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Asymmetric Impact of International Trade on Consumption-Based Carbon Emissions in MINT Nations

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Abstract: The association between carbon emissions and international trade has been examined thoroughly; however, consumption-based carbon emissions, which is adjusted for international trade, have not been studied extensively. Therefore, the present study assesses the asymmetric impact of trade (import and export) and economic growth in consumption-based carbon emissions (CCO_2) using the MINT nations (Mexico, Indonesia, Nigeria and Turkey) as a case study. We applied the Nonlinear ARDL to assess this connection using dataset between 1990 and 2018. The outcomes from the BDS test affirmed the use of nonlinear techniques. Furthermore, the NARDL bounds test confirmed long-run association between CCO_2 and exports, imports and economic growth. The outcomes from the NARDL long and short-run estimates disclosed that positive (negative) shocks in imports increase (decrease) CCO_2 emissions in all the MINT nations. Moreover, positive (negative) shocks in exports decrease (increase) CCO_2 emissions in all the MINT nations. As expected, a positive shock in economic growth triggers CCO_2 emissions while a negative shift does not have significant impact on CCO_2 emissions in the MINT nations. Furthermore, we applied the Gradual shift causality test and the outcomes disclose that imports and economic growth can predict CCO_2 emissions in the MINT nations. The study outcomes have significant policy recommendations for policymakers in the MINT nations.

Keywords: consumption-based carbon emissions; economic growth; imports; exports; environmental sustainability

1. Introduction

The size of international trade has been rising for several years; but, between 2005 and 2015, the amount of international trade rose by roughly 62 percent. International trade's proportion to overall gross domestic product (GDP) has also increased, from 23 percent in 1960 to 58 percent in 2019 [1]. The single most important factor linking international trade to rising emissions of CO_2 is the international trade growth [2,3]. On a larger scale, trade is seen to improve efficiency of economy; nevertheless, some critics see international trade as a tool used by affluent countries to decrease their emissions levels. Such emissions reduction, on the other hand, are likely to be (at least partially) balanced by an increase in emissions in the region(s) where services and goods are traded—a phenomena described as Carbon–Leakage [4–6]. Conversely, the "Pollution Haven Hypothesis" claims that the global trade system shifts severely polluting sectors to low-income nations with less rigorous emissions controls [7].

Nonetheless, emissions generated inside a country's territorial boundaries, i.e., production or territory-based emission, continue to get noticed [8–10]. Consumption-based carbon emissions (CCO_2), which are modified for international trade, receive far less consideration [11–13]. However, it is maintained that older methods of calculating carbon emissions are inaccurate. For example, it ignores the fact that modern economies concentrate in knowledge and service-based industries, which emit less carbon than industries and economies that is agriculture-based [14–17]. Likewise, emerging nations create commodities that are purchased by affluent economies, but carbon emissions associated with their creation are assigned to developing countries [18–22]. As a result, developed nations appear to be lowering their CO_2 emissions, as stated by the widely contested Inverted-U shaped environmental Kuznets curve [23]. They do, nevertheless, fulfill the growing demand from emerging markets [24,25].

Since these emissions (consumption-based emissions) cannot be isolated from growing levels of income, which boosts the volume of trade and level of emissions across the world, the veracity of the assertion that with a particular point of income, the emissions levels falls, is called into question [26]. As a result, a consumption-based strategy is perhaps more suited for addressing the full carbon chain, demonstrating carbon stock obligation, and assessing the efficacy of initiatives to reduce growing emissions levels [27]. Additionally, comparative research indicates that trade has a substantial influence on CCO_2 emissions whilst having no influence on emissions based on territory [3,14,28].

Prior studies on carbon emissions and trade have focused on production-based emissions whilst disregarding consumption-based carbon emissions [3,12]. Furthermore, prior research focused on the fundamental connection in aggregated trade situations, ignoring the disaggregated influence of trade, or how imports and exports influence CO_2 emissions individually [29]. Nevertheless, research suggests that exports reduce CCO_2 emissions whereas imports increase emissions [2,13,14]. Furthermore, scant studies on trade and CCO_2 emissions utilize various panels of nations; for instance; [30] for BRICS nations, [3] for nine oil exporting nations, and [27] for MINT nations. The above studies only utilized panel linear techniques such as panel ordinary least square (POLS), fully modified ordinary least square (FMOLS), augmented mean group (AMG), Common Correlated Effect Mean Group (CCEMG), cross sectional autoregressive distributed lag (CS-ARDL) and other techniques. Nevertheless, these techniques do not take into account shocks (positive and negative) of trade on CCO_2 emissions. Therefore, the current study fills the gap in ongoing literature on CCO_2 emissions. In light of this discrepancy, the primary goal of this research is to determine how the asymmetric influence of trade (imports and exports) affects the emissions levels of MINT countries.

