to examine data from 2000 to 2020 for

TABLE 1 Summary of previous studies overview in green logistics.

Author(s)	Countries	Period	Method	Results
Barut et al. (2023)	E-7 and G-7	1996–2018	Durbin–Hausman cointegration test	E7 countries: FDI and TO reduce GRL. G7 countries: FDI and TO increase GRL.
Jianguo et al. (2022)	BRICS-T countries	2000–2018	CS-ARDL	GRL, GRI and renewable energy decrease CO_2 emissions
Liu et al. (2023)	Asian countries	2007–2020	2SLS, GMM	GRL significantly reduces carbon emissions
Chen et al. (2023)	China	2001–2019	GEE regression	Technological innovation and TO positively affect the GRL
Mohsin et al. (2022)	BRI countries	2007–2018	GMM	GRL is negatively correlated with fossil fuel energy consumption and carbon emissions GRL increase the national income
Magazzino et al. (2021)	25 ranked logistics countries	2007–2018	FMOLS, GMM, QR	Technological innovation and TO significantly boost GRL
An et al. (2021)	BRI countries	2000–2017	FGLS, Sys-GMM	FDI improves GRL operations
Li et al. (2021)	OBRI countries	2007–2019	2SLS, GMM	GRL improves the EG in OBRI, Europe, and MENA countries GRL enhances the environmental pollution in OBRI, Central Asia, and MENA countries
Khan et al. (2020)	ASEAN countries	2007–2018	SEM	Renewable energy in GRL helps with EG and reduces emissions
Khan (2019)	Asian countries	2001–2007	FMOLS, DOLS	GRL operations positively correlated with economic factors.
Khan et al. (2017)	43 countries	2003–2016	GMM	Renewable energy sources can mitigate the harmful effect of logistics operations on environmental sustainability
Aldakhil et al. (2018)	BRICS countries	1995–2015	FMOLS, DOLS	Positive relationship between GRL and country's per capita income
Wang et al. (2018)	113 countries	2007–2014	Heckman's two-stage	GRL performance positively affects exporting of countries.
Zaman and Shamsuddin (2017)	27 EU countries	2007–2014	GMM	Energy, environment, and EG are the determinants of GRL

Source: Author's compilations.
Abbreviations: 2SLS, two-stage least square; BRI, Belt and Road initiative; BRICS-T, Brazil, the Russian Federation, India, China, South Africa and Turkey; DOLS, dynamic ordinary least squares; EG, economic growth; EU, European countries; FDI, foreign direct investment; FGLS, feasible generalized least squares; FMOLS, fully modified ordinary least squares; GEE, generalized estimation equations; GMM, generalized method of moments; GRL, green logistics; MENA, Middle East and North Africa; OBRI, one belt and road initiative; QR, quantile regression; Sys-GMM, system generalized method of moments; TO, trade openness.

the E-7 countries. The study revealed that high levels of financial development, rapid economic growth and increased use of non-renewable energy resources had a significant impact on environmental sustainability over the long-term. Bonab et al. (2023) evaluates risk factors related to the implementation of GRL in renewable energy transition using a modified failure mode and effects analysis approach. They highlighted the importance of considering logistics and renewable energy in sustainable development efforts.

2.2 | Relationship between green logistics and environment

The environment is predominantly influenced by logistics activities. The adoption of GRL can improve environmental quality and alleviate environmental degradation. In logistics operations, various green practices have been implemented, such as procurement, warehousing, distributing, product innovation, transportation and labelling. These practices aim to improve environmental sustainability (Agyabeng-Mensah et al., 2020; Du et al., 2023; Li et al., 2021).

However, the effectiveness of GRL practices may vary depending on the specific context and the adoption of environmentally-friendly technologies. Rao and Holt (2005) highlighted the significance of incorporating green concepts throughout various stages of the supply chain to enhance competitiveness and long-term economic growth. Ubeda et al. (2011) argued that integrating environmental sustainability goals with logistics indicators supports the adoption of GRL, emphasizing the need for efficient mechanized processes and green supply chain practices in transportation logistics. Geiger (2016) examined how information and communication technologies promote environmentally sustainable transportation of goods in Europe, emphasizing their role in reducing freight logistics consumption and enhancing sustainable transportation logistics.

Wang et al. (2017) analyze the impact of GRL on the US economy. Their findings indicated that there is a negative association between GRL and environmental degradation. According to their results, the adoption of GRL practices can improve business performance and reduce CO_2 emissions. Khan et al. (2017) also emphasized the potential of GRL in mitigating CO_2 emissions and solid waste, which ultimately contributes to increased environmental sustainability and societal health. In a study spanning from 2007 to 2016, Liu et al. (2018) examined the relationship between logistics performance and environmental quality for the case of 42 Asian countries. They employed system generalized methods of moments for empirical analysis and discovered that an improvement in GRL leads to a decrease in carbon emissions. Furthermore, their research showed significant relationships between different categories of logistics and environmental quality in different Asian sub-regions.

