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DOES GREEN FINANCING AFFECT THE SUSTAINABLE ECONOMIC GROWTH OF EMERGING ECONOMIES? EVIDENCE FROM PANEL ARDL MODEL

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ABSTRACT

This study examines the nexus between green finance determinants and sustainable economic growth in Brazil, India, China, and South Africa using a panel Autoregressive Distributed Lag (ARDL) approach. These rapidly developing countries face the dual challenge of maintaining economic growth while addressing environmental sustainability. The analysis focuses on five key independent variables: Comparative Advantage in Low Carbon Technology Products, Total Trade in Low Carbon Technology Products, Trade Balance in Low Carbon Technology Products, Annual CO_2 Emissions, and Lack of Coping Capacity. Short-run results indicate that Total Trade in Low Carbon Technology Products negatively affects GDP, suggesting that while green trade is expanding, it currently lacks stable, revenue-generating mechanisms. Annual CO_2 Emissions and Lack of Coping Capacity positively influence GDP in the short term, reflecting continued dependence on emission-intensive industries and limited infrastructure for resilience. Comparative Advantage and Trade Balance in Low Carbon Technology Products are statistically insignificant in the short run, implying delayed economic benefits. In the long run, none of the green finance indicators show a significant relationship with GDP, possibly due to the substantial upfront investments required for green projects, which delay economic returns. The study underscores the need for strategic investments in technology, infrastructure, and governance to align economic growth with long-term sustainability goals.

Keywords: *Emerging Economies, Green Finance, Sustainable Economic Growth, Low Carbon Technology Products, Environmental Sustainability*

1. INTRODUCTION

Green finance has become an important catalyst for sustainable economic growth, especially in emerging and developing economies such as China, Brazil, India, and South Africa. Since the latter are transforming to align industrialisation with conservation, green finance offers them a chance to manage climate risks without discouraging economic development. Broadly defined, green finance encompasses a suite of financial products and services such as investments, credit instruments, and insurance mechanisms designed to support environmentally sustainable initiatives, including green technological innovation, renewable energy deployment, and im-

provements in energy efficiency. Empirical studies by Yang et al. (2020), Hailiang et al. (2022), and Sadiq et al. (2024) underscore the positive impact of green finance on both environmental and economic outcomes in BRICS countries. Their findings highlight significant reductions in carbon dioxide emissions and a notable acceleration in the adoption of renewable energy sources, thereby affirming the dual role of green finance in promoting ecological sustainability and economic resilience.

Although there is a growing volume of research highlighting the role of green finance in promoting sustainable development, several important gaps remain unaddressed. Most existing studies focus on individual developing countries and do not offer a comprehensive, cross-country analysis. For instance, studies by Mejía-Escobar et al. (2020) and Gull et al. (2020) are limited to specific national contexts and do not capture broader patterns or differences across multiple nations. This limits our understanding of how green finance operates in different policy and economic environments. For example, Brazil and China have adopted green finance measures more rapidly and proactively, while India and South Africa have implemented them more gradually and at a later stage. These differences suggest that the adoption and impact of green finance vary across countries, but there is little research examining these variations systematically. Without such comparative studies, it is difficult to evaluate how green finance contributes to sustainable development in different national contexts. In addition, while some studies like Sadiq et al. (2024) examine the overall impact of green finance, eco-innovation, and renewable energy on reducing CO_2 emissions, very few look at how green finance works in specific sectors, such as energy, manufacturing, or agriculture. Since trade and economic relationships between these countries are important, it is necessary to study how different sectors benefit from green finance. This would give clearer insights into how green finance helps cut emissions and support economic development (Srdelić, 2024). Moreover, earlier research has not considered important factors like a country's Economic Coping Capacity, which could play a key role in shaping the effectiveness of green finance policies.

For instance, a country's low Economic Coping Capacity can significantly affect its ability to recover from disasters, regardless of the presence of formal response mechanisms or government-led infrastructure aimed at reducing disaster risk. Coping capacity encompasses a range of economic, political, and social characteristics that determine how resilient a population is during and after a hazard event. If these systems are weak, a country may face prolonged recovery and greater vulnerability, even with green finance mechanisms in place. However, studies such as Sadiq et al. (2024), while insightful in examining the broader impacts of green finance, have not accounted for these critical dimensions. Incorporating such factors into future research could offer a more holistic understanding of how green finance interacts with broader measures of sustainability, particularly resilience and adaptive capacity, and how it ultimately supports sustainable economic growth (Idris & Rahman Razak, 2025). Moreover, as emphasised by Jaiswal et al. (2024), there is a pressing need to investigate the transferability and applicability of effective green finance policies across different national contexts within the BRICS bloc. Although each BRICS country has adopted its own distinct green finance framework, understanding how successful elements of one country's policy might be adapted or implemented in others could greatly enhance the collective impact of green finance initiatives across the region. Such comparative policy research could help identify best practices and foster more coordinated and effective approaches to green finance among emerging economies.