Ensuring efficient and effective economic growth, particularly in emerging nations, is a crucial consideration when setting climate objectives. In the near future, the BRICS group of countries (Brazil, Russia, India, China, and South Africa) is anticipated to become the primary source of global development [31]. Nevertheless, due to their quick development, economist [32] recognized and publicized another coalition of nations, namely Mexico, Indonesia, Nigeria, and Turkey (MINT), as a possible rising bloc of the global economy. MINT nations have had significant growth in recent years, with similar features characterizing this growth. That is to say, these nations have generally been distinguished by big and growing populations, providing them with outstanding human resource availability and growth possibilities. MINT nations are gathering steam as a result of their unique economic characteristics, and are anticipated to be global leaders in the next three decades. In this respect, Goldman Sachs has anticipated a steady growth tendency in these nations until 2020, while investment patterns have projected a 5% growth in the economies of these nations [33]. Nonetheless, the MINT nations' ecological sustainability is being eroded by an increasing population and substantial growth. As a result of their status as major and developing nations, MINT nations must collaborate on international reduction of emission activities in order to limit the greenhouse gas emissions (GHGs) impacts that arise [34]. As a result, it is necessary to investigate the panel of MINT countries individually for the asymmetric influence of trade on CCO_2 emissions.

As previously stated, the primary goal of this research is to investigate the asymmetric influence of trade on CCO_2 emissions in MINT nations. Our panel includes MINT nations—Mexico, Indonesia, Nigeria and Turkey. To the understanding of the authors, no existing studies have investigated the asymmetric effect of international trade on CCO_2 emissions for the case of MINT countries. Therefore, this study contributes to the existing literature in a number of ways. (i) This study exclusively considers the MINT nations the next emerging bloc. Increased import capacity may lead to an increase in CCO_2 emissions, making it worthwhile to empirically evaluate for MINT countries. The interrelationship between CCO_2 emissions and trade is investigated by disintegrating trade into exports and imports. (ii) Now, in order to achieve this policy-level objective, it is necessary to understand that the model parameters might not have the same impacts on the target policy variable, whenever they will be encountering any external shock. On the other hand, it is possible that those shocks will be appearing in certain time differentials. Hence, in order to design a robust policy framework, the methodological adaptation needs to complement these aspects of policy formulation. In this pursuit, the nonlinear autoregressive distributed lag (NARDL) method by [35] is employed in this study. This method is capable of capturing the differential impacts of model parameters on target policy variable in incidents of positive and negative shocks. Moreover, NARDL is capable of capturing the impacts appearing with time differentials. In view of this, this method is able to complement the policy-level contributions of the study, and thereby, indicating the analytical contribution of the study.

The next section presents the summary of studies conducted which is followed by the theoretical framework, data and method in Section 3. Section 4 discusses the methods employed and Section 5 presents the study's findings and conclusion.

2. Literature Review

The current study sheds light on the linkage between economic growth, export and import on consumption-based carbon emissions (CCO_2). However, little research has been done to examine the asymmetric effect of economic growth, export and import on CCO_2 emissions in the case of MINT economies. For policymakers and practitioners, the literature thoroughly examined the distinct components of the considered variables to give beneficial results for the researchers. This section is divided into three parts.

2.1. Environmental Degradation and Economic Growth

Over the years, numerous studies have been conducted regarding the effect of economic growth on environmental degradation. For instance, the study of [12] using the dual adjustment approach found that economic growth contributes to CCO_2 of Mexico over the period between 1990 and 2018. Similar outcome was reported in the study of [27] undertaken in a research of MINT economies based on the AMG and CS-ARDL approaches. Moreover, [36] studied the Indian economy using the quarterly dataset from 1990Q1 to 2015Q4 employing the DOLS and FMOLS, and established that economic growth contributes to CCO_2 insignificantly. The study of [14] investigated the 20 Asian Nations using the dataset from 1990 to 2013 using the CCEMG and found that GDP increases CCO_2, indicating that they have a direct influence on the environmental pollution. The study of [37] explored the impact of GDP on CO_2 emissions in Nigeria using dataset from 1971–2015. The investigators applied utilized ARDL and wavelet approaches and uncovered that an increase in economic growth increase environmental degradation in Nigeria.