For the case of 117 economies, Karaman et al. (2020) investigated the impact of the GRL and environmental quality from 2007 to 2016. The results indicate a positive, eco-friendly relationship that contributes to the reduction of environmental deterioration. Similarly, Karaman et al. (2020) explored the nexus between GRL and CO_2 emissions in Balkan economies and identified a positive association between these variables. Agyabeng-Mensah et al. (2020) examine the impact of GRL on Ghana's economy and using structural equation modelling. Their study demonstrated that GRL enhances financial performance and contributes to improved environmental quality in Ghana. For the case of 25 leading logistics countries, Magazzino et al. (2021) evaluate the logistics performance from 2007 to 2018 and using the quantile regression method. Their findings confirmed that a higher levels of logistics performance is associated with decreased environmental sustainability and increased carbon emissions. They also recommended that governments should implement GRL to enhance environmental quality. Wan et al. (2022) analyzed data from 22 emerging nations spanning the period from 2007 to 2018. They used moments quantile regression analysis and discovered the existence of a positive relationship between GRL and environmental degradation. Maji et al. (2023) examines the impact of GRL on environmental sustainability in Bauchi Metropolis, revealing that while 2/3 of logistics managers are aware of the negative impact of logistics activities, only 1/5 actively engaged in GRL initiatives. In the context of 45 Belt and Road Initiative regions, Ali, Jianguo, Kirikkaleli, Oláh, & Altuntaş. (2023) examined the association between technological innovation, financial inclusion, and natural resources, and their impact on environmental degradation from 2001 to 2018. Their findings confirm that natural resources and financial inclusion seem to have contributed to higher levels of regional environmental degradation. Therefore, it is widely recognized that technological innovation plays a crucial role in reducing the amount of CO_2 emissions generated by industrial activities.

2.3 | Relationship between green logistics and economic indicators

The logistics industry is a vital component of a nation's economy (Agyabeng-Mensah et al., 2020; Fan et al., 2022; Karaman et al., 2020; Mohsin et al., 2022; Wang & Wang, 2010; Yu et al., 2018). Studies indicate that incorporating renewable assets into GRL operations can reduce environmental footprints while improving economic outcomes (Cosimato & Troisi, 2015). Coto-Millán et al. (2013) demonstrated that a 1% increase in the GRL leads to an economic growth increase ranging from 0.01% to 0.03%. These studies offer valuable insights at a macroeconomic level regarding the relationship between GRL and EG. Furthermore, Martí et al. (2017) discovered that improvements in the GRL have a positive effect on trade integration in emerging economies.

Boukherroub et al. (2015) demonstrated that firms can mitigate the negative impacts of CO_2 emissions from logistics activities, leading to enhanced economic development, access to new market opportunities, and improved environmental quality. Zaman and Shamsuddin (2017) employed the GMM technique to examine the interrelationship among GRL and various indicators of economic development, observing a positive correlation between GRL and economic growth. In the case of 15 countries, Khan et al. (2017) analyzed the nexus between GRL and economic growth between 2007 and 2015. Their outcomes indicate GRL plays a crucial role in fostering economic development. Moreover, Geng et al. (2017) employed meta-analysis as a methodology to examine the interaction between GRL and the economic development of companies. They established a positive relationship between the implementation of GRL and the economic progression of companies.

Wang et al. (2018) identified a statistically significant relationship between GRL and exports from 2007 to 2014 across 113 countries. Agyabeng-Mensah et al. (2020) utilized structural equation modeling to analyze the economic dynamics of Ghana. Their outcomes found that GRL positively impacts FDI and contributes to the overall economic growth. Similarly, Khan et al. (2020) emphasized the positive impact of GRL on economic development, particularly in relation to FDI across 42 countries. In the case of top Asian economies, Suki et al. (2021) showed that GRL leads to an increase in economic growth.

Li et al. (2021) examined the influence of GRL and environmental goals on the economies of Belt and Road Initiative countries. Their research revealed that GRL strategies contribute to economic development in Central Asia and the Middle East and North Africa. Furthermore, Barut et al. (2023) conducted a comparative analysis of the Group of seven (G7) and Emerging Seven (E7) countries to examine the effects of different economic and financial factors on GRL. The findings indicate that FDI and TO have a negative impact on the implementation of environmentally sustainable logistics practices in E7 countries. Nevertheless, in the G7, FDI and TO contribute to the growth and development of environmentally sustainable logistics systems. Jayarathna et al. (2023) explore how the logistics sector has integrated sustainability practices to promote a circular economy.

They identify three key themes that offer a holistic strategy for implementing circular economy principles in the logistics sector.

2.4 | . Summarizing research gaps and contributions of the study

The efficacy of GRL in mitigating CO_2 emissions has been demonstrated in previous studies (Adebayo et al., 2021; Kirikkaleli et al., 2023; Zhou et al., 2023). However, the impact of GRL on transport-related CO_2 emissions remains inconclusive. Since logistics activities are significant contributors to greenhouse gas emissions, it is crucial to elucidate the precise influence of GRL practices in this context. Addressing this gap is essential for formulating targeted policies and strategies to reduce the environmental footprint of logistics operations.

The role of FDI in shaping GRL practices has not received adequate attention in previous scholarly works. FDI can bring not only capital but also advanced technologies and management practices to host countries. Understanding how FDI influences the adoption and effectiveness of GRL practices is vital, as it can significantly impact a country's economic development and its ability to implement environmentally sustainable logistics systems. Closing this gap will provide valuable insights for policymakers and business leaders seeking to attract FDI while promoting green logistics. Furthermore, previous scholarly works have inadequately addressed the impact of GRI on GRL, despite the potential of this variable to directly influence a country's logistics operations. Therefore, a significant scholarly contribution would be to elucidate the variables that may exert an influence on GRL. The objective of this study is to address the existing research gap within the context of BRICS and Gulf countries by employing the CS-ARDL model. To the best of our knowledge, no studies have been conducted on GCC and BRICS countries utilizing the CS-ARDL to examine the effects of EG, FDI, REC, GRI, TO, and TCO_2 emissions on GRL. To ensure robustness, this study also incorporates the AMG and CCEMG methodologies. A comprehensive understanding of these factors will empower policymakers to formulate strategies aimed at promoting the growth and development of environmentally sustainable logistics practices.

3 | DATA AND METHODOLOGY

3.1 | Data

The present study employed the CS-ARDL approach to analyze the effects of EG, FDI, REC, TO, GRI, and TCO_2 emissions on GRL in BRICS and GCC countries spanning the period from 1992 to 2020. This analysis focused on GRL as the dependent variable, while examining EG, FDI, REC, TO, GRI, and TCO_2 emissions as explanatory variables.