In response to existing knowledge gaps, this study seeks to conduct a comparative analysis of Brazil, India, China, and South Africa, focusing on the relationship between green finance and key drivers of sustainable economic development. Specifically, the study examines the association between green finance and variables such as the comparative advantage in low-carbon

technology products, trade in low-carbon technology products, trade balance, annual CO_2 emissions, economic coping capacity, and GDP. A panel Autoregressive Distributed Lag (ARDL) model is employed to capture both short-run and long-run dynamics. It is important to note that Russia has been excluded from the analysis due to data limitations. By assessing the temporal effects of green finance on economic growth, this study aims to provide meaningful insights into the effectiveness of green finance in promoting sustainable economic progress in emerging economies. Moreover, the research contributes to the existing literature by offering a broader, cross-national perspective on the role of green finance in advancing sustainability objectives within developing countries.

2. LITERATURE REVIEW

This study examines the role of green finance in promoting sustainable economic growth in emerging economies. In the early stages of development, countries often experience heightened thenvironmental degradation as industrial activity expands rapidly. However, as economic progress continues and income levels rise, there is a growing shift toward more sustainable practices. Green finance plays a pivotal role in supporting this transition by funding low-carbon technologies, renewable energy, and environmentally responsible infrastructure. By channelling financial resources into sustainable initiatives, green finance contributes to long-term economic stability where environmental protection and economic growth can progress hand in hand.

2. 1. GDP AND LOW-CARBON TECHNOLOGY PRODUCT COMPARATIVE ADVANTAGE (ADV)

The idea of green finance has gained more attention from scholars and policymakers, especially for its contribution to comparative advantages in low-carbon technology. Yang et al. (2020) analysed the contribution of green finance to the economic development of China and concluded that there are three channels by which green finance promotes high-quality growth: structural adjustment of industry, environmental upgrading, and promoting new economic development. Comparative advantages in low-carbon technology export are at the core of this purpose, as this makes emerging economies leaders in green business in sustainable markets while fostering GDP growth. Mejía-Escobar et al. (2020) noted how government and regulator support play a pivotal role in pushing green financial products to enhance the comparative advantage of a country in green technology. They underlined that countries like Brazil and China have been successful in utilizing regulatory instruments so that they could implement green finance models that facilitate the export of low-carbon technology while countries like India and Russia lag behind in the same. Furthermore, developments in green credit and financing assistance have been promising to drive the expansion of green technology, which is crucial in the development of economic sustainability. The prevalence of green finance with a positive connotation regarding low-carbon technologies on a comparative basis is attested by facts that identify its function as an innovator. Green technology investment not only saves the environment but also presents economies with the opportunity to achieve a competitive edge in green industries (Mahesh et al., 2022). Green investments have a key function towards promoting sustainable long-term economic growth, as well as towards solving the environmental problems of the world (Elhassan, 2025).

2. 2. GDP AND TOTAL TRADE IN LOW-CARBON TECHNOLOGY PRODUCTS (TOT)

Overall trade of low-carbon technology goods is crucial in promoting green economic growth through the creation of green financial programs. Yang et al. (2022) give an extensive overview of the ways in which green economic development, green finance, and clean energy have in-

fluenced sustainable industrial practice. They also find that green bonds and clean energy initiatives heavily influence practices for sustainability and thereby indirectly cascaded an effect towards the increased trade in low-carbon technology. Udeagha and Ngepah (2023) compared the effects of green finance networks (GFNs) as drivers of eco-friendly trade procedures. They realized that GFNs strengthen the environment, in a stimulation effect indirect one, for the low-carbon technology commodity trade. Similarly, Qadri et al. (2024) laid emphasis on increased priority to local economic development, green innovation, and the circular economy in their effects on the efficiency of trade. The conclusions highlight the importance of the convergence of financial and industrial systems in facilitating sustainable trade activities, particularly among the member states of the BRICS. Beyond this, regulatory policy and global cooperation have pivotal functions in increasing trade in low-carbon technology. There is evidence that green finance pioneers such as China and Brazil have achieved remarkable progress in the areas of green technology trade volumes (Mejía-Escobar et al., 2020). This growth gives the green finance disruptive force momentum to reshuffle world trade flows.

