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Article

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Are Trade Openness Drivers Relevant to Carbon Dioxide Emission? A Study of Emerging Economies

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ABSTRACT

This research is focused on an in-depth analysis of the trade drivers that influence trade openness and their impact on carbon dioxide emissions, with a concentrated examination of emerging economies from 1995 to 2020. This examination is contextualized within the scope of various trade and environmental theoretical frameworks. In our analysis, we employed a range of advanced panel regression methods, including stepwise regression for model selection, as well as Fully Modified Ordinary Least Squares (FMOLS), Panel Ordinary Least Squares (Panel OLS), and Fixed Effects Model (FEM). The long-term patterns were evaluated using Johansen co-integration tests. Additionally, the study delves into the causal links between carbon dioxide emissions and the key drivers of trade, employing Granger causality tests for this purpose. Our findings disclose a complex web of relationships, both in the short and long term, between trade openness and carbon dioxide emissions, influenced by several key factors: (i) net inflows of foreign direct investment, (ii) trade reserves, (iii) per capita income, (iv) exchange rates, and (v) gross national savings.

Keywords: Trade Openness, Trade Openness Drivers, Cointegration, Carbon Dioxide Emissions, Emerging Economies
JEL Classifications: N7, O1

1. INTRODUCTION

International trade plays a pivotal role in fostering extensive market integration and the globalization of trade activities among nations (Bashir et al., 2024; Dsouza et al., 2024; Kayani et al., 2024; Nasim et al., 2023). This phenomenon exerts a positive impact on economic growth by facilitating the utilization of comparative advantages and the efficient allocation of resources (Sarkar, 2008; Keho, 2017; Ajayi and Araoye 2019; Klishch and Larionov 2022; Seyfullayev, 2022; Kayani et al., 2023). Such economic growth, in turn, contributes significantly to the overall improvement of human well-being (Kumari et al., 2023). However, it's noteworthy that the influence of trade openness on the environment within countries can manifest as either positive or negative, contingent upon changes in trade patterns associated with the prevalence of global supply chains. Over the past 130 years, there has been a substantial escalation in carbon dioxide (CO_2) emissions, particularly since the advent of the Industrial Revolution (Bekun et al., 2018: Akbar et al., 2024). Notably, developed nations, influenced by trade openness, have made significant strides in reducing their production of environmentally detrimental goods (Dauda et al., 2021: Martins et al., 2022).

The identification of factors that underpin trade openness in emerging economies carries significant implications for policymakers. It enables them to craft strategies aimed at enhancing the competitiveness of local industries, improving export performance, and attracting foreign investments. It's worth noting that trade openness tends to be favorably received by foreign investors, leading to an increase in Foreign Direct Investment (FDI). This influx of capital infusion, technological progress, and managerial expertise can be of substantial benefit to emerging economies (Alfaro et al., 2004).

Moreover, trade openness plays a pivotal role in diversifying economic activities, thereby helping mitigate risks associated with an overreliance on a single or a limited range of commodities or industries (Rafiq et al., 2022). The exposure to global markets fosters the diversification of income sources (Imbs et al., 2003). In the context of contemporary policy initiatives emphasizing rapid industrialization and the development of urban infrastructure to spur economic growth, it's imperative to address the issue of pollution as a negative externality that poses a threat to environmental sustainability (Mahmood et al., 2019; Dauda et al., 2021). This concern is particularly pronounced in emerging market economies. Recent research findings underscore the fact that urbanization in emerging nations is associated with increased energy consumption and heightened CO_2 emissions (He et al., 2017; Ozatac et al., 2017).

Balancing the imperative of sustainable economic development alongside the preservation of the environment constitutes one of the most formidable challenges currently facing humanity (Aye and Edoja, 2017). The degradation of our natural surroundings is profoundly influenced by factors such as population growth and sustained economic expansion, primarily driven by technology that heavily relies on the consumption of energy derived from fossil fuels (Cherniwchan, 2012; Martins et al., 2023). This underscores the integral role of industrialization in propelling economic progress, even as it concurrently contributes significantly to environmental degradation Oh and Bhuyan (2018).

It's essential to recognize that industrialization plays a pivotal role in environmental deterioration, as emphasized by Lu (2017). Economic advancement is intricately tied to resource accessibility, leading to the excessive depletion of natural resources, disruption of ecosystems, and climatic shifts-all of which intensify critical environmental concerns. Consequently, numerous governments grapple with the complex decision of whether to persist with the utilization of fossil fuel-based energy sources or prioritize economic growth. Within the research community, there is a growing emphasis on the deterioration of the environment. As previously mentioned, particular attention is drawn to the substantial contribution of greenhouse gases, notably carbon dioxide (CO_2) emissions, in the context of climate change and the phenomenon of global warming.

The present research has unveiled a notable void within the current body of literature, specifically the dearth of studies delving into the factors driving trade openness and their influence on CO_2 emissions within the context of emerging economies. Investigating the determinants of how trade openness drivers affect CO_2 emissions in emerging economies holds profound significance in our endeavor to gain insight into the forces that shape the trade and environmental policies of these nations, ultimately guiding their integration into the global economic framework. It is crucial to acknowledge that trade agreements and policies wield substantial influence over emissions within emerging economies. Trade agreements, for instance, may encompass environmental provisions or standards that exert an impact on emissions levels. Simultaneously, governments may enact policies that discourage practices aimed at reducing emissions.

This study makes a substantial and novel contribution to the existing body of literature on international trade and sustainable environmental practices. It accomplishes this by scrutinizing how trade drivers influence carbon dioxide emissions in emerging economies. Trade drivers encompass various factors that shape a country's trade dynamics. While prior research in this field has predominantly focused on empirical findings, there has been a notable omission of insights that can be derived from diverse theoretical perspectives. This study advances existing knowledge by delving into the theoretical foundations of trade drivers that facilitate trade openness and their consequential impact on CO2 emissions in emerging nations.

It is essential to acknowledge, however, that this study comes with certain limitations arising from factors such as dataset availability, variable selection, temporal constraints, and the methodologies employed for econometric analysis. These limitations should be considered when interpreting the study's outcomes. This exploration of trade openness, its associated drivers, and their effects on CO_2 emissions within emerging economies carries profound policy implications. These implications hold relevance for policymakers, governmental authorities, and business leaders alike.

This study constitutes a third significant addition to the existing body of literature, setting itself apart by employing a comprehensive dataset covering seventy-five countries over a period of 26 years. Instead of merely establishing a relationship, this research aims to confirm the presence of a long-term causal relationship. The initial step involved the identification of five key drivers associated with carbon dioxide emissions, a process facilitated by model fitness assessments using stepwise AIC selection and state-of-the-art advanced panel regression techniques. The robust findings consistently indicate that these five drivers, namely, (i) per capita income, (ii) foreign direct net flow investment, (iii) gross national savings, (iv) trade reserves, and (v) exchange rates, are intricately linked to trade openness and CO_2 emissions within emerging economies. Consequently, after an initial analysis, cointegration tests conducted using the Johansen method reveal both short-term and long-term integration relationships. These results suggest that the connection between trade openness, CO_2 emissions, and the five trade drivers extends beyond a mere association, indicating a deeper, more intricate relationship. Furthermore, by employing Granger causality tests, this study provides evidence supporting the idea that trade openness and CO_2 emissions are influenced by these five theory-driven factors. This directional causality underscores the dynamic nature of these relationships, with trade openness exerting an impact on the identified drivers. To the best of the author's knowledge, this research represents the first comprehensive exploration of theory-driven factors influencing trade openness and CO_2 emissions within the context of emerging economies.