This research focuses on estimating the factors that influence GRL. Previous studies have explored various methods to define GRL. Lau (2011) developed an index known as the "Green Logistics Performance Index" to evaluate the performance of GRL. Nevertheless, this index exclusively evaluates the industries in China and Japan. Similarly, Chen et al. (2015) developed an index to quantify the concept of GRL using carbon emission data specific to the city of Beijing. These two measures were focused on specific nations and sectors, considerably limiting the scope of the datasets. In contrast, Khan et al. (2017) employed an alternative approach in which they evaluated GRL performance by utilizing the Logistic Performance Index, developed by the World Bank to assess countries strengths and opportunities. Other researchers combined this index with total CO_2 emissions to create the Environmental Logistics Performance Index (Aldakhil et al., 2018; Zaman & Shamsuddin, 2017). However, this index isn't perfect because it relies on total CO_2 emissions.

In this study, we measured GRL as the ratio of total GDP to transport-related CO_2 emissions, as established by Zhou et al. (2023), Du et al. (2023), Barut et al. (2023), and Wang et al. (2018). The measurement of TCO_2 emissions is expressed in metric tons per capita, and GDP is measured in constant 2015 US dollars. REC is measured as a percentage of total final energy consumption. TO and FDI are both measured as a percentage of GDP. This study quantifies technological innovation using the GRI, which is determined as the total number of patent applications. The variable of GRI is based on the empirical investigations conducted by Kirikkaleli et al. (2023). The data on GRI is derived from the OECD (2023), while data on GDP, TCO2, FDI, REC and TO is obtained from the WDI (2023). To ensure that the data follows a normal distribution, the parameters were transformed into logarithmic forms.

3.2 | Methodology

The logistics industry is facing increasing pressure to address its contribution to environmental degradation, mainly because it heavily relies on fossil fuels (Saidi et al., 2020). International stakeholders are advocating for eco- friendly alternatives in various aspects such as procurement, warehousing, packaging, and delivery. The goal is to conserve energy and reduce material usage. These discussions have led to the development of the concept of GRL, which promotes ecologically sustainable practices throughout the entire supply chain. Numerous studies have demonstrated a clear nexus between GRL performance and EG (Khan et al., 2017; Li et al., 2021; Mohsin et al., 2022; Zaman & Shamsuddin, 2017). In the 2000s, numerous companies embraced the concept of GRL as a means to boost economic growth. According to Khan et al. (2018), the performance of GRL plays a crucial role in contributing to economic activities and has a direct impact on air pollution.

Existing literature shows that effectively implementing GRL practices effectively alleviates environmental damage, reduces operational costs, enhances energy conservation, and boosts the competitiveness of goods and services (Dhull & Narwal, 2016; Khan et al., 2017). Moreover, the development of the green and low-carbon logistics heavily relies on the implementation of GRI (Chen et al., 2023). GRI introduces new technologies and products that improve energy and operational efficiency in logistics, such as electric vehicles with extended mileage, and the utilization of the Internet of Things. These innovations are crucial for promoting sustainability and reducing the ecological footprint of logistics operations.TO significantly influence GRL as it plays a vital role in the efficient movement of goods and services, contributing to the development and enhancement of the logistics sector and related industries (Wang et al., 2018).

To examine the key determinants of GRL, we developed a model based on the previous studies (Aldakhil et al., 2018; Barut et al., 2023; Du et al., 2023; Zhu et al., 2023), which is given in Equation (1):

$$\mathrm{GRL}_{it} = f\left(\mathrm{GDP}_{it}, \mathrm{FDI}_{it}, \mathrm{REC}_{it}, \mathrm{GRI}_{it}, \mathrm{TO}_{it}, \mathrm{TCO2}_{it}\right). \tag{1}$$

To address multicollinearity and heteroscedasticity issues, all variables in Equation (2) are transformed into natural logarithms (Kirikkaleli & Ali, 2023):

$$\begin{aligned}\mathrm{LnGRL}_{it} = {} & \beta_0 + \beta_1 \mathrm{LnGDP}_{it} + \beta_2 \mathrm{LnFDI}_{it} + \beta_3 \mathrm{LnREC}_{it} + \beta_4 \mathrm{LnGRI}_{it} \\ & + \beta_5 \mathrm{LnTO}_{it} + \beta_6 \mathrm{LnTCO2}_{it} + \varepsilon_{it}.\end{aligned} \tag{2}$$

In Equation (2), Ln signifies the logarithmic transformation applied to all variables, where *i* represents BRICS countries and GCC countries, t spans from 1992 to 2020, and GRL represents green logistics. The other variables are economic growth (GDP), foreign direct investments (FDI), renewable energy consumption (REC), green innovation (GRI), trade openness (TO) and transport carbon dioxide emissions (TCO2). Finally, ε_{it} represents the model's error term.

3.3 | Econometric methodology

This study explores the role of economic growth, green innovation, foreign direct investment, transport emissions, renewable energy, and trade openness in green logistics in BRICS and GCC countries. We employed several econometric procedures to achieve our research objectives. The methodology employed is discussed in detail below.

3.3.1 | Cross-sectional dependence test

The econometric analysis aims to detect the existence of cross-sectional dependence test (CSD). Detecting CSD is crucial to prevent inaccuracies in terms of bias, stationarity, and cointegration results. CSD is a common issue observed in panel data due to factors such as the interdependence of residuals and unobserved common shocks. Neglecting the interconnection between units can lead to incorrect inference, biased stationarity, and cointegration findings. Therefore, we employ Pesaran's (2015) Cross-Sectional Dependence test to examine cross-sectional dependence issues.