2. 3. GDP AND TRADE BALANCE OF LOW-CARBON TECHNOLOGY PRODUCTS (BAL)

The trade balance of low-carbon technology products is a measure of the net export excellence of a country in green technologies. Mejía-Escobar et al. (2020) indicated that countries with positive low-carbon trade balances, such as China and Brazil, have a greater tendency to possess higher evidence of the implementation of green finance. Such countries have managed to become global leaders in the green industry, and this has contributed to the growth of GDP in a positive manner. The Environmental Kuznets Curve (EKC) hypothesis is also able to account for the connection between GDP and trade balance. Economic development first worsens environmental degradation and later encourages environmentally friendly trading practices as income improves, according to Udeagha and Ngepah (2023). The transformation enables countries to gain favourable trade balances for low-carbon technology, as evidence of the green finance policy emphasis. Spatial existence of the effect of trade balance is not the same, though. India and Russia, for instance, lag behind the rest of the world in adopting green finance policies and hence maintaining poor green technology trade balances (Mejía-Escobar et al., 2020). Policy intervention at the regional level is needed to turn around regional imbalances and promote sustainable trade practices.

2. 4. GDP AND CO_2 EMISSIONS (CO_2)

The connection between CO_2 emissions and GDP has been extensively examined in the context of the Environmental Kuznets Curve (EKC). The EKC theory predicts that economic growth initially exacerbates environmental deterioration, like CO_2 emissions at first, but finally decreases emissions as countries adopt sustainable practices. Wang et al. (2022) agree to this notion that green financial instruments and technological innovations are the causes of the decrease in CO_2 emissions. Sadiq et al. (2024) examined the effect of green finance, sustainable innovation, and clean energy on CO_2 emissions in BRICS countries. According to their findings, green finance has a remarkable effect of decreasing emissions through encouraging environmental behaviour and innovations. Carbon taxation is also taken into account in the study to regulate carbon-energy operations with the motive of further reducing emissions. Environmental technology investment is also a major reason behind declining CO_2 emissions. Mahesh et al. (2022) demonstrated that investment in green sustainable products not only reduces emissions but also increases economic growth and coverage. This two-way benefit is evidence of the game-changer nature of green finance in averting environmental problems while promoting economic growth.

2. 5. GDP AND INADEQUACY OF COPING CAPACITY (COP)

Inadequacy of coping capacity (COP) refers to a country's ability to deal with disasters and infrastructure problems, which can influence GDP directly. Yang et al. (2020) indicated the way in which green financial intervention contributes to ecological resilience construction, with the spin-off of accelerating GDP growth through averting environmental catastrophe. Their study documents the contribution of green finance to enhancing a nation's disaster and infrastructure capacity deficit. Gull et al. (2020) defined that green financing facilitates long-term economic growth by investing in infrastructure development, while it may be zero in the short term. Thus, investment in green finance can enhance the resilience capacity of a nation in the long term, resulting in sustainable economic growth. Jaiswal et al. (2024) explained that stronger collaboration in the green finance networks is required for foreign investment purposes as well as to increase the coping capacity. International cooperation, they claimed, is required for addressing global problems and achieving economic stability in the emerging markets. Hailiang et al. (2022) further added that green finance networks can be employed to propel renewable energy into use and help in evading climate change, thereby further enhancing the country's resilience. Green finance and GDP literature confirm that there are intricate relationships between independent variables like ADV, TOT, BAL, CO_2, and COP and economic development.

Literature evidently suggests that green finance has the capability to turn around sustainable development, environmental risk reduction, and social inclusion. Take-up regional heterogeneity of, and its effects, requires differential approaches towards universal attainment of gains from interventions through green finance. Consistent endeavours at policy design enhancement as well as enhanced international cooperation shall play a central role in upholding sustainability on the long-term scale as well as economic resilience.

3. OBJECTIVES

To understand the impact of green finance indicators on the sustainable economic growth of developing nations.

To find the long-run and short-run relationship between Comparative advantage in low carbon technology products, Total trade & Trade balance in low carbon technology products, Lack of coping capacity, Annual CO2, and GDP.

4. HYPOTHESES

H_1-There is a long run relationship between Comparative advantage in low carbon technology products and GDP.

H_2-There is a long run relationship between Total trade in low carbon technology products and GDP.

H_3-There is a long run relationship between Trade balance in low carbon technology products and GDP.

H_4-There is a long run relationship between Annual CO2 and GDP.

H_5-There is a long run relationship between Lack of coping capacity and GDP.

H_6-There is a short run relationship between Comparative advantage in low carbon technology products and GDP.

H_7-There is a short run relationship between Total trade in low carbon technology products and GDP.

H_8 -There is a short run relationship between Trade balance in low carbon technology products and GDP.

H_9-There is a short run relationship between Annual CO2 and GDP.