Moreover [38], studied Japan over the period 1965–2019 employing the DOLS and FMOLS, and established that GDP contributes to CO_2 and the square of GDP decreases CO_2, suggesting that EKC is valid in Japan. Moreover, using dataset between 1990 and 2016 [39], assessed the impact of economic growth on CO_2 emissions using the ARDL approach. The study outcome revealed that an increase in imports contribute to environmental degradation in Russia. Conversely [40], applied the DOLS and FMOLS and established that GDP positively affects environmental degradation in Latin America countries using a dataset between 1980 and 2017. This implies that an increase in economic growth in the Latin American countries contribute to environmental degradation. Moreover, the research of [41] explored the effect of GDP on CO_2 emissions in MINT economies over the period 1980–2018. The investigators applied the mean group approach and the outcome revealed a positive and statistically significant association between GDP and emissions and GDP Granger causes CO_2. For the case of South Korea [42], established the existence of a positive and significant connection between GDP and emissions over the period 1980–2018 utilizing the ARDL approach. In addition [43], confirmed the presence of a positive and significant connection between GDP and emissions.

2.2. Environmental Degradation and Imports

It is predicted that boosting exports will minimize CCO_2 emissions in the host nation, whereas boosting imports will raise CCO_2 emissions in the host nation. Theory suggests that an increase in imports is linked to an increase in consumption because it is one of the critical parts of any nation's total level of consumption. Over the years, several studies have explored the association between imports and environmental degradation. For instance [3], studied the G7 economies for the period 1990–2017 applying the CCEMG and DH causality approach and established that import helps triggers environmental degradation. Furthermore, there is a unidirectional causal association from import to CCO_2 emissions. A stream of research such as [13] scrutinized the association between CCO_2 emissions and import employing DOLS, CRR and FMOLS for the dataset for period 1990Q1–2017Q4 and demonstrated that a positive and significant association between import and CCO_2 emissions. More precisely [44], studied the Turkey over the period 1971–2014 using the ARDL and found that import contributes to the decrease in environmental quality. In related research of Azerbaijan using ARDL approach [45], established that a positive and significant association between import and CCO_2 emissions. Likewise, the research of [46] on a sample of 24 sub-Saharan African nations observed that the increase in imports reduces environmental degradation over the period 1980–2010 and there is a unidirectional causal association from import to CO_2. The study of [47] in China using the ARDL found a positive and insignificant association between import and CO_2 over the period 1965–2016.

2.3. Environmental Degradation and Export

Exports give more products and services for destination nations to use while leaving less for local utilization. Exports include services and goods created in the nation of origin and used in the receiving nation. As a result, CO_2 from exports must be emitted in the receiving nation. Studies on the on the effect of exports on environmental degradation have been undertaken by prior scholars; however, their findings are mixed. For instance, the study of [48] using 7 ASEAN Nations for the period 1990–2017 and applying the panel quantile approach established that export tends to reduces environmental degradation. Conversely, the study of [49] for 9 Oil exporting Nations using the AMG and CS-ARDL for the dataset for period 1990–2018 and demonstrated that a negative and significant association between export and CCO_2. The study of [50] confirmed a negative association between export and CCO_2 in RCEP economies over the period 1990–2020 using the CS-ARDL. Furthermore, the DH causality approach established a bidirectional causal association between export and CCO_2. In a study on Turkey applying the NARDL [51], uncovered that the increase in export contributes to CO_2 insignificantly, while the decrease in export resulted in the decrease in CO_2 over the period between 1974 and 2014. The study of [52] for Italy applying the NARDL and uncovered that the increase in export tends to reduce CCO_2 while the decrease in export resulted in the decrease in CCO_2 but insignificant over the period between 1970Q1 and 2018Q4. Table 1 presents the summary of the reviewed studies.

Table 1. Summary of Related Studies.