The rest of the paper is divided into four more sections. The following section is a summary of the relevant literature. Section 3 describes the methodology and the research design for (i) measuring theory suggested drivers and the estimated parameters of the relationship between trade openness and its drivers. The results are discussed in Section 4 before concluding the paper in Section 5.

2. LITERATURE REVIEW

2.1. Applicable Theories

Several pertinent theories are relevant to the scope of this study. The concept of trade openness can be traced back to the economic doctrine of Mercantilism, which dominated trade practices from the 16th century through the 18th century. Mercantilism placed a strong emphasis on the significance of exports in national economies during the 16th century, contending that achieving a trade surplus was the most advantageous outcome in international trade. This doctrine is actively advocated for the stimulation of exports and the protection of domestic industries. However, as time progressed, Mercantilism gradually yielded ground to the ideas put forth by Smith (1776), a prominent economist of the 18th century. In his seminal work, "The Wealth of Nations," published in 1776, Smith expounded upon the positive impacts of international trade on the global economy. Within the context of the historical evolution of international trade, he posited that the principles of free trade and open international competition held greater benefits for nations compared to the prevailing Mercantilist policies that had been widespread in Europe until the late 18th century.

The theoretical underpinnings of international trade trace their origins to the concept of absolute advantage, initially formulated by Adam Smith during the 18th and 19th centuries. The theory of absolute advantage posits that a nation should concentrate its production on goods where it can achieve greater efficiency than any other country. When one country possesses an absolute advantage in producing one type of good, and another nation excels in a different category, specialization occurs by their respective comparative advantages.

In 1817, David Ricardo expanded upon Smith's concept of absolute advantage by introducing the concept of comparative advantage. He argued that relative advantage, rather than an absolute cost advantage, would dictate the patterns of international trade. Consequently, nations would specialize in the production of goods and services with comparatively lower production costs, exporting these products to offset their relative disadvantages. Ricardo (1817) further asserted that under conditions of free trade, a nation's real income would be higher.

Heckscher and Ohlin further expanded upon the concept that "a nation will export goods that require abundant factors of production and import goods that require factors in relative scarcity" (Heckscher, 1919; Ohlin, 1933). This principle is commonly referred to as the Heckscher-Ohlin (H-O) theory or the factor-endowments theory. According to the factor-endowments trade theory (Hill, 2008), specialization in production should involve the most efficient combination of production factors, providing a cost advantage to the producing nation.

The Solow Growth Model posits that the accumulation of capital, labor force growth, and population expansion contribute to increased productivity through technological advancements (Vella, 2018). Solow (1956) emphasizes technological progress as the driving force behind growth. Technological advancements enhance labor productivity and overall output capacity, leading to improved efficiency (Yasin, 2022). These factors ultimately result in sustained economic growth, prompting more countries to participate in international trade, which, in turn, leads to financial inflows and economic expansion (Guru and Yadav 2019; Kayani et al., 2023). Financial inflows, particularly trade surpluses (when exports surpass imports), significantly impact a nation's currency reserves.

2.2. Environmental Kuznets Curve (EKC) Theory

The Environmental Kuznets Curve (EKC) is a theoretical concept that explores the relationship between environmental degradation and economic development. It is named after the economist Simon Kuznets, who first proposed a similar curve to describe the relationship between income inequality and economic growth. The Environmental Kuznets Curve suggests that environmental quality initially declines as a country undergoes industrialization and economic growth. In the early stages of development, industrialization and urbanization tend to lead to increased pollution, deforestation, and resource depletion. This is often driven by the high demand for energy and natural resources to support economic activities.

However, as the country's economy continues to grow and reach a certain income level, the trend reverses. At this point, the curve starts to bend and shows that environmental degradation begins to decrease as economic development progresses further. The underlying idea is that as countries become wealthier, they can afford to invest more in environmental protection and adopt cleaner and more sustainable technologies. Additionally, the focus of economic activities may shift towards less resource-intensive and more environmentally friendly industries.

Critics of the EKC argue that it might not hold true for all environmental indicators and that the curve's shape might be influenced by various other factors, such as trade patterns, population growth, and technological spillovers between countries. While the Environmental Kuznets Curve can offer insights into the relationship between economic development and environmental impacts, it should not be viewed as a prescription for environmental policy. Addressing environmental challenges requires comprehensive and context-specific approaches that consider the unique circumstances of each country and the specific environmental issues they face.

2.3. Review of Relevant Studies

In a recent study by Akbar et al. (2024), the researchers discovered a negative correlation between Foreign Direct Investment (FDI) and CO_2 emissions in the G7 countries. This finding indicates that in these nations, an increase in FDI is associated with a decrease in CO_2 emissions. Rahman and Vu (2020) conducted a study that examined the influence of urban development, inward Foreign Direct Investment (FDI), and Gross Domestic Product (GDP) on CO_2 levels in Canada. Their empirical analysis revealed a positive relationship between GDP growth and carbon footprint. Moreover, increased inflows of FDI were found to be associated with higher CO_2 emissions. Similarly, Ulucak et al. (2020) researched to investigate the causal relationship between natural resource depletion, economic growth, FDI, and eco-sustainability in the BRICS countries. Their findings indicated a positive relationship between environmental pollution indicators and economic growth. Additionally, the study highlighted that the quality of the environment was deteriorating due to emissions, particularly those associated with import-export volumes used to regulate emission levels.

Grossman and Kruger (1991) identified a direct relationship between per capita income and CO_2 emissions, indicating that higher income levels were associated with increased emissions. Conversely, Stern and Common (2001) revealed a curvilinear connection between per capita income and CO_2 emissions, demonstrating that emissions initially rose as income increased but declined once a certain income threshold was reached. Böhringer and Rutherford (2002) analyzed to examine the effects of fluctuations in exchange rates on energy-intensive industries within the European Union. Their findings revealed that when exchange rates depreciated, there was a subsequent reduction in energy consumption and emissions within these sectors. A depreciation of the domestic currency can enhance the competitiveness of a country's exports in the global market by making them more affordable. This competitiveness may lead to an uptick in export levels, which can, in certain cases, result in increased production and, consequently, higher emissions. Huang (2017) observed a similar phenomenon when the Chinese yuan depreciated, leading to an expansion in the country's volume of exports, thereby contributing to elevated CO_2 emissions.