H_{10}-There is a short run relationship between Lack of coping capacity and GDP.

5. METHODOLOGY OF THE STUDY

This study investigates the impact of green finance on green economic growth for emerging economies using panel data analysis. The four biggest emerging economies, namely Brazil, India, China, and South Africa, are considered between 2013 and 2022. The econometric model used here is the Panel Autoregressive Distributed Lag (ARDL) model that is appropriate for both short-run and long-run relationships between variables in a panel framework.

The dependent variable (DV) of the study is Gross Domestic Product (GDP), albeit utilized as a proxy for economic growth. GDP captures the economic performance of the subject economies and enables one to gauge the impact of green financing and other variables on their sustainable growth.

Independent variables (IVs) are several measures that are associated with green financing, green technology, and environmental sustainability. Comparative Advantage in Low Carbon Technology (LCT) products, a relative export capacity of an economy in low carbon products to the global level. It shows how competitively the country can produce in the green technology sector. Total Trade and Trade Balance in Green Technology Products indicate total trade performance and balance and whether the economy is a net exporter or net importer of green tech products (Vardar et al., 2023). Average Annual CO2 Emissions per capita is a measure of green financing impact on the environment and capacity to decrease carbon output (Udeagha & Ngepah, 2023). Lack of Coping Capacity is a measure of the capacity of a country to respond to environmental risks and their vulnerability to climate risks (Vardar et al., 2023).

The information used in this study is derived from reliable sources, such as the IMF Climate Change Dashboard, for complete coverage of economic and environmental factors. The sample is the panel data for Brazil, India, China, and South Africa from 2013-2022. They are chosen based on their front-runner status in green finance around the globe and as emerging nations, hence well placed to be used in determining the relationship between green finance and sustainable growth (Stojanovic & Ilic, 2018).

To investigate the nexus between green finance and sustainable economic growth in emerging economies, this study employs the Pooled Mean Group (PMG) estimation technique within the Panel ARDL (Autoregressive Distributed Lag) framework, as developed by Pesaran et.al. (1999). The choice of PMG is appropriate given the balanced panel structure and the assumption of a common long-run relationship across countries, while allowing for heterogeneity in short-run dynamics and error variances. Furthermore, the selection of this econometric technique is grounded in its distinct advantages over other panel data models, particularly in the context of heterogeneous, dynamic, and non-stationary data commonly observed across countries at different stages of development. One of the key strengths of the Panel ARDL model is its ability to simultaneously estimate both short-run dynamics and long-run equilibrium relationships between variables (Pesaran & Shin, 1998; Pesaran et al., 2001), .This dual focus is essential in understanding how green finance influences GDP, not just immediately, but also over extended periods, capturing the evolving nature of green investments and their economic implications.

Moreover, Panel ARDL is particularly well-suited for panels where variables are integrated of mixed order-i.e., I(0) and I(1)-but not I(2). Unlike other models that require pre-testing for stationarity and differencing of variables, Panel ARDL allows the estimation of level relationships without losing valuable long-term information inherent in the original data. This feature is especially beneficial when analysing green finance variables, which may exhibit different levels of integration due to varying policy maturities and reporting practices across countries.

Moreover, the Panel ARDL framework is particularly advantageous in modelling dynamic relationships because it allows the inclusion of lagged values of both the dependent and independent variables. This feature is critical in capturing delayed effects, which are often present in macroeconomic phenomena such as green finance, where the impact on GDP may not be immediate. By accounting for these lags, the model can more accurately reflect the temporal structure of causal relationships (Pesaran et.al., 1999). Additionally, the model accounts for cross-country heterogeneity in both short-run coefficients and adjustment speeds toward long-run equilibrium. Estimation techniques such as the Pooled Mean Group (PMG) estimator enable countries to exhibit unique short-run dynamics while imposing common long-run relationships where theoretically appropriate. This is especially pertinent in a study involving emerging economies, where financial systems, institutional capabilities, and environmental policies vary widely. Lag length selection for the ARDL model was based on the Schwarz Information Criterion (SIC), which balances model fit and parsimony, ensuring optimal lag structure for each country in the panel. These methodological choices enhance the robustness and reliability of the estimated short- and long-run relationships and align with best practices for dynamic panel data analysis in the context of heterogeneous emerging economies.