3.3.2 | Slope heterogeneity test

When analyzing panel data, it is important to ensure the homogeneity of the coefficients across different groups. To address this issue, Pesaran and Yamagata (2008) proposed a test to check this slope heterogeneity (SH) of the coefficients. They determine the weighted fixed effect pooled estimator to determine SH, and identify deviations from the mean. The estimator suggested by Pesaran and Yamagata (2008) is presented in Equations (3) and (4):

$$S = \sum_{i=1}^{N} \left(\beta_i - \beta_{\mathrm{WFE}}\right), \frac{\left(x_i M_\tau x_i\right)}{\sigma_i^2} \left(\beta_i - \beta_{\mathrm{WFE}}\right), \tag{3}$$

$$\Delta = \sqrt{N}\left(\frac{N^{-1} S - k}{\sqrt{2k}}\right), \tag{4}$$

where β_i is obtained from the OLS estimate. β_{WFE} is the coefficients obtained from the weighted fixed effect pooled estimation. M_τ shows the identity matrix.x^i indicates the processor that is sensitive to deviation from the mean containing explanatory variables.

3.3.3 | Panel unit root test

The next step is the second-generation panel unit root test to examine the data stationarity, after confirming the presence of CSD and SH between the variables. The first generation unit root test has limitation in its ability to handle challenges related to CSD. In order to address this issue, we utilized Pesaran's (2007) second-generation unit root test. Equation (5) outlines the cross sectionally augmented Dickey-Fuller (CADF) unit root test as follows:

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \gamma_i \overline{y}_{t-1+} \sum_{j=0}^{p} \theta_{ij} \Delta \overline{y}_{t-j} + \sum_{j=1}^{p} \delta_{ij} \Delta y_{it-j} + \epsilon_{it}, \tag{5}$$

where $\overline{y} = N^{-1} \sum_{j=1}^{N} y_{it}$.

3.3.4 | Panel cointegration test

This study used the second-generation cointegration test to evaluate the long-run association among GRL, GDP, GRI, FDI, TCO_2 emissions, REC, and TO. The second-generation cointegration such as Kao (1999), Pedroni (2004) and Westerlund (2005) cointegrating tests are employed in this study. The application of the Westerlund panel cointegration test allows the same null hypothesis as Kao and Pedroni, but the alternative hypothesis is different. In the Westerlund test, the alternative hypothesis suggests that the variables are cointegrated in some panels, as indicated by the group average statistics. The alternative theory implies that the variables are cointegrated in all panels.

The Pedroni panel cointegration test offers significant flexibility, enabling the examination of unrelated long-term cointegrating vectors. Pedroni's cointegration technique incorporates various tests that allow for diverse constants and trend coefficients across multiple countries. Pedroni (2004) hypothesizes seven tests covering both within- and between-panel dimensions.

3.3.5 | Cross-sectionally augmented autoregressive distributed lags

Panel data can experience persistent CSD as a result of various determinants affecting all segments. For instance, economic and financial shocks can impact various socioeconomic elements.

This CSD in the data can lead to inaccurate results in regression analysis. To address the issue of CSD and SH, the CS-ARDL method is employed to examine the presence of the short- and long-run correlation between GRL, GDP, GRI, FDI, TCO_2 emissions, REC, and TO. This approach analyzed dynamic common correlation impacts, accounting for time dynamics (Sharif et al., 2023). In this context, our research focuses on the common elasticity coefficients in CS-ARDL framework and their potential role in contributing to a shared policy framework for promoting sustainable development.

Equation (6) represents the initial form of CS-ARDL:

$$\mathrm{GRL}_{it} = \sum_{i=0}^{Pu} \varphi_{l,i}\mathrm{GRL}_{it-1} + \sum_{i=0}^{Pu} \beta_{it} W_{it-1} + \varepsilon_{i,t}, \tag{6}$$

where in Equation (6), GRL_{it} (green logistics) is the dependent variables, W_{it} represent all explanatory variables (economic growth, green innovation, foreign direct investment, transport emissions, renewable energy, and trade openness).

In addition, by employing the average cross-section of each regressive, Equation (6) was expanded into Equation (7):

$$\overline{K}_{i,t-1} = \left(\overline{\mathrm{GRL}}_{i,t-1}, \overline{W}_{i,t-1}\right), \tag{7}$$

where $\overline{K}_{i,t-1}$ represents the mean of the core variable values, $\overline{\mathrm{GRL}}_{i,t-1}$ and $\overline{W}_{i,t-1}$ is the mean of the explanatory variables. Finally, $\overline{K}$ specifies the average of CSD that has a spillover effect on the data under consideration. Additionally, we extract long-term figures from the short-term coefficient. The mean estimator is given in Equation (8):

$$\pi_{\mathrm{CS-ARDL},i} = \frac{\sum_{l=0}^{pw} \widehat{B_{l,i}^{PU}}}{1-\sum l=0}\varphi_{l,i}. \tag{8}$$

3.3.6 | Robustness check

The two most effective methods for addressing with non-stationary variables are the CCEMG method by Pesaran (2006) and the AMG method by Teal and Eberhardt (2010).

The CCEMG offers a significant advantage by addressing the identification issue through the consideration of SH constraints that might be overlooked due to temporal variations. To eliminate the spillover effects caused by CSD while excluding trends, we achieve this by calculating the average of determinants for all cross-sections. The alternative approach of CCEMG and AMG not only addresses CSD, SH, and structural breaks but also incorporates year-specific adjustments. Consequently, dealing with unobservable factors becomes a more manageable and robust process (Du et al., 2023).