Gross National Savings (GNS) can also have an impact on emissions by influencing infrastructure development. Greater savings can facilitate investments in initiatives like public transportation, energy-efficient structures, and sustainable urban planning, all of which have the potential to lower emissions. This was demonstrated in a study by Zhang and Zhang (2018) that investigated the connection between infrastructure investment (linked to savings) and CO_2 emissions in China. The research revealed that increased investment in infrastructure played a role in reducing emissions by enhancing energy efficiency and transportation systems. Individuals and businesses that have accumulated substantial savings might exhibit a greater propensity to channel their resources into environmentally sustainable initiatives and technologies (Haider and Tehseen, 2022). This inclination is primarily attributed to their extended-term perspective and bolstered financial stability. This concept finds corroboration in the research conducted by Böhringer and Rutherford (2002), who delved into the impact of savings on decision-making concerning environmental policies. Their study indicated that elevated levels of savings could potentially result in the implementation of more rigorous environmental policies designed to mitigate CO_2 emissions.

This study aims to provide a valuable addition to the existing body of knowledge by establishing a relationship between trade openness, CO_2 emission, and its underlying trade drivers within the context of emerging economies. The motivation for this research stems from the apparent gap in both the literature and empirical investigations. As far as the authors are aware, no prior research, spanning from classical economists like Smith (1776) and the 19th-century Laissez-Faire thinkers to more contemporary studies such as those by Kumari et al. (2023) and Fankem and Oumarou (2020), has specifically delved into the fundamental determinants of trade openness and CO_2 emission in the context of emerging economies.

3. METHODS

3.1. Data and Variables

The primary aim of this research study is to explore the relationship between macro drivers' impact on trade openness and as well as CO_2 emission in emerging economies. The macroeconomic variables under examination encompass a wide spectrum, comprising gross national savings (GNS), foreign direct net flow investment (FDI), trade reserves (TR), trade balance (TB), per capita incomes (PCI), labor force participation rate (LFP), gross capital formation (GCF), human capital (HC), exchange rate (ER), and population (POP). These variables were chosen due to their theoretical potential as factors influencing trade openness. To fulfill this objective, the study employs a panel data methodology and leverages data collected over the period spanning from 1995 to 2020. The utilization of the panel data approach allows for the incorporation of both time-series and cross-sectional variations into the analysis, facilitating a comprehensive and nuanced understanding of the intricate relationship between macroeconomic factors and trade openness.

This research study exclusively focuses on a cohort of emerging economies for three principal reasons. Firstly, these nations exhibit distinct determinants of trade drivers when compared to other regions, primarily due to fundamental disparities in their economic and political institutions. Secondly, the deliberate narrowing of the sample to a specific group of economies serves to mitigate sample heterogeneity, enhancing the study's precision and relevance. Thirdly, the inclusion of countries in the sample was contingent upon the availability of data on the variables of interest from reliable sources, thus ensuring data adequacy and accuracy.

The foundation of this study primarily rests upon the accessibility of data about trade openness drivers within the context of emerging economies. As an initial exploratory study, the availability of data dictated the inclusion of variables of interest, with data records commencing from the year 1995. Consequently, the study's analysis begins from the year 1995. The sample encompasses a set of seventy-five emerging economies, each characterized by an average degree of trade openness of 87 percent. The panel data for these countries was meticulously collected from various authoritative sources, including the World Development Indicators (WDI), and the International Monetary Fund (IMF).

3.2. Procedure

To ensure the robustness and trustworthiness of our analysis, this study employed various validation techniques to evaluate the statistical significance of the results and validate the model. Firstly, the Akaike Information Criterion (AIC) was utilized to assess whether the model, which incorporated nine independent variables, was correctly specified, and to identify any instances of over-specification or under-specification. Subsequently, stepwise regression (SR) was employed to identify the most influential independent variables for predicting trade openness. This process led to the selection of five variables that exhibited statistical significance: Foreign Direct Investment (FDI), Per Capita Income (PCI), Gross National Savings (GNS), and the combined effect of Exchange Rate (ER) and Trade Reserves (TR). To enhance the model's overall robustness, we incorporated various estimation methods, which encompassed Pooled Ordinary Least Squares (Pool OLS), Fully Modified Ordinary Least Squares (FMOLS), and Fixed Effects Models (FEM). The choice of employing the FEM approach was primarily motivated by the need to tackle the endogeneity concern within the model, a recommendation made in previous studies (Arize et al., 2015). Moreover, we utilized F-statistics to gauge the statistical significance of the model's fit. Additionally, we performed the Breusch-Pagan and Lagrange Multiplier tests to assess the variances associated with individual effects. To conduct a comprehensive comparison between two models, specifically the random effect and fixed effect methods, we applied the Chow and Housman tests.

To delve into the causality and cointegration of variables, our study focused on five variables that were identified through step-wise regression and endorsed by theoretical literature. Causality analysis was carried out using Granger's (1969) causality framework, a method that has been widely employed in previous research studies (Green, 2003; Wooldridge, 2002). Furthermore, we conducted both the Granger (1981) and Johansson cointegration tests. These tests involve an examination of the residuals resulting from a spurious regression conducted with I(1) to determine whether the variables are co-integrated. If the residuals exhibit I(0) characteristics, it indicates co-integration among the variables; otherwise, they are categorized as I(1). It's important to note that Pedroni (1999, 2004) extended the Engle-Granger method to panel data tests to enhance the analysis in this context.

3.3. Test Models

In Section 3.3, we present two models. The first model is designed to investigate the association between trade openness and the marginal effects of trade openness drivers. In the second model, we examine how trade openness drivers influence CO2 emissions in emerging economies. In this context, the primary dependent variables are represented as TO (trade openness) and CO_2 emissions. The left-hand side of Eq.1 comprises nine key factors that impact trade openness. Trade openness is defined as the ratio of a nation's trade to its gross domestic product denoted as TOjt, where "j" represents a specific country ranging from 1 to N, and "t" spans the years. CO_2 emissions are defined as the ratio of carbon dioxide emissions to per capita income, represented as CO2_jt, where "j' signifies a specific country ranging from 1 to N, and "t" encompasses the years.

The independent variables that drive this relationship are denoted as X_jt, encompassing a set of X factors, with "i" ranging from 1 to K. These variables are observed within country "j," ranging from 1 to N, and cover the period 1995 to 2020. Consequently, the test models can be succinctly expressed as follows:

$$TO_{jt} = \theta_{jt} + \theta_{jt}(PCI_{jt}) + \theta_{jt}(FDI_{jt}) + (GNS_{jt}) + \theta_{jt}(TR_{jt}) + \theta_{jt}(ER_{jt}) + \theta_{jt} + (GCF_{jt}) + \theta_{jt}TIN) + \grave{e}_{jt}\left(ADR\right) + \grave{e}_{jt}\left(LFP\right) + \eta_{jt} \quad (1)$$

$$CO2_{jt} = \theta_{jt} + \theta_{jt}(PCI_{jt}) + \theta_{jt}(FDI_{jt}) + (GNS_{jt}) + \theta_{jt}(TR_{jt}) + \theta_{jt}(ER_{jt}) + \theta_{jt} + (GCF_{jt}) + \theta_{jt}TIN) + \theta_{jt}\left(ADR\right) + \theta_{jt}\left(LFP\right) + \eta_{jt} \quad (2)$$

Moreover, the analysis encompasses several variables, including per capita income, foreign direct net flow investment, gross national savings, trade balance, exchange rate, gross capital formation, and human capital. All these variables are integrated into a multiple regression model, which will be conducted using panel regression techniques. In this context, "j" represents individual countries, and "t" corresponds to the selected annual time. It is anticipated that the parameters in Eq. (1) will demonstrate a significant relationship with trade openness and CO_2 emissions. Each of the X factors should exhibit statistical significance according to predetermined significance levels (P = 0.10, P = 0.05, or P = 0.01). The specific variables employed in this study are comprehensively detailed in Table 1.