Table 1. Variable Description

Variable	Variable Definition	Unit of Measurement	Reference Period	Source
Endogenous Variable				
GDP Growth (GDP)	Serves as an indicator of economic growth or contraction.	Percentage	2013-2022	World Bank Database
Exogenous Variables				
Comparative advantage in low carbon technology products (ADV)	Measures an economy's relative advantage in exporting low-carbon technology products. A value above one indicates an advantage, while below one shows a disadvantage. It is calculated as the share of low-carbon technology exports in an economy relative to the global share.	Index	2013-2022	IMF Climate Change Dashboard Website
Total trade in low carbon technology products (TOT)	Total goods in trade are estimated by aggregating all commodities.	Percentage	2013-2022	IMF Climate Change Dashboard Website
Trade balance in low carbon technology products (BAL)	Trade balance in low carbon technology products is calculated as low carbon technology products exports less low carbon technology products imports. A positive trade balance means an economy has a surplus in low carbon technology products, while a negative trade balance means an economy has a deficit in low carbon technology products.	Percentage	2013-2022	IMF Climate Change Dashboard Website
Annual CO2 (CO2)	CO_2 emissions per capita measure the average annual emissions per person for a country or region. It is calculated by dividing the total annual emissions of the country or region by its total population.	Tonnes per capita	2013-2022	Our World in Data Website
Lack of coping capacity (COP)	Lack of coping capacity relates to the ability of a country to cope with disasters in terms of formal, organized activities and the effort of the country's government as well as the existing infrastructure which contribute to the reduction of disaster risk.	Index	2013-2022	IMF Climate Change Dashboard Website

Source: World Bank and IMF data base

By including green finance indicators alongside variables related to green technology, foreign trade, and environmental risk, the Panel ARDL model facilitates a comprehensive understanding of the impact of green investment. It provides a rigorous framework for disentangling the immediate and enduring economic effects of green finance, yielding insights that are critical for formulating effective, forward-looking sustainability policies.

Prior to applying any econometric model, the order of integration is important for internal consistency among the chosen variables. The results of the Unit root test for level and first differences using trend and intercept are given in Table 2. The Unit root's performance is carried out using the Im-Pesaran-Shin (IPS) unit root test. The results of the unit root test show that GDP, ADV, TOT, BAL, CO2 and COP are stationarity at first difference. Yet, no variables are included subsequent to the achievement of the second difference I(2).

Table 2. Summary of Unit Root Test Results

Variables	Trend and Intercept		Order of Integration
	Level	First Difference	
GDP	-0.81522(0.2075)	-2.00258**(0.0226)	I(I)
ADV	1.20897(0.8867)	-1.58310**(0.0567)	I(I)
TOT	-0.27665(0.3910)	-2.29201*(0.0110)	I(I)
BAL	1.26205(0.8965)	-0.30641**(0.0462)	I(I)
CO2	0.72739(0.7665)	-0.63263**(0.0368)	I(I)
COP	-0.22608(0.4106)	-0.35611*(0.0112)	I(I)

Note: *,**,*** significance at 1, 5 & 10 percent significantly, () values indicates p values

Source: Authors' Calculation

Table 3. Summary of Descriptive Statistics

Variable	Mean	Std. Dev	Min	Max
GDP	3.3875	4.024425	-6	9.7
ADV	.6496072	.4130538	.181882	1.39387
TOT	1.287676	.6318298	.4711772	2.629429
BAL	-.1892593	.2817327	-.6178613	.6145626
CO2	4.841608	2.823897	1.545232	8.621777
COP	4.09	.3801484	1.545232	8.621777

Source: Authors' Calculation

Descriptive statistics provide a foundational understanding of the dataset by summarising key features such as central tendency, dispersion, and range. In this study, six variables-GDP, ADV, TOT, BAL, CO_2, and COP-each based on 40 observations, are examined to offer an initial insight into the characteristics of the data. GDP, representing economic growth, has a mean value of 3.39% and a standard deviation of 4.02%, with a range spanning from –6% to 9.7%. This indicates substantial variation in economic performance across the observed period. ADV, which reflects the comparative advantage in low-carbon technology products and is indicative of technological advancement and related economic activity, has a mean of 0.65, a standard deviation of 0.41, and ranges from 0.18 to 1.39, suggesting moderate variability. TOT (Terms of Trade) has

an average value of 1.29 and a standard deviation of 0.63, with a range from 0.47 to 2.63. This points to notable fluctuations in trade conditions over time. BAL, capturing the trade balance in low-carbon technology products, exhibits an average of –0.19, a standard deviation of 0.28, and a range between –0.62 and 0.61, indicating alternating trade deficits and surpluses within the sample.CO_2 emissions average at 4.84 units with a standard deviation of 2.82, and range from 1.55 to 8.62, reflecting significant disparities in emission levels among countries. Lastly, COP, which measures the lack of coping capacity in the face of environmental risk, shows a mean of 4.09, a relatively low standard deviation of 0.38, and a range aligned with that of CO_2, suggesting some consistency in institutional and infrastructural vulnerabilities. Together, these descriptive statistics offer a comprehensive overview of the dataset, highlighting the variability and patterns across key economic and environmental indicators relevant to the green finance–growth nexus.