3.3.7 | Panel granger causality test

We investigated causality between the variables using the Dumitrescu and Hurlin (2012) test, a simplified version of Granger's (1969) non-causality test. We opted for this test because it accommodates two distinct dimensions of heterogeneity: one in the regression model employed to assess Granger causality and another in the causality relationship itself. We utilized the following linear model in Equation (9):

$$y_{it} = \alpha_i + \sum_{i=1}^{k} \gamma_i^{(k)} y_{i,t-k} + + \sum_{i=1}^{k} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{i,t}, \tag{9}$$

where $\beta_i^{(k)}$ represents the slope coefficients, α_i represents the cross-sectional unit, and K denotes the lag length. In this context, the null hypothesis suggests that there is no causal relationship in at least one cross-sectional unit. To test this null hypothesis, we used Z-bar statistics ($\overline{Z}$) and Wbar statistic ($\overline{W}$) test, which can be computed as follows:

$$\overline{W} = \frac{1}{N}\sum_{i=1}^{N} W_i, \tag{10}$$

$$\overline{Z} = \sqrt{\frac{N}{2K}}\left(\overline{W} - K\right). \tag{11}$$

4 | EMPIRICAL RESULTS

4.1 | Cross-sectional dependency and slope homogeneity test

Table 2 indicates the presence of CSD among the variables in both BRICS and GCC countries, respectively. The results confirm the existence of CSD among nations for all the variables such as GRL, GRI, GDP, FDI, REC, TO, and TCO2, as observed in the panel data.

Furthermore, as shown in Table 3, we reject the null hypotheses of homogeneity of slope coefficients at a significance level of 1%, confirming the existence of heterogeneity in slope coefficients across both country categories.

4.2 | Panel unit root test

To address cross-sectional dependence and heterogeneity, we employ the CADF test developed by Pesaran (2007) to analyze the stationarity of the variables. Table 4 shows that the GRL and FDI variables are stationary at the first difference, whereas the remaining variables, including GDP, TO, REC, GRI and TCO_2 are stationary at the level in the BRICS country. Nevertheless, all variables demonstrate stationarity at the first difference in the GCC context.

4.3 | Panel cointegration test

Next, we applied panel cointegration tests to investigate the existence of a long-run relationship between the variables. The cointegration analyses are based on Pedroni (2004), Westerlund (2005), and Kao (1999) cointegration tests, with GRL considered as the dependent variable. The results are presented in Table 5. For both panels, the Westerlund (2005) tests indicate a significant long-run relationship, with two out of four tests rejecting the null hypothesis of no cointegration among the time series, as evident from the obtained p-values. Pedroni's (2004) results remain consistent across both panels; two panel-statistic tests within the dimension and two group statistic tests among three reject the null hypothesis of no cointegration. Finally, the computed ADF statistic from Kao's (1999) test confirms that we can accept the alternative hypothesis. In conclusion, based on the results of these tests, it can be concluded that a significant long-term relationship is observed among the analyzed series for both groups of countries.

TABLE 2 Results of cross-sectional dependence test for Brazil, Russia, India, China, and South Africa (BRICS) and Gulf Cooperation Council (GCC) countries.

	BRICS countries		GCC countries	
Variables	Statistics	*p* values	Statistics	*p* values
GRL	17.920***	.000	23.918***	.000
GDP	14.217***	.000	9.556***	.000
TO	19.265***	.000	15.241***	.000
REC	3.045***	.000	4.059***	.000
GRI	4.623***	.000	4. 959***	.000
TCO_2	16.256***	.000	13.199***	.000
FDI	7.269***	.000	6.470***	.000

Note: Significance levels 1%, 5%, 10% are denote by ***, **, and *.
Source: Author's estimations.

TABLE 3 The findings of the slope heterogeneity analysis.

	BRICS countries		GCC countries	
Statistics	Statistics	*P* values	Statistics	*p* values
Delta tilde	7.758***	.001	5.260***	.000
Delta tilde adjusted	9.746***	.000	4.896***	.000

Note: Significance levels 1%, 5%, 10% are denote by ***, **, and *.
Source: Author's estimations.

4.4 | Estimation of long-run and short-run coefficients

In this paper, we employed the CS-ARDL methodology to investigate the dynamic relationships between GRL and several key variables, including FDI, REC, GDP, GRI, TCO2, and TO, in both the BRICS and GCC country groups. As demonstrated in Table 6, our analysis revealed the presence of a significant long-term relationship among these variables, supported by the negative and significant error term, confirming the model's convergence over the long term. Considering the nexus between GRL and GDP, our findings indicate that in the BRICS countries, a 1% increase in GDP leads to a 0.793% increase in GRL over the long term. However, the impact of GDP on GRL is positive but insignificant in the GCC countries. In the context of BRICS countries, our findings reveal a surprising trend: an increase in TCO_2 corresponds to an improvement in GRL performance. Conversely, in GCC countries, the results show that an increase in TCO_2 emissions leads to a decrease in GRL. Furthermore, in BRICS countries, the results demonstrate that FDI positively influences GRL.

Specifically, a 1% increase in FDI corresponds to a 0.124% increase in GRL. In contrast, our results for Gulf GCC countries show that FDI has a negative impact on GRL. Similarly, a 1% increase in FDI decreases GRL by 0.174%. The study's findings reveal distinct patterns in the relationship between TO and GRL across two groups of countries. In GCC countries, a positive relationship between TO and GRL is evident. The coefficient of TO implies that a 1% increase in TO increases GRL by 0.742%. However, in the case of BRICS countries, a negative correlation between TO and GRL has been observed; a 1% increase in TO leads to a decrease in GRL by 0.593%. Similarly, the GRI significantly increases GRL in both GCC and BRICS countries, contributing to substantial environmental benefits and promoting sustainable economic growth.

TABLE 4 CADF panel unit root test.

	BRICS countries		GCC countries	
Variables	Level	First difference	Level	First difference
GRL	−2.464	−3.472***	−1.320	−3.321***
GDP	−1.297***	−3.104***	−2.446	−3.782***
TO	−1.654***	−3.210***	−2.430	−3.770***
REC	−1.994***	−3.986***	−2.161	−3.346***
GRI	−1.768***	−3.761***	−2.630	−3.340***
TCO_2	−1.935***	−3.402***	−2.149	−4.932***
FDI	−3.330	−3.623***	−1.840	−3.203***

Note: Null hypothesis indicates that time series are not stationary, ***, **, and * denote statistical significance level at 1%, 5%, and 10%, level, respectively.
Source: Author's estimations.