Table 2 provides a comprehensive overview of the descriptive statistics for both the dependent and independent variables across 75 emerging countries. The descriptive statistics encompass key metrics, including the mean, minimum, maximum, standard deviation, and the number of observations. The average trade openness value stands at 87.05, with a range spanning from 7.03 to 442.62. This data, covering the period from 1995 to 2020, suggests that nations characterized by open trading systems exhibit notably higher average trade openness. Gross national savings exhibit an average value of 23.28, ranging from −64.72 to 0.44. Meanwhile, trade reserves have an average value of 17.05, ranging from 0.01 to 141.85. Per capita income demonstrates an average of 3.75, with a range between 2.26 and 5.01. Likewise, FDI displays an average value of 4.34, with values spanning from 40.08 to 108.42. Importantly, these mean values closely align with those typically reported in previous studies, reaffirming the accuracy of these variables in representing the trade openness dynamics.

4. FINDING

4.1. Data Diagnostic Test

Table 3 presents the outcomes of the multicollinearity variance inflation factors (VIF) test. The mean VIF ratio is employed to

Table 1: Data description and variable computation

Variables	Description	Symbol	Source
Trade openness	Trade/GDP	TO	WDI
Carbon dioxide emission	Carbon dioxide/per capita income	CO2	WDI
Savings	Gross National Savings)/GDP	GNS	IMF/WDI
Foreign direct net flow investment	FDI Net inflow/GDP	FDI	WDI
Trade reserve	Total reserve minus gold/GDP	TR	WDI
Exchange rate	Exchange rate (Domestic Currency per U.S. Dollar, End of Period)	ER	IMF/WDI
GDP per capita incomes	Total GDP/Total Population	PCI	WDI
Labour force participation	Economically active labour (Labour force participation rate, %of the total population	LFP	WDI
Gross capital formation	Gross capital/GDP	GCF	IMF/WDI
Age Dependency Ratio	Total Population (Age 15-64) % of total population	ADR	WDI
Total Investment	Total Investment/GDP	TIN	IMF/WDI

Table 2: Descriptive statistics

Variables	Mean	Median	Max	Min	SD	J-B
TO	87.05	76.10	442.62	7.03	56.06	Normal
CO2	6.41	3.85	192.06	0.03	14.35	Normal
GNS	23.28	22.43	64.72	0.44	8.99	Normal
TR	17.05	12.71	141.85	0.01	18.20	Normal
PCI	3.75	3.73	5.01	2.26	0.64	Normal
ER	557.48	8.91	23155.00	0.06	2209.49	Normal
FDI	4.34	2.65	108.42	−40.08	7.28	Normal

This table presents a descriptive summary of statistics for the model. TO, GNS, TR, PCI, ER, and FDI represent the trade openness, gross national savings, total reserves minus gold (% of GDP), gross national saving, per capita income, exchange rate, and foreign direct investment net inflow respectively. **Significance: ***P<0.01; **P<0.05; *P<0.1 denotes significance level respectively. Moreover, Table 1 contains no missing values (balance panel)

Table 3: Summary of multicollinearity test (VIF)

Variables model I	T	VIF
GNS	0.67	1.49
TR	0.60	1.68
PCI	0.85	1.18
ER	0.91	1.10
FDI	0.81	1.23
Variables Model II		
GNS	0.78	1.27
TR	0.80	1.23
PCI	0.92	1.08
ER	0.96	1.03
FDI	0.98	1.01

This table presents the results of the cross-dependency VIF test. VIF≤10; no multicollinearity: VIF>10; multicollinearity

assess the presence of multicollinearity among the variables. To examine potential multicollinearity, we have included all the variables of interest in the table and performed a mean-variance analysis of the factor. The VIF values for the variables all fall below VIF ≤ 10, indicating the absence of multicollinearity within the models.

The unit root statistics, as presented in Table 4, pertain to both the level and first-difference series of these variables for each intercept category. The unit root tests indicate that all variables are non-stationary in their original levels but become stationary after being differenced once. Consequently, these variables are integrated at order one, denoted as I(1). With the establishment that the variables are first-difference stationary, the subsequent step involves conducting the Granger causality test to examine short-term causal relationships among the variables under consideration. Before performing this test, it is crucial to determine the optimal lag length. in Table 5. This step is essential for the application of advanced econometric techniques such as Johnson cointegration, Pedroni, and the Granger causality test.

4.2. Alternate Estimation Techniques

Table 5 displays the results of the Dickey-Fuller tests conducted for emerging economies. We utilized five distinct lag selection criteria: the likelihood ratio (LR), final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SC), and Hannan Quinn information criterion (HQ) to identify the most suitable lag order. In this process, we opted for the lag order that yielded the lowest value for each criterion. Following this analysis, a lag order of 2 was selected.

Table 6 presents the outcomes of the Johansen–Fisher cointegration test (Johansen, 1988, 1991, 1995; Johansen and Juselius, 1990). Our analysis has revealed the existence of multiple co-integrating relationships among the variables being examined, as demonstrated by the trace test conducted at both the 1% and 5% levels of significance. To gain further insight into the relationship between two variables and facilitate predictions, we employed the Granger causality test. While the co-integration test identifies long-term relationships, the Granger causality test investigates the possibility of past values of one variable influencing the current values of another variable.

The Granger causality results, as presented in Table 7, offer insightful observations for emerging economies. Our study's outcomes reveal a bidirectional causal relationship between per capita income and Trade Openness, with per capita income Granger causing TO at a significance level of 1%. This discovery suggests that as per capita income increases in emerging economies, trade openness also experiences an increase. Notably, this finding aligns with the results of previous research conducted by Afzal et al. (2012) and Zaman (2012). Their studies concentrated on the association between trade openness and per capita income, uncovering a unidirectional causality from trade openness to per capita income.