Scholars	Country of Study	Period	Methodology	Outcome(s)
		Environmental Degradation and Economic Growth		
[36]	India	1990Q1–2015Q4	DOLS and FMOLS	$GDP \rightarrow CCO_2$ (+)
[27]	MINT	1990–2017	AMG and CS-ARDL	$GDP \rightarrow CCO_2$ (+)
[12]	Mexico	1990–2018	Dual adjustment approach	$GDP \rightarrow CCO_2$ (+)
[11]	Chile	1990–2018	NARDL	$GDP^+ \rightarrow CCO_2$ (+) $GDP^- \rightarrow CCO_2$ (+)
[14]	20 Asian Nations	1990–2013	CCEMG	$GDP \rightarrow CCO_2$ (+)
[42]	South Korea	1980–2018	ARDL	$GDP \rightarrow CO_2$ (+)
[53]	South Korea	1965–2019	ARDL, DOLS, FMOLS and GSB	$GDP \rightarrow CO_2$ (+) $CO_2 \rightarrow GDP$
[39]	Russia	1990–2016	ARDL	$GDP \rightarrow CO_2$ (−)
[54]	China	1985–2019	ARDL and GSB	EKC is valid $GDP \rightarrow CO_2$
[5]	Argentina	1970–2018	ARDL	EKC is valid $CO_2 \rightarrow GDP$
[37]	Nigeria	1971–2015	FMOLS, ARDL and DOLS	$GDP \rightarrow CO_2$ (+)
[40]	Latin America countries	1980–2017	DOLS and FMOLS	$GDP \rightarrow CO_2$ (+)
[41]	Malaysia	1960–2018	FMOLS, ARDL and DOLS	$GDP \rightarrow CO_2$ (+) $GDP \rightarrow CO_2$
		Environmental Degradation and Import		
[3]	G7 Nations	1990–2017	CCEMG and DH causality approach	$IMP \rightarrow CCO_2$ (+) $IMP \rightarrow CCO_2$
[55]	G7	1990–2018	CS-ARDL, AMG and DH causality	$IMP \rightarrow CCO_2$ (+) $IMP \rightarrow CCO_2$
[44]	Turkey	1971–2014	ARDL	$IMP \rightarrow CO_2$ (+)
[46]	24 sub-Saharan Africa Nations	1980–2010	ARDL	$IMP \rightarrow CO_2$ (−) $IMP \rightarrow CO_2$
[45]	Azerbaijan	1995–2013	ARDL	$IMP \rightarrow CCO_2$ (+)
[47]	China	1965–2016	ARDL	$IMP \neq CO_2$ (+)
		Environmental Degradation and Export		
[49]	9 Oil exporting Nations	1990–2018	AMG and CS-ARDL	$EXP \rightarrow CCO_2$ (−)
[50]	RCEP economies	1990–2020	CS-ARDL and DH causality	$EXP \rightarrow CCO_2$ (−) $EXP \leftrightarrow CCO_2$
[51]	Turkey	1974–2014	NARDL	$EXP^+ \neq CO_2$ (+) $EXP^- \rightarrow CO_2$ (−)
[56]	Tunisia	1980–2009	ARDL	$EXP \rightarrow CO_2$ (+)
[52]	Italy	1970Q1–2018Q4	NARDL	$EXP^+ \rightarrow CCO_2$ (−) $EXP^- \neq CCO_2$ (−)

According to the literature (Table 1), there are scant studies that investigated the effect of international trade (import and export) on consumption-based carbon emissions for emerging economies. However, more significantly, none of the previous research have employed the nonlinear technique to assess the effect of international trade and economic growth on consumption-based carbon emissions for the case of the MINT economies. Furthermore, this study employed a county-specific analysis during estimation. The asymmetric association was examined by using the NARDL approach and dataset between 1990 and 2018. In light of this development, the present research fills the gap in environmental and energy literature.

3. Theoretical Framework, Data and Methods

3.1. Theoretical Framework

This section explains the theoretical procedure through which imports, GDP and exports influence consumption-based carbon emissions (CCO_2). CCO_2 emissions include both government and government household final domestic consumption demand, gross capital creation, purchases made overseas by residents and inventory changes [3]. This metric is trade-adjusted, spanning the entire carbon chain, and aids in identifying the carbon emissions production in one nation and its absorption in other nations [12,27]. As a result, the impact of international trade in this research is assessed by separating imports and exports.