TABLE 5 Cointegration tests results.

	BRICS countries		GCC countries	
Westerlund cointegration test				
Statistic	Value	*p* value	Value	*p* value
G_t	−3.679	.000***	−2.569	.109
G_a	−3.537	.007**	−3.932	.702
P_t	−2.312	.198	−8.670	.030**
P_a	−1.968	.027**	−9.342	.020**
Pedroni cointegration test				
Alternative hypothesis: Common AR coefficients (within-dimension)				
	Statistic	*p* value	Statistic	*p* value
Panel v-statistic	−2.081	.370	−3.589	.870
Panel rho-statistic	−0.562	.450	2.319	.733
Panel PP-statistic	−4.316	.003***	−5.216	.001***
Panel ADF-statistic	−4.317	.004***	−6.898	.000***
Alternative hypothesis: Individual AR coefficients (between-dimension)				
Group rho-statistic	1.708	.948	1.509	.820
Group PP-statistic	−2.674	.005***	−5.702	.000***
Group ADF-statistic	−2.116	.007***	−4.332	.000***
Kao cointegration test				
	***t* statistic**	**Prob**	***t* statistic**	**Prob**
ADF	−3.253	0.002***	−1.247	0.078*

Note: ***, ** and * shows statistical significant at 1%,5% and 10%, respectively.

4.5 | Robustness check

Table 7 displays the results derived from the AMG and CCEMG models, which were employed to conduct a comprehensive assessment of the robustness check. The findings from the analysis of GCC countries indicate that the variables TCO_2 emissions and FDI have coefficient values of 0.033 and 0.270, respectively. These coefficients suggest that a 1% increase in these variables leads to a decrease in the GRL. Regarding the BRICS countries, the analysis of the AMG model reveals coefficients of 0.180, 0.363, and 0.270 for the variables of GDP, GRI, and FDI, respectively. These coefficients suggest that a 1% increase in these variables is associated with an increase in the GRL. Both the AMG and CCEMG tests align with congruent findings to the CS-ARDL, as corroborated by Barut et al. (2023), who provide support for these statistical outcomes.

4.6 | Dumitrescu-Hurlin Granger causality test

In order to enhance the development of more appropriate policy recommendations, a causal analysis will be employed. The results of the Dumitrescu-Hurlin causality analysis are presented in Table 8.

It is evident that there exists a unidirectional causality from TCO2, TO, and GRI to GRL in BRICS countries. Additionally, we observed a bidirectional causality between GDP and GRL, FDI and GRL, and REC and GRL in BRICS countries. In GCC countries, we identified unidirectional causality from GDP, TO, and REC to GRL. Moreover, there is bidirectional causality between TCO2, FDI, GRI, and GRL. These results shed light on the causal links between various factors and green logistics practices in both BRICS and Gulf countries, providing valuable insights for policymakers and stakeholders.

5 | DISCUSSION AND POLICY IMPLICATIONS

5.1 | Discussion

In this study, we investigated the nexus between economic growth, green innovation, foreign direct investment, transport emissions, renewable energy, and trade openness on green logistics in BRICS and Gulf countries from 1992 to 2020. In recent years, the nexus between GRL and sustainable development has garnered international interest from scholars, economists, governments, and policymakers (Karaman et al., 2020; Kurbatova et al., 2020; Mete, 2020; Vienažindienė et al., 2021). The BRICS and GCC regions also face unique environmental challenges. BRICS countries, in particular, are known for their significant contributions to global carbon emissions, making them pertinent for studying the environmental impact of logistics (Wahab et al., 2022). The GCC countries, on the other hand, recognize the need to diversify their economies away from fossil fuels due to environmental concerns, making GRL a crucial aspect of their sustainability efforts.

Considering the nexus between GRL and GDP, our findings indicate that in the BRICS countries, a 1% increase in GDP leads to a 0.793% increase in GRL. These results align with previous studies by Zaman and Shamsuddin (2017), Aldakhil et al. (2018), Barut et al. (2023), and Nazir et al. (2023). For the BRICS countries, economic growth creates an environment favorable to adopting green logistics practices due to increased consumer demand, growing environmental concerns, technological advancements, international pressure, cost-effectiveness, alignment with sustainable development goals, and the presence of attractive investment opportunities.

In the context of BRICS countries, the outcomes indicated that TCO_2 has a significant positive influence on GRL. This means that as these countries experience higher carbon emissions, they tend to adopt more sustainable logistics practices. Several factors may contribute to this positive relationship, such as government policies, investments in eco-friendly technologies, and growing environmental awareness. Conversely, in GCC countries, the results show that an increase in TCO_2 emissions leads to a decrease in GRL. This suggests that higher carbon emissions are associated with lower levels of adoption of sustainable logistics practices in this region. The divergent relationship observed between TCO_2 and GRL in BRICS and GCC countries highlights the importance of considering regional disparities, policies, and cultural factors when addressing environmental issues and promoting sustainable practices. Factors such as access to

TABLE 6 Findings of cross-sectionally augmented autoregressive distributed lag (CS-ARDL) for both panels (dependent variables: GRL).

	BRICS countries				GCC countries			
	Long-run		Short-run		Long-run		Short-run	
Variables	Coefficients	*p* values	Coefficients	*p* values	Coefficients	*p* values	Coefficients	*p* values
GDP	0.793	.000***	0.953	.109	0.213	.356	0.953	.000***
TCO_2	0.255	.001***	−0.006	.019**	−0.071	.049**	0.349	.552
TO	−0.593	.000***	0.084	.829	0.742	.002***	−0.467	.812
REC	0.836	.000***	0.043	.910	0.417	.007***	0.418	.526
FDI	0.124	.000***	−0.251	.000***	−0.017	.042**	−1.677	.040**
GRI	0.058	.004***	−0.025	.025**	0.018	.000***	0.571	.260
ECM (−1)			−1.367	.000***			−0.176	.002***

Note: Significance levels 1%, 5%, 10% are denoted by ***, **, and *.
Source: Author's estimations.