Table 4. Correlation Matrix

Variables	GDP	ADV	TOT	BAL	CO2	COP
GDP	1.0000					
ADV	0.390	1.0000				
TOT	0.270	0.894	1.0000			
BAL	0.239	0.787	0.548	1.0000		
CO2	-0.012	0.728	0.886	0.522	1.0000	
COP	-0.123	-0.785	-0.630	-0.842	-0.619	1.000

Note: *,**,*** significance at 1, 5 & 10 percent significantly

Source: Authors' Calculation

Correlation analysis offers a preliminary statistical insight into the direction and strength of associations among the variables under consideration. In this study, the correlation matrix in Table 4 examines the interrelationships between GDP, ADV, TOT, BAL, CO_2, and COP, providing an initial understanding of how these variables interact within the context of green finance and economic performance. The results in Table 4 indicate a weak positive correlation between GDP and ADV ($r = 0.3904$), suggesting that improvements in technological capabilities, as proxied by comparative advantage in low-carbon technologies, are modestly associated with higher levels of economic growth. A similarly weak positive association is observed between GDP and TOT ($r = 0.2703$), implying that favourable terms of trade may contribute positively to economic performance. Additionally, GDP is weakly and positively correlated with BAL ($r = 0.2394$), indicating that an improved trade balance in low-carbon goods may exert a modest influence on growth trajectories. In contrast, GDP exhibits a near-zero negative correlation with CO_2 emissions ($r = –0.0123$), suggesting an inconclusive or negligible inverse relationship between economic activity and environmental degradation within the observed data. A weak negative correlation is also noted between GDP and COP ($r = –0.1233$), which may indicate that lower coping capacity-reflecting vulnerability to environmental stress-has a marginally adverse association with economic growth. These findings underscore the heterogeneous nature of the relationships between green finance indicators and economic performance, warranting further investigation through dynamic panel data models to uncover potential causal linkages and long-run effects.

6. AUTOREGRESSIVE DISTRIBUTED LAG MODEL (ARDL)

The ARDL model also has its own strengths, which make it a better choice in this study. In contrast to other methods, the ARDL model is appropriate for ordered variables to be heterogeneous at different integrations—non-stationary or stationarity—with high flexibility levels (Pesaran et al., 2001). The model particularly performs well even with small samples and accommodates short-

run dynamics and long-run equilibrium relationships in one framework. The used ARDL model is best suited for the short-run time series estimation. According to its error correction mechanism to make sense in equilibrium corrections, the ARDL model avoids the defects of the traditional method and presents a suitable platform for econometric analysis (Nkoro & Uko, 2016).

$$GDPit = \alpha 0 + \beta_1 ADV_{it} + \beta_2 TOT_{it} + \beta_3 BAL_{it} + \beta_4 CO2_{it} + \beta_5 COP_{it} + \varepsilon_{it}$$

Table 5. Impact of green finance indicators on Economic Growth (GDP)

D.GDP	Coef	Std. Err	z	P > |z|
Long Run				
ADV	14.81304	14.81304	1.00	0.317
TOT	-2.848709	4.461038	-0.64	0.523
BAL	-4.092944	8.310805	-0.49	0.622
CO2	-5.166248	4.380385	-1.18	0.238
COP	2.416846	2.416846	1.00	0.317
Short Run				
ECT	-1.733419***	0.6210432	-2.79	0.005
ADV (DI)	21.80322	14.26593	1.53	0.126
TOT (DI)	-16.1058**	8.192738	-1.97	0.049
BAL (DI)	-13.37961	16.84973	-0.79	0.427
CO2 (DI)	23.7756**	11.27608	2.11	0.035
COP (DI)	9.94953*	5.454931	1.82	0.068
_cons	-5.144711	43.12258	-0.12	0.905

Note: ***, ** , * significance at 1, 5 & 10 percent significantly

Source: Authors' Calculation

Table 5 gives the result of the Autoregressive Distributed Lag (ARDL) model to find the short-run (SR) and long-run (LR) relationship between the comparative advantage of low-carbon technology products (ADV) and GDP for emerging markets. In the long run, the ADV coefficient is positive (14.81), indicating that higher comparative advantage in low-carbon technology products is related to higher GDP. However, the impact is statistically insignificant (p = 0.317), meaning that the long-run impact of ADV on GDP is insignificant. Short-run-wise, the error correction term (ECT) is significant and negative (-1.733, p = 0.005), which is an affirmation of the presence of the fact that long-run equilibrium deviations are corrected at a rate of 17.3% per period. The short-run ADV (DI) coefficient is 21.80, with a positive correlation with GDP, but still statistically insignificant (p = 0.126). The constant term is also statistically insignificant. These implications indicate that green financing and comparative advantage in low-carbon technology products are able to contribute to growth, but only limitedly in the short run and still statistically insignificant in the long run. The large ECT, by contrast, reflects strong adjustment dynamics, suggesting that GDP adjusts rapidly to short-run disturbances. This is to demonstrate that, in making green finance achieve significant effects on sustainable economic development in emerging economies, favourable policy, investment stimulus, and structural reforms can be necessary.