According to the theory, growing exports give more products and services for destination nations to use while leaving less for local utilization. Exports include services and goods created in the nation of origin and used in the receiving nation. As a result, CO_2 from exports must be emitted in the receiving nation. Based on this knowledge, imports is anticipated to decrease CCO_2 emissions, i.e., $\left(\beta_1 = \frac{\alpha CCO_2}{\alpha EXP} < 0\right)$.

Imports, on the flip side, encompass products and services created by a foreign nation and used locally, and must release CO_2 internally. It is predicted that boosting exports will minimize CCO_2 emissions in the host nation, whereas boosting imports will raise CCO_2 emissions in the host nation. Theory suggests that an increase in imports is linked to an increase in consumption because it is one of the critical parts of any nation's total level of consumption. As a result, the imports from the MINT nations represent a significant percentage of the intermediate and finished services and goods used by the host nations. Studies such as [12–14] others have documented this occurrence in the past. Based on this knowledge, imports are anticipated to increase CCO_2 emissions, i.e., $\left(\beta_2 = \frac{\alpha CCO_2}{\alpha IMP} > 0\right)$.

It is the same with gross domestic product (GDP), which covers diverse aspects of the economy such as investment, consumption, and net exports (including goods and services exported). This is as expected since consumption accounts for the majority of GDP, and rising consumption is related with increases in CCO_2 emissions [3,11]. Furthermore, when income levels rise in MINT nations, which are emerging nations, there is a chance that not only the state, but also households and firms, will consume more, leading an upsurge emissions level. Based on this knowledge, imports are anticipated to increase CCO_2 emissions, i.e., $\left(\beta_3 = \frac{\alpha CCO_2}{\alpha GDP} > 0\right)$.

3.2. Data

This research investigates the influence of trade (imports and exports) on consumption-based emissions (CCO_2) as well as the role of economic growth (GDP) in the MINT economies using dataset spanning from 1990 to 2018. Consumption-based carbon emission is the dependent variable while its regressors are economic growth and trade (import and export). In this empirical analysis, all the variables are transformed into their natural logarithm. This is done to ensure that data conform to normality. Table 2 highlights the measurement and source of the series used.

Figure 1 highlights the trends of the variables (exports, imports, consumption-based carbon emissions, and economic growth) of study. We observed increasing trend in CCO_2 emissions and economic growth in the MINT nations from 1990 to 2018. These finding are unexpected given the fact that developing nations such as MINT nations' policy agenda is pro-growth which favors economic expansion at the expense of deterioration of the environment. Therefore, growth and CCO_2 are expected to move in the same direction.

Table 2. Data description.

Variables	Symbol	Measurement	Source
Consumption-based carbon emissions	CCO_2	Million tons of CO_2 ($MtCO_2$)	GCA
Economic growth	GDP	GDP per capita (constant 2010$)	WDI
Export	EXP	Exports % of GDP	WDI
Import	IMP	Imports % of GDP	WDI

Note: GCA—Global Carbon Atlas; WDI—World Development Indicators.