TABLE 7 Findings of AMG–CCEMG analysis (dependent variables: GRL).

	BRICS countries		GCC countries	
Variable	AMG	CCEMG	AMG	CCEMG
GDP	0.180 (0.000)***	0.210 (0.000)***	0.233 (0.000)***	0.353 (0.006)***
TCO_2	0.265 (0.000)***	0.123 (0.000)***	−0.033 (0.001)***	−0.026 (0.05)**
TO	−0.175 (0.000)***	−0.163 (0.000)***	0.173 (0.001)***	0.218 (0.000)***
FDI	0.270 (0.000)***	0.257 (0.000)***	−0.270 (0.000)***	−0.257 (0.000)***
GRI	0.363 (0.001)***	0.263 (0.048)**	0.302 (0.05)**	0.263 (0.048)**
REC	0.132 (0.012)**	0.212 (0.000)***	0.119 (0.002)***	0.203 (0.000)***
Wald test	12.630 (0.000)***	22.690 (0.000)***	13.160 (0.000)***	16.981 (0.000)***

Note: Significance levels 1%, 5%, 10% are denoted by ***, ** and *.
Source: Author's estimations.
Abbreviations: AMG, augmented mean group common; CCEMC, correlated effect mean group.

TABLE 8 Panel Dumitrescu and Hurlin (2012) granger causality test for BRICS and Gulf countries.

	BRICS countries			GCC countries		
Null hypothesis (H0)	*F* statistic	*p* value	Decision	*F* statistic	*p* value	Decision
GRL ≠ GDP	3.737	.001***	GRL cause GDP	4.836	.716	No causality
GDP ≠ GRL	4.103	.013**	GDP cause GRL	5.947	.080*	GDP cause GRL
GRL ≠ TCO2	1.819	.602	No causality	2.770	3E−05***	GRL cause TCO_2
TCO2 ≠ GRL	5.967	2E−05***	TCO_2 cause GRL	2.350	5E−07***	TCO_2 cause GRL
GRL ≠ TO	5.124	.872	No causality	5.740	.667	No causality
TO ≠ GRL	2.124	.000***	TO cause GRL	2.654	.000***	TO cause GRL
GRL ≠ FDI	3.136	.002***	GRL cause FDI	5.934	.036**	GRL cause FDI
FDI ≠ GRL	4.695	.029*	FDI cause GRL	3.935	.061*	FDI cause GRL
GRL ≠ GRI	3.071	.128	No causality	4.070	.023**	GRL cause GRI
GRI ≠ GRL	5.908	.003***	GRI cause GRL	2.825	.011**	GRI cause GRL
GRL ≠ REC	5.956	.001***	GRL cause REC	4.637	.157	No causality
REC ≠ GRL	7.515	.000***	REC cause GRL	6.428	.010**	REC cause GRL

Note: $X \neq Y$ means that *X* does not cause *Y*. Significance levels 1%, 5%, 10% are denoted by ***, ** and *.
Source: Author's estimations.

renewable energy, regulatory frameworks, technological infrastructure, and public awareness play a vital role in how TCO_2 emissions affect GRL practices in different regions.

In BRICS countries, the results show that FDI positively influences GRL. Specifically, a 1% increase in FDI corresponds to a 0.124% increase in GRL. This finding aligns with the conclusions of several previous studies (An et al., 2021; Barut et al., 2023; Li et al., 2021; Saidi et al., 2020). This trend can be attributed to a growing awareness among investors about environmental responsibility, leading to the introduction of eco-friendly technologies and practices into their investments. Governments also play a critical role in promoting green logistics by implementing policies that encourage and incentivize environmentally friendly practices for both domestic and foreign companies.

The study's findings reveal distinct patterns in the relationship between TO and GRL across the two groups of countries. In GCC countries, a positive relationship between TO and GRL is evident. However, in the case of BRICS countries, a negative correlation between TO and GRL has been observed. The positive correlation in GCC countries can be attributed to their economic context. In developing nations like these, there is a strong emphasis on boosting productivity to increase exports. However, this focus on productivity can sometimes lead to environmental degradation, as noted by Dinda (2004). Environmental regulations may not be as stringent, and increased trade can introduce pollution-intensive technologies through imports. Additionally, the expansion of trade often spurs transportation operations, resulting in higher environmental degradation due to increased transportation activities. Furthermore, the prevalence of land transportation in logistics operations, often reliant on fossil fuels, can contribute to this outcome.

In contrast, economically developed nations tend to adopt more rigorous environmental regulations. They engage in trade while simultaneously incorporating modern, fuel-efficient vehicles and advanced technologies into their logistics operations. This approach helps alleviate the adverse environmental impacts related to transportation and logistics. These findings highlight the complex interplay between trade openness and green logistics. While GCC countries experience a positive relationship due to their focus on productivity and less stringent environmental regulations, BRICS countries demonstrate a negative correlation as they prioritize environmental sustainability through advanced technologies and regulatory measures.

Similarly, GRI significantly increases the GRL in both GCC and BRICS countries, leading to substantial environmental benefits and promoting sustainable economic growth. Our findings align with Ding et al. (2021), Xu et al. (2022), Li et al. (2023) and Liu et al. (2023). GRI refers to the development and implementation of technologies, practices, and processes prioritizing environmental sustainability and minimize negative impact on the planet. When integrated into logistics operations, GRI enhances the optimization of transportation, distribution, and supply chain processes, fostering more sustainable and efficient practices.