Furthermore, our examination uncovers a bidirectional causal connection between trade reserves and Trade Openness, with trade reserves being the Granger cause of TO at a significant level of 1%. This result suggests that an increase in trade reserves within emerging economies leads to an elevation in trade openness. This

Table 4: Panel unit root results

	ADF-Fisher Chi-square		PP-Fisher Chi-square		Im, Pesaran, Shin		Levin, Lin and Chu	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
	Intercept		Intercept		Intercept		Intercept	
TO	229.02*	965.59***	216.74	1518.80***	−2.19***	−24.40***	−4.45***	−21.06***
CO2	154.18	797.06***	153.58	1401.51***	5.18	−19.69***	1.01	−11.96***
GNS	257.56***	965.08***	275.73***	1707.21***	,	−24.43***	−3.13***	18.25***
FR	212.03	921.27***	227.77	1515.10***	0.419	−23.03***	0.54	18.66***
PCI	144.25	642.03***	137.07	835.95***	2.43	−16.11***	−5.45***	−16.60***
ER	278.99***	911.30***	215.77	1559.01***	−0.30	−23.16***	−0.61	−24.20***
FDI	458.24***	1246.50***	637.02***	2189.77***	−10.45	−31.15***	5.92***	−24.06***

**Significance: ***P<0.01; **P<0.05; *P<0 denotes significance level respectively

Table 5: Lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
1	−30541.46	35715.20	16484040	33.64517	33.77235	33.69209
2	−30340.21	399.6199	13743992	33.46337	33.69958*	33.55052*
3	−30281.12	116.9372	13399370	33.43798	33.78320	33.56535
1	−26784.43	38537.72	360933.70	29.82	29.95	29.87
2	26258.23	1044.80	209290.80	29.28	29.51699*	29.36669*

Table 6: Johansen panel co-integration results

Model I	Without trend				With trend			
Hypotheses no of integration	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from the max eign test)	Prob.	Fisher Stat.* (from trace test)	Prob.	Fisher Stat.* (from the max eign test)	Prob.
None	984.80	0.00	1003.00	0.00	108.10	1.00	458.10	0.00
At most 1	4639.00	0.00	2896.00	0.00	1565.00	0.00	1565.0	0.00
At most 2	3013.00	0.00	2084.00	0.00	3939.00	0.00	2947.0	0.00
At most 3	1707.00	0.00	1137.00	0.00	2195.00	0.00	1509.0	0.00
At most 4	903.90	0.00	778.40	0.00	1154.00	0.00	909.70	0.00
At most 5	385.70	0.00	385.70	0.00	639.200	0.00	639.20	0.00
Model II	**Without trend**				**With trend**			
Hypotheses no of integration	**Fisher Stat.* (from trace test)**	**Prob.**	**Fisher Stat.* (from the max eign test)**	**Prob.**	**Fisher Stat.* (from trace test)**	**Prob.**	**Fisher Stat.* (from the max eign test)**	**Prob.**
None	2524	0.00	1499	0.00	2674	0.00	1576	0.00
At most 1	1297	0.00	766.7	0.00	1366	0.00	807.7	0.00
At most 2	708.1	0.00	423.3	0.00	717.8	0.00	453.2	0.00
At most 3	436.5	0.00	300.6	0.00	402.8	0.00	267.3	0.00
At most 4	300.3	0.00	273.8	0.0001	277.6	0.00	231.4	0.02
At most 5	299.0	0.00	299.0	0.4463	274.2	0.00	274.2	0.00

**Significance: ***P<0.01; **P<0.05; *P<0 denotes significance level respectively

finding aligns with the outcomes of a prior study conducted by Maysami and Koh (2000), which involved Granger causality tests for eight Asian countries and identified a unidirectional causality from trade reserves to trade openness. Moreover, the results unveiled a unidirectional causal link from GNS to TO, with GNS Granger causing TO at a significance level of 1%. This outcome indicates that a rise in Gross National Savings (GNS) leads to increased trade, and conversely, an augmentation in trade also leads to heightened trade openness in emerging economies. This observation aligns with earlier research, including the work of Odhiambo (2007), which identified a causal connection between trade and savings.

Moreover, our analysis indicates that the exchange rate does not exert a significant impact on trade openness, as no evidence of either unidirectional or bidirectional causality was observed between the exchange rate and trade openness. This outcome aligns with the findings of a previous study conducted by Bahmani-Oskooee and Brooks (1998), which investigated the dynamic relationship between the exchange rate and trade balances for the U.S. and its trading partners and found no Granger causal relationship between the exchange rate and trade openness.

Furthermore, the results of this study reveal a unidirectional relationship between Foreign Direct Investment to TO, where FDI Granger causes TO at a significance level of 1%. This result is consistent with earlier research conducted by Chiappini (2011) and Nelson et al. (2018), who explored the association between trade openness and FDI inflows in Egypt. Their findings indicated a unidirectional causality running from trade openness to FDI inflows.

The Granger causality results for model 2 presented in Table 7 provide compelling insights for emerging economies. This study finding revealed a unidirectional causal relationship between GNS and CO_2 emission, with GNS Granger causing

Table 7: Granger causality test results

Null hypotheses	Alternate hypotheses	F-statistic	Prob.
Model I			
GNS does not Granger Cause TO	GNS Granger-Cause TO	4.10	0.02
TO does not Granger Cause GNS	No causation	1.58	0.21
TR does not Granger Cause TO	TR Granger Cause TO	16.27	0.00
TO does not Granger Cause TR	TO Granger Cause TR	4.25	0.01
PCI does not Granger Cause TO	PCI Granger Cause TO	4.17	0.02
TO does not Granger Cause PCI	TO Granger Cause PCI	9.68	0.00
ER does not Granger Cause TO	No causation	2.13	0.12
TO does not Granger Cause ER	No causation	0.85	0.43
FDI does not Granger Cause TO	No causation	1.39	0.25
TO does not Granger Cause FDI	TO Granger Cause FDI	52.35	0.00
Null Hypotheses	**Alternate Hypotheses**	**F-Statistic**	**Prob.**
Model II			
GNS does not Granger Cause CO_2	GNS Granger-Cause CO_2	4.10	0.02
CO2 does not Granger Cause GNS	No causation	1.58	0.21
TR does not Granger Cause CO_2	No causation	1.09	0.33
CO2 does not Granger Cause TR	No causation	0.22	0.79
PCI does not Granger Cause CO_2	PCI èGranger Cause CO_2	3.07	0.04
CO2 does not Granger Cause PCI	No causation	1.37	0.25
ER does not Granger Cause CO_2	No causation	0.03	0.96
CO2 does not Granger Cause ER	No causation	0.02	0.97
FDI does not Granger Cause CO_2	FDI Granger Cause CO_2	52.35	0.00
CO2 does not Granger Cause FDI	No causation	52.35	0.25

**Significance: ***P<0.01; **P<0.05; *P<0 denotes significance level respectively

CO_2 emission at a 1% level of significance. This finding suggests that an increase in GNS leads to an increase the CO_2 emission in emerging economies. This finding is in line with prior research, such as Lee (2005). His study focuses on energy consumption and GDP, it also explores Granger causality relationships between these variables and CO_2 emissions. Gross national savings, as a component of GDP, may indirectly affect emissions.

In our analysis, we observed that the impact of trade reserves on CO_2 emissions is not significant, demonstrating neither unidirectional nor bidirectional causality between exchange rates and carbon dioxide emissions in emerging economies. This finding suggests a limited direct effect of trade reserves on environmental outcomes, at least in terms of carbon emissions in these economies. Conversely, the study by Halicioglu (2009) focusing on Turkey presents a contrasting perspective. Halicioglu's research identified a clear link between trade openness and increased CO_2 emissions, underscoring the potential environmental impacts of trade activities. This discrepancy between the findings highlights the complexity of the relationship between trade policies and environmental outcomes, varying across different economic contexts.

Our research elucidates a distinct unidirectional causal link between per capita income and CO_2 emissions, where a rise in per capita income significantly Granger causes an increase in CO_2 emissions at a 1% significance level. This relationship implies that in emerging economies, higher per capita income is associated with increased CO_2 emissions. This outcome aligns with the findings of Fodha and Zaghdoud (2010), who also observed a long-term cointegrating relationship between per capita emissions of pollutants and per capita GDP, underlining the environmental implications of economic growth.