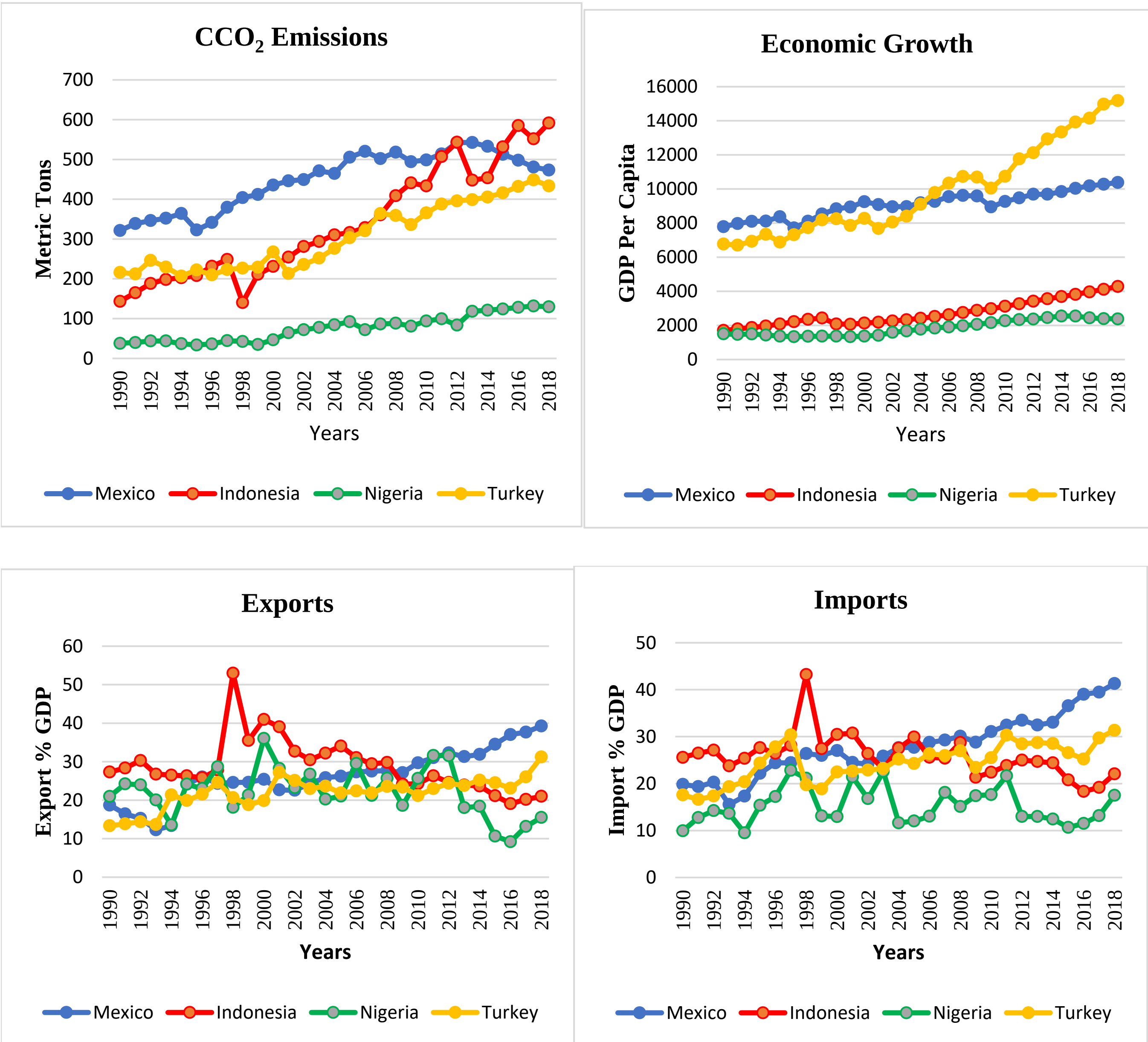

Figure 1. Trend of variables of study.

3.3. Empirical Methods

3.3.1. BDS and Unit Root Test

It is critical to investigate the series for nonlinearity before assessing the nature of stationarity. Therefore, the present research applied BDS test to assess if linear or non-linear modelling is acceptable for the research. Rejection of the null hypothesis shows the presence of nonlinearities against that nonlinear modelling is relevant to the research.

Conventional stationary tests, such as the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root tests, are incapable of capturing breaks that may exist in variable [57]. Based on this shortcoming, using the traditional unit roots test will result in inconsistent results if there is proof of break(s). As a result, this study used the Zivot Andrews (ZA) unit root test initiated by [58].

The ZA is illustrated by Equations (1)–(4) as follow:

$$\text{Model A}: \ \Delta \text{y} = \sigma + uy_{t-1} + \beta \text{t} + \gamma \text{DU}_t + \sum_{j=i}^{t} d_j \Delta y_{t-j} + \varepsilon_t \tag{1}$$

$$\text{Model B}: \ \Delta y = \sigma + uy_{t-1} + \beta t + \theta DT_t + \sum_{j=i}^{t} d_j \Delta y_{t-j} + \varepsilon_t \tag{2}$$

$$\text{Model C}: \ \Delta y = \sigma + uy_{t-1} + \beta t + \theta DT_t \gamma DU_t + \sum_{j=i}^{t} d_j \Delta y_{t-j} + \varepsilon_t \tag{3}$$

where: dummy variable's mean shift that happens at the probable break-date is indicated as DU_t, whereas the associated variable's trend change is indicated as DT_t. Model A and B denotes the intercept, and trend respectively. The combination