Similarly, the adoption of REC significantly increases GRL in both GCC and BRICS countries, contributing to an environmentally friendly supply chain. Our results align with those of Wang et al. (2018), Yu et al. (2021), Gawusu et al. (2022), Jianguo et al. (2022), and Barut et al. (2023). It is essential to note that the adoption of renewable energy is a crucial aspect of GRL; it is most effective when combined with other sustainable practices, such as efficient transportation, route optimization, and eco-friendly packaging. The incorporation of REC encourages research and development in sustainable technologies, driving innovation in the logistics sector and promoting the creation of more efficient and eco-friendly logistics solutions.

5.2 | Policy implications

Based on our comparative analysis, we propose several recommendations to enhance logistics development in both groups of countries. These recommendations aim to strike a balance between economic growth and environmental preservation, fostering a greener and more sustainable future. By adopting green logistics practices and implementing the proposed strategies, BRICS and Gulf countries can contribute to mitigate the environmental impact of the logistics sector while strengthening their national economies.

In order to reduce transport emissions in Gulf nations, it is essential to implement strict regulations. This can be achieved by promoting the use of eco-friendly transportation technologies, such as electric vehicles and fuel-efficient vehicles, to minimize the environmental impact of logistics activities. Furthermore, encouraging foreign direct investment that aligns with sustainable development goals and supports environmentally friendly logistics practices is crucial. Gulf countries can incentivize investors who contribute to green initiatives and technologies in the logistics sector, ensuring that foreign direct investment supports sustainability goals. Raising awareness about the negative effects of transport emissions on green logistics among stakeholders in the logistics industry is vital. Additionally, investing in capacity building and training programs can equip logistics professionals with the necessary knowledge and skills to adopt sustainable practices. To accelerate the adoption of green logistics practices, it is crucial to facilitate public-private partnerships. Collaborative efforts between governments, businesses, and non-governmental organizations can drive sustainable changes in the logistics sector. These partnerships can leverage expertise, resources, and innovation to create a more environmentally friendly and efficient logistics ecosystem.

In the case of the BRICS countries, it is crucial to harmonize their economic growth with sustainable development goals. This can be achieved by creating and implementing policies that promote not only economic growth but also prioritize inclusivity and environmental responsibility. Furthermore, to mitigate the environmental impact of logistics activities, it is essential to develop policies that encourage the adoption of clean transportation technologies. Reducing emissions from logistics operations in BRICS countries can significantly enhance environmental sustainability. To achieve this, integrating sustainability into trade agreements while pursuing trade openness is essential. The adoption of renewable energy in the logistics sector is important for sustainability. Policymakers should promote investments in renewable energy technologies, including solar-powered logistics facilities and electric vehicle charging infrastructure, to reduce the carbon footprint of logistics operations. Fostering a culture of green innovation through research and development initiatives can drive innovation in the logistics industry. This approach can position BRICS countries as leaders in sustainable logistics and contribute to global environmental goals.

6 | CONCLUSION

6.1 | Concluding remarks

This paper aims to provide a user-friendly guide for logistics service providers and the general public to develop and execute green logistics strategies. These strategies are intended to promote an eco-friendly environment, benefiting society, the economy, and the ecology on a global scale. The adoption of GRL practices emerges as a promising solution to mitigate the environmental impact of the logistics sector. The paucity of research in the literature on the link between environmental sustainability and green logistics initiatives has also inspired the study. The objective of this study is to analyze the relationship between green logistics, economic growth, green innovation, foreign direct investment, transport emissions, renewable energy, and trade openness in both BRICS countries and GCC economies. We applied a variety of empirical techniques, such as Kao (1999), Pedroni (2004), and Westerlund (2005) cointegrations. Additionally, we used the CS-ARDL approach to evaluate both the long-run and short-run models. Furthermore, AMG and CCEMG methodologies serve as robustness checks in this study. For GCC countries, the negative impact of foreign direct investment on green logistics demands urgent attention. Implementing measures to promote sustainable investments in the logistics sector can significantly enhance sustainability in these nations. Conversely, in BRICS countries, the positive influences of economic development, trade openness, renewable energy consumption, and green innovation on green logistics present opportunities for further growth. Results of the Dumitrescu and Hurlin (2012) Granger causality test show that there exists a unidirectional causality from transportation-related carbon emissions, trade openness, and green innovation to green logistics in BRICS countries. In GCC countries, we identified unidirectional causality from economic growth, trade openness and renewable energy consumption to green logistics. Moreover, there is bidirectional causality between TCO_2 emissions, green innovation and green logistics. Emphasizing sustainable development policies and encouraging innovation can be effective strategies to boost the positive impact of logistics on the environment.

6.2 | Limitations and future research

This research has certain limitations. The study focused on two distinct country groups, limiting the generalizability of our findings. Additionally, we also used a specific set of variables, which may affect the comprehensiveness of the analysis. Another limitation involves the use of transportation-related carbon dioxide as a proxy for measuring the environmental sustainability of logistics practices. Future research should consider a more diverse range of country groups and variables to enrich our understanding of environmentally sustainable logistics practices. Additionally, incorporating alternative environmental indicators alongside CO_2 emissions can provide a more comprehensive evaluation of these strategies Moreover, this study has limitations concerning the measurement of the nexus between GRL, economics and environmental factors. Future researches may explore the social aspects, human well-being, and the impact on fauna in polluted logistics systems. This study utilized the CS-ARDL, AMG, and CCEMG methodologies to establish short-term and long-term associations. Academic researchers are strongly encouraged to employ non-linear models, such as the non-linear autoregressive distributed lag technique, to gain novel and valuable perspectives.

AUTHOR CONTRIBUTIONS

All the authors whose names appear on the submission made substantial contributions to the conception or design of the work.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Research data can be obtained from the corresponding author through email.

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