Furthermore, our study reveals that the exchange rate's influence on CO_2 emissions in emerging economies is not substantial. The analysis indicates a lack of both unidirectional and bidirectional causality between exchange rates and CO_2 emissions in these economies. This finding contrasts with the research conducted by Zhang and Zhang (2018) in China, which identified a negative relationship between the exchange rate and CO_2 emissions. Their study suggests that variations in exchange rates have implications for CO_2 emissions in the Chinese context, underscoring the diverse impacts of economic variables on environmental outcomes across different national settings.

The results of this investigation indicate a unidirectional relationship between Foreign Direct Investment (FDI) to CO_2 emissions, demonstrating that FDI is a Granger cause of CO_2 emissions at a significance level of 1%. This relationship can be attributed to the fact that FDI often stimulates industrial growth and augments production capacities in emerging economies. When such industrial expansion is predicated on energy-intensive processes that depend on fossil fuels, it can lead to an escalation in CO_2 emissions. Additionally, the energy sources utilized in FDI projects are pivotal in determining the extent of emissions. Specifically, the reliance of foreign investments in high-emission energy sources like coal can exacerbate the emission levels. This observation contradicts the prior findings Chien et al. (2023). Their finding showed foreign direct investment has a negative influence on carbon emissions.

The key findings resulting from the panel pooled data regression analysis are summarized in Table 8, encompassing four different types of test results. The FEM emerges as the most robust explanatory model, with a P-value below 0.01 and an F-test value of 272.72, indicating a highly significant model fit. Additionally, the adjusted R-squared value stands at 92%, signifying a

Table 8: Summary results on panel regression

Model I Dep. Var. is TO	SR	FEM	Pooled	FMOLS
Constant	−38.45***	46.79***	−38.45***	
	(−7.35)	(8.56)	(−7.35)	
GNS	0.57***	0.25***	0.57***	0.23**
	(5.50)	(3.96)	(5.50)	(2.20)
TR	1.08***	0.32***	1.08***	0.34***
	(20.92)	(8.83)	(20.92)	(5.55)
PCI	21.50***	7.01***	21.50***	8.88***
	(15.84)	(4.62)	(15.84)	(3.46)
ER	0.00***	0.00***	0.00***	0.00***
	(15.84)	(3.74)	(15.84)	(2.62)
FDI	2.71***	0.39***	2.71***	0.50***
	(6.48)	(7.25)	(6.48)	(5.75)
Adj R^2	0.43	0.92	0.43	0.92
F-test	388.77***	272.93***	388.77**	
B-P-LM			15729.65***	
Hausman chi^2		156.81***		
Model II Dep. Var. is Co2	**SR**	**FEM**	**Pooled**	**FMOLS**
Constant	−18.33***	2.06**	−18.33***	-
	(−11.05)	(2.08)	(−11.05)	
GNS	0.13***	0.01***	0.13***	0.03***
	(4.15)	(2.51)	(4.15)	(0.82)
TR	−0.02	0.00	−0.02	0.00
	(−1.28)	(0.50)	(−1.28)	(0.69)
PCI	7.52***	1.13***	7.52***	1.01***
	(17.69)	(4.06)	(17.69)	(2.06)
ER	0.00***	0.00***	0.00***	0.00***
	(−2.19)	(0.43)	(−2.19)	(0.60)
FDI	1.08***	1.61***	1.08***	1.51***
	(20.92)	(2.01)	(20.92)	(71.94)
Adj R^2	0.21	0.92	0.21	0.91
F-test	62.99***	561.05	62.99***	
B-P-LM				
Hausman chi^2		9.91		

significance level ***P<0.01; **P>0.05. *P<0.1 respectively

substantial level of explained variation within the model. Upon implementing stepwise regression for model selection, only five factors exhibit statistically significant estimated coefficients. These factors are identified as the primary drivers of trade openness in emerging economies and comprise gross national savings, foreign direct net flow investment, exchange rate, trade reserves, and per capita income.

The analysis also revealed a statistically significant positive relationship between the coefficient for gross national savings and trade openness. The estimated coefficient for GNS stood at 0.25 ($P < 0.01$), indicating that a one-unit change in GNS corresponds to a 0.25-unit change in trade openness. It implies that emerging economies characterized by higher levels of gross national savings tend to exhibit greater trade openness. This finding suggests that an increase in gross national savings is associated with a concurrent increase in trade openness in emerging countries. Notably, this finding aligns with previous research, including the study conducted by Sinha and Sinha (2004), which identified a relationship between trade openness and savings.

The coefficient associated with FDI was calculated to be 0.39 ($P < 0.01$), indicating a statistically significant and positive relationship with trade openness. This suggests that a one-unit change in FDI results in a 0.39-unit change in trade openness. In essence, an increase in FDI is accompanied by a corresponding increase in trade openness. This finding suggests that foreign companies may be more inclined to invest in emerging economies that have more open trade policies, which, in turn, fosters greater international trade. These findings are consistent with prior research; for example, Asiedu (2006) conducted a study examining the determinants of FDI inflows to African countries and identified trade openness as a significant factor positively influencing FDI inflows. This supports the observed relationship between trade openness and net FDI inflows.

In our examination of the impact of Per Capita Income (PCI) on trade openness in emerging economies, we observed a coefficient value of $\beta = 0.00$ ($P < 0.01$) at a 1% significance level. This outcome suggests that per capita income exerts an inconsequential influence on trade openness within emerging nations. To clarify, a one-unit alteration in PCI does not result in any noticeable change in trade openness. This finding challenges the conventional wisdom that per capita income plays a substantial role in determining trade openness. Nevertheless, it's important to acknowledge that prior research studies conducted by Dollar (1992), Sachs et al. (1995), Harrison (1996), Edward (1998), Frankel and Romer (1999), Ezeani (2013), Tahir et al. (2016), and Tahir and Azid (2015) have consistently indicated that income is the primary driver of economic openness, which contrasts with our present findings.

The present study found a positive relationship between trade reserves and trade openness, signifying that nations with higher TR exhibit a greater inclination toward international trade. This highlights the substantial impact of trade reserves on trade openness in emerging economies, as indicated by a coefficient of β = 0.32 (P < 0.01) at a 1% significance level. A single-unit change in trade reserves corresponds to a 0.32-unit adjustment in trade openness. These results provide strong evidence of the influential and affirmative connection between trade reserves and trade openness in emerging nations, underscoring the crucial role of trade reserves in promoting international trade. These findings align with previous research conducted by Boateng et al. (2015), Uddin et al. (2019), and Lane and Burki (2001), which explored the relationship between trade openness and foreign exchange reserves, consistently revealing a positive and substantial association. These studies propose that trade openness contributes to the accumulation of foreign exchange reserves by fostering trade surpluses and attracting capital inflows.