From Table 5, the total trade of low-carbon technology products (TOT) is negative (-2.85), indicating that the increase in total trade in low-carbon technology products is linked with a decrease in GDP. But this is statistically insignificant (p = 0.523), which suggests that the long-run effect of TOT on GDP is negligible. In the short run, the error correction term (ECT) is statistically significant and negative (-1.733, p = 0.005), which verifies that the imbalances from the long-run equilibrium are corrected at a high speed of 17.3% per period. The short-run coefficient of TOT (DI) is negative (-16.11) and significant at 5% (p = 0.049), indicating short-

run increase in total trade in low-carbon technology products reduces GDP. The constant is not statistically significant (p = 0.905), indicating no strong underlying trend. These results show that aggregate low-carbon technology good trade is not a significant driver of long-run economic growth in emerging economies and could have a short term trade off in the short term. The big ECT indicates there are strong adjustment dynamics, whereby GDP reacts quickly to short-run shocks. This would imply that although green trade policy may promise possible gains, its effect on growth in the short term could be checked by structural inefficiencies, trade imbalance or transition costs of a transition towards low-carbon technologies. Policy interventions, investment in-country in production capability, and higher trade agreements would be required to check such short-run adverse effects.

When it comes to low-carbon technology product trade balance (BAL), in the long run, the coefficient for the trade balance of low-carbon technology products **(BAL**) is negative (–4.09). However, the effect is statistically insignificant ($p = 0.622$), indicating that the estimated long-run impact of **BAL** on **GDP** is not robust and should be interpreted with caution. In the short term, the error correction term (ECT) is also negative and significant (-1.733, p = 0.005), validating that errors from long-run equilibrium are being corrected at a rate of 17.3% per period. This indicates that GDP adjusts quickly to short-run shocks. The short-run BAL (DI) coefficient, which is negative (-13.38) but statistically insignificant (p = 0.427), indicates that the change in the low-carbon technology product trade balance has no significant effect on GDP in the short run. The constant term is statistically insignificant (p = 0.905), indicating no inherent significant trend. These findings suggest that the trade balance of low-carbon technology products does not contribute much to long-term economic growth in emerging markets and does not significantly affect GDP in the short term. The large ECT suggests strong adjustment mechanisms, which means that GDP responds quickly to short-run shocks. These findings suggest that green technology trade balance can indeed be an aspect of economic change, but its specific contribution to economic growth is being restrained. The policymakers could choose to focus on structural quality, innovation stimulus, and efficiency gains of low-carbon technology in a bid to bring out the economic advantages.

In the case of CO_2 emissions (CO_2), in the long term, the CO_2 coefficient is negative (-5.166), indicating that an increase in CO_2 emissions is linked with a decrease in GDP. This effect is, however, statistically insignificant (p = 0.238), since CO_2 emissions do not affect economic growth in the long term. In the short run, the error correction term (ECT) is significant and negative (-1.733, p = 0.005), which verifies that the long-run equilibrium errors are corrected at a rate of 17.3% per period. It implies that GDP respond quickly to short-run shocks. In the short run, the CO_2 coefficient is positive and statistically significant at 5 5% level (23.776, p = 0.035), and this guarantees there is a rise in GDP following short-run rises in CO_2 emissions. This is consistent with the study by Pachiyappan et al. (2021) establishing a nexus between CO2 and GDP. These results imply that CO_2 emissions have no long-term effect on GDP, but there exists a significant and positive short-run relationship between CO_2 emissions and economic growth. This can be an implication that economic growth in developing nations is presently based on carbon-intensive industries. The strong ECT indicates good adjustment dynamics, implying that GDP adjusts fast to short-run shocks. Policymakers might have to take into account policies for shifting towards sustainable models of growth that lower the dependency on carbon emissions without jeopardising economic stability.