Following a comprehensive examination of the influence of the exchange rate on trade openness in emerging economies operating within open-trading conditions, our analysis yielded an ER coefficient of β = 0.00 (P < 0.1), signifying its lack of statistical significance. This outcome implies that the ER exerts minimal sway over trade openness within emerging economies. Put differently, a one-unit change in ER does not bring about a noticeable shift in Trade Openness. This revelation challenges the conventional assumption that ER plays a substantial role in shaping TO within emerging nations. In their extensive literature review on ER's association with international trade, Auboin and Ruta (2013) concluded that while ER's impact on trade can be intricate and occasionally noteworthy, it is not consistently straightforward or substantial.

The results of our panel data regression analysis, as detailed in Table 8 for model 2, show four types of test outcomes. The Fixed Effects Model (FEM) stands out as the most robust explanatory model, demonstrated by a P < 0.01 and an impressive F-test value of 561.05, which strongly signifies the model's significant fit. Moreover, the model exhibits an adjusted R-squared value of 92%, indicating a high level of variability explained within the model. In our approach, we employed stepwise regression for the selection of the model, which identified that only five factors had statistically significant estimated coefficients. These factors are thus identified as the key determinants influencing carbon dioxide emissions in emerging economies.

The study identifies a significant positive correlation between gross national savings (GNS) and carbon dioxide emissions. The analysis reveals that with a P < 0.01, the coefficient for GNS is 0.01. This implies that for every unit increase in GNS, there is a corresponding 0.01-unit increase in CO_2 emissions. This trend suggests that in emerging economies, higher gross national savings are often accompanied by increased CO_2 emissions. This phenomenon may be linked to the fact that elevated levels of savings in these economies could correlate with increased investment and, consequently, higher energy consumption leading to greater CO_2 emissions. This observation is in line with the findings of Soytas et al. (2007), who noted a long-term equilibrium relationship between investment, energy consumption, and CO_2 emissions in the United States, highlighting that investment-promoting policies (which contribute to higher GNS) need to account for the potential rise in CO_2 emissions and explore mitigation strategies.

In the conducted analysis, the relationship between trade reserves and carbon dioxide emissions in emerging economies was found to be statistically insignificant. This outcome, denoted by a coefficient β of 0.00 with a p-value less than 0.50, implies that changes in trade reserves do not meaningfully alter CO_2 emissions, as each unit change in trade reserves is associated with a negligible 0.00-unit change in CO_2 emissions. This finding contrasts with Halicioglu's (2009) study, which explored the dynamics between trade, CO_2 emissions, and energy consumption in Turkey and reached the conclusion that increased trade activity leads to a rise in CO_2 emissions.

In our analysis assessing the impact of per capita income on CO_2 emissions in emerging economies, we identified a statistically significant coefficient of β = 1.13 with a P < 0.01. This significant level of 1% indicates a strong relationship, where each unit increase in per capita income is associated with a corresponding 1.13-unit increase in CO_2 emissions. This trend suggests that in emerging economies, as per capita income increases, there is a tendency for a rise in consumption of energy-intensive goods and services, leading to higher CO_2 emissions. This phenomenon aligns with the Environmental Kuznets Curve (EKC) hypothesis, which posits a relationship between economic growth and environmental degradation. Grossman and Krueger (1991) similarly documented the positive link between increased income and energy consumption, which subsequently elevates CO_2 emissions. Their research also highlighted that this curve is not consistently linear; at higher income levels, emissions may decrease, indicating that wealthier societies might invest more in environmental protection measures.

Our analysis delved into the relationship between the exchange rate (ER) and carbon dioxide emissions in emerging economies. The results indicate an ER coefficient of β = 0.00 with a P < 0.01, highlighting its statistical insignificance. This suggests that the exchange rate has negligible influence on CO_2 emissions in these countries. In other words, variations in the exchange rate do not translate into significant changes in CO_2 emissions. This conclusion is consistent with findings from Wang and Li (2016), who also explored the impact of exchange rate fluctuations on CO_2 emissions in China and India, discovering that these fluctuations do not significantly affect emissions in either country.

The analysis revealed a significant and positive relationship between FDI and CO_2 emissions, as indicated by a coefficient of 1.61 with a P-value below 0.01. This implies that for every unit increase in FDI, there is a corresponding 1.61-unit increase in CO_2 emissions. This trend highlights that FDI in emerging economies tends to escalate CO_2 emissions. This relationship can be understood in the context of FDI projects, often concentrated in energy-intensive sectors like manufacturing and mining in these economies. These sectors typically contribute to higher emissions, particularly when they depend on fossil fuel-based energy sources. This observation is in line with the findings of prior studies, such as those by Frankel and Rose (2005), which have similarly noted the impact of FDI on emissions in the context of emerging economies.

4.3. Additional Analysis using Alternate Measurements

To reinforce the reliability of our research findings, we employed various alternative estimation techniques, including stepwise regression (SR), the Pooled Ordinary Least Squares (OLS) method, and FMOLS. The foundational theory behind FMOLS, which posits that this estimator yields consistent and efficient estimates of short-term coefficients while addressing issues of endogeneity, stems from the influential study by Phillips and Hansen (1990). They validated the asymptotic properties of FMOLS, showing its consistency and efficiency under specific conditions. The results from applying these diverse estimation methods are presented in Table 8. In using SR, Pooled OLS, and FMOLS, a consistent pattern emerges positive and significant correlations between Gross National Savings (GNS), Foreign Direct Investment (FDI), Trade Reserves (TR), Per Capita Income (PCI), and Exchange Rate (ER) with trade openness are observed. This uniformity across multiple estimation methods lends substantial credibility to our initial findings.

It is noteworthy that across all four estimation techniques (SR, Pooled OLS, FEM, and FMOLS), the coefficient for the exchange rate was consistently zero. This indicates that ER does not hold significant economic influence as a determinant of trade openness in emerging economies. Furthermore, in Model 2, we found that GNS, FDI, and PCI consistently exhibit a positive association with CO_2 emissions across all four estimation methods, suggesting these trade-related factors are influential drivers of CO_2 emissions in emerging economies. Also, it was observed in all methods that the coefficient for the exchange rate consistently remains zero, indicating its lack of significant impact as a determinant of CO_2 emissions. Additionally, trade reserves were found to have an insignificant relationship with CO_2 emissions across all estimation techniques. In conclusion, the application of alternative estimation methods confirms the robustness and reliability of our principal results, as comprehensively detailed in Table 8.

4.4. Policy Implication

To address the challenge of increasing CO_2 emissions alongside the rise in Gross National Savings (GNS), the following policy recommendations are proposed: (1) Adoption of Eco-Friendly Technologies: Policies should incentivize the adoption of clean technologies, ensuring that GNS growth does not lead to proportional increases in CO_2 emissions. This approach could be supported by leveraging trade openness to import advanced green technologies. (2) Enforcement of Stringent Environmental Standards: The introduction of strict environmental regulations can compel industries to cut down their carbon emissions, thereby reducing the environmental impact associated with rising GNS (Choudhury et al., 2023). (3) Incorporation of Environmental Considerations in Trade Policies: Modifying trade policies to include environmental concerns can sustain economic growth without exacerbating CO_2 emissions. This step ensures that the benefits of trade openness are not negated by increased environmental degradation. These strategies emphasize a comprehensive approach, intertwining economic growth with environmental protection, especially vital in scenarios of growing GNS and expanding trade activities.

To align Foreign Direct Investment (FDI) with environmental objectives, the following policy recommendations can be implemented: (1) Promotion of Eco-Friendly FDI: Governments can offer incentives such as tax breaks, subsidies, or other financial benefits to foreign investors who focus on clean technologies, renewable energy, and sustainable practices (Nasim et al., 2023). This strategy aims to attract FDI that not only contributes to economic growth but also aligns with environmental conservation goals, helping reduce CO_2 emissions. (2) Policies should be geared towards facilitating the transfer of technology from FDI ventures to local firms. This approach would build domestic capacity in green technologies, enabling emerging economies to leverage new knowledge and technology. Adopting cleaner production processes would not only foster sustainable industrial development but also contribute to a reduction in emissions.

The Environmental Kuznets Curve (EKC) hypothesis posits an inverted U-shaped relationship between per capita income and environmental degradation, including CO2 emissions. It suggests that with initial increases in per capita income, emissions typically rise due to industrialization and development. However, after surpassing a certain income threshold, further income growth leads to a reduction in emissions, likely due to increased environmental awareness and technological advancements. For policymakers aiming to expedite reaching and moving beyond this threshold, the focus could be on investing in and promoting clean technologies and sustainable infrastructure, governments can foster a transition towards a greener economy while continuing to grow. Offering incentives for adopting eco-friendly technologies can encourage both businesses and individuals to shift towards more sustainable practices. Policymakers should Introduce carbon taxes or emissions trading systems that can provide economic incentives for emission reductions. Such mechanisms make emitting CO_2 more costly, prompting businesses and individuals to seek out greener alternatives. Formulating strategies that promote sustainable economic development while minimizing carbon emissions is crucial for emerging economies. This involves encouraging economic growth that is decoupled from emissions and focusing on investments in clean energy, energy efficiency, and sustainable practices. These policy approaches align with the EKC hypothesis, aiming to reduce environmental degradation while supporting economic development, particularly in emerging economies.

Foreign exchange reserves are pivotal in shaping a sustainable global economy, especially for emerging countries. Their management has implications for a nation's capacity to import energy resources, including fossil fuels. Utilizing these reserves to finance the import of carbon-heavy energy sources can escalate emissions. In some instances, emerging economies with substantial foreign exchange reserves might opt to invest in foreign assets, potentially encompassing industries linked to fossil fuels. Such investments can inadvertently bolster sectors with high emission levels. However, there's an opportunity for emerging economies to direct a segment of their foreign exchange reserves towards environmentally friendly and sustainable ventures. Investments in renewable energy projects, reforestation initiatives, and infrastructure resilient to climate change represent a strategic use of reserves. This proactive approach can aid these economies in lowering their carbon footprint while maintaining financial stability.

Moreover, the association of a stronger currency with increased CO_2 emissions necessitates a delicate balancing act for policymakers in emerging economies. They must align their exchange rate management strategies with environmental objectives. This balance could require active interventions in foreign exchange markets or modifications to monetary policies to steer the exchange rate. Additionally, the impact of exchange rates on trade is significant. A stronger currency, by making imports more affordable, may result in a rise in the consumption of imported products that have substantial carbon footprints. To counter this, governments could contemplate the implementation of tariffs or quotas on these high-carbon imports or offer incentives for alternatives that are more environmentally friendly.

4.5. Limitation and Future Direction

Like all scholarly endeavors, this research has its limitations, which could potentially pave the way for future scholarly inquiries. The reliability of this study's outcomes heavily relies on the accuracy and authenticity of the secondary data employed. The robustness and broader applicability of the findings are largely dependent on the availability, comprehensiveness, and period of the data sample used. Therefore, it is imperative to ensure the meticulousness, reliability, and validity of both the data collection and analysis methodologies to affirm the study's effectiveness and the extrapolation of its conclusions. It's important to note that macroeconomic data relevant to investigating trade openness and its influencing factors in emerging markets before 1995 is limited and often not comprehensive. The time frame for the data analyzed in this study spans from 1995 to 2020.

This multi-country study employs a multi-model testing approach to explore data about carbon dioxide emission and its theoretically proposed trade drivers within a sample of emerging economies. This methodology serves as a foundation for generating fresh insights and presents various avenues for further research. For example, evaluating the effectiveness, validity, and reliability of the proposed multi-model testing technique in diverse geographic regions, such as the Gulf or the South Asian Association for Regional Cooperation (SAARC) regions, could yield intriguing results. Therefore, this current research encourages scholars to delve into additional factors suggested by the trade and environmental theories that influence CO_2 emission in various geographical contexts.

The data used in this study was sourced from the World Trade Organization (WTO) and covers the period from 1995 to 2020. Future research endeavors might explore alternative time frames, such as data spanning from 1964 to 2020 from the United Nations Conference on Trade and Development (UNCTAD) or from 1985 to 2020 from Uruguay, providing an opportunity to further enrich the understanding of trade drivers impact on CO_2 emission dynamics.

5. CONCLUSION

In this study, an examination was undertaken to explore both the immediate and extended interplay between trade openness, carbon dioxide emissions, and key trade drivers, namely gross national savings, net foreign direct investment inflow, per capita income, exchange rate, and trade reserves. The research aimed to uncover unidirectional Granger causative links among carbon dioxide emissions and these five key factors of trade, thereby establishing a causal nexus as suggested by various trade theories.

Initially, the research employed a stepwise regression approach to pinpoint the most impactful factors influencing trade openness. Following this, a range of analytical techniques were utilized to validate the observed relationships. Sophisticated panel regression methods, including Fully Modified Ordinary Least Squares (FMOLS), Ordinary Least Squares (OLS), and Fixed Effects Model (FEM), were applied to derive the findings. To probe into the long-term dynamics and confirm enduring relationships, Pedroni and Johansson's cointegration methods were employed. Lastly, the investigation included Granger causality tests to establish the directionality of causality between trade openness, CO_2 emissions, and the identified trade determinants. It is pertinent to note that the data analyzed in this study covered the period from 1995 to 2020.

The outcomes of this investigation corroborate prior academic findings, affirming the link between CO_2 emissions and crucial trade-related factors across both immediate and extended timescales. The study effectively establishes a profound connection between trade openness, CO_2 emissions, and a range of macroeconomic indicators. Notably, as trade liberalization deepens in emerging economies, the influence of these macroeconomic variables on trade openness and CO_2 emissions becomes more pronounced. In the first model of the analysis, Foreign Direct Investment (FDI) is identified as a key driver of trade openness in these regions. On the other hand, variations in exchange rates are shown to have a minimal effect on trade openness, suggesting a weak correlation between these elements.

In the second model, the study unveils that gross national savings, net inflow of FDI, per capita income, and exchange rates are positively and significantly correlated with CO_2 emissions. However, the influence of exchange rate fluctuations on CO_2 emissions is relatively limited in emerging economies, pointing to a minimal role in shaping environmental outcomes. The research also finds an insignificant relationship between trade reserves and CO_2 emissions, indicating that trade reserves do not notably affect CO_2 emission levels.

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