From table 5, the absence of coping capacity (COP) coefficient is positive in the long run (2.417), but statistically insignificant (p = 0.317), which shows no significant effect on GDP. The COP In the short run, the error correction term (ECT) is negative and significant (-1.733, p = 0.005), and this again confirms that GDP reacts quickly to shocks in the short run. The short-run COP (DI) coefficient is positive (9.950) and significant (p = 0.068), indicating that

ineffective economies in coping capacity can rise in the short run based on rising government and foreign aid inflow during crises. But these increases would be temporary in the absence of institutional change. These findings highlight the dual character of coping capacity such that its immediate effect on GDP could be underpinned by economic activities responding to vulnerabilities as expounded by Kumpulainen, S. (2006).

7. RESULTS AND POLICY DISCUSSION

The Panel ARDL model estimations reveal both short-run and long-run dynamics between green finance indicators and environmentally sustainable economic growth in developing economies. The results suggest that Total Trade of Low-Carbon Technology Products (TOT) exerts a statistically significant negative effect on GDP in the short run, highlighting the presence of an initial trade-off associated with low-carbon trade integration. This may reflect adjustment costs, limited market access, or transitional inefficiencies that accompany early-stage adoption of green trade practices. Conversely, both Lack of Coping Capacity (COP) and Annual CO_2 Emissions (CO_2) emerge as statistically significant and positively associated with GDP in the short run. This counterintuitive result may reflect the persistent reliance on emissions-intensive growth strategies and the infrastructural expansion typical of industrialising economies, where economic gains are achieved at the cost of environmental degradation and institutional vulnerability.

In contrast, Comparative Advantage in Low-Carbon Technologies (ADV) and Trade Balance in Low-Carbon Products (BAL) are statistically insignificant in the short run, suggesting that their economic effects are more likely to manifest over an extended time horizon. Notably, the long-run estimations indicate no statistically significant relationship between the independent variables and GDP, implying that the influence of green finance on growth is predominantly short-run in nature under current conditions.

These findings carry important policy implications. First, the short-run costs associated with low-carbon trade highlight the need for transitional policy support, such as subsidies, tax incentives, or trade facilitation measures targeted at green technology sectors. Policymakers should account for initial adjustment burdens and implement buffer mechanisms—including temporary compensation frameworks for affected industries—to mitigate the negative short-run impacts. Second, the positive association of CO_2 emissions and limited coping capacity with GDP underscores the structural reliance on unsustainable growth pathways. To address this, governments should strengthen climate-resilient infrastructure, invest in human and institutional capacity-building, and promote decarbonisation strategies that do not compromise growth. Third, the lack of long-run significance suggests that green finance initiatives are yet to be sufficiently mainstreamed into macroeconomic development frameworks. Therefore, there is a critical need for integrated green finance strategies, involving sustained investment, regulatory reform, and financial sector engagement, to ensure that green finance translates into durable economic benefits. Finally, policy frameworks must be forward-looking, with a focus on relaxing regulatory bottlenecks, enhancing green infrastructure, and aligning national development plans with climate objectives. By fostering an enabling environment through public-private partnerships and international cooperation, developing countries can better leverage green finance for inclusive and sustainable economic transformation.

Despite its contributions, the study has several limitations. The exclusion of Russia due to data unavailability restricts the generalizability of findings across the full BRICS framework. Additionally, the focus on macroeconomic variables leaves out sector-specific insights. Future research should explore the impact of green finance across sectors such as agriculture, industry, and energy to capture microeconomic dynamics. Investigating financial instruments like green bonds and carbon markets may further enhance understanding of green finance's long-term vi-

ability and its potential to support sustained economic transformation in emerging economies.

8. CONCLUSION

This study contributes to the growing empirical literature on green finance by exploring its impact on sustainable economic development in emerging economies. The findings reveal that certain green finance indicators exert statistically significant effects on GDP in the short run, while long-run impacts remain inconclusive. These results suggest that, although green finance has the potential to influence immediate economic performance, its capacity to drive sustained growth is contingent upon broader structural and policy-related factors. In the context of emerging and developing economies, a successful green transition will require more than financial flows—it demands coordinated efforts in public policy, infrastructural development, and adaptive regulatory frameworks. To ensure that green finance becomes a genuine driver of long-term sustainable development, governments must integrate it with national economic objectives, particularly by aligning green investments with strategies for inclusive growth, industrial transformation, and technological innovation. Policymakers should also recognise the interconnectedness between green trade and economic development, and work toward facilitating the transfer of green technologies, strengthening institutional capacities, and creating incentive structures that support environmental goals without compromising development priorities. By fostering an enabling policy environment and adopting a long-term vision, emerging economies can make rational adjustments toward a more resilient, equitable, and sustainable economic future.

DECLARATION

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this Manuscript we confirm that the research was conducted with utmost integrity and without any undue influence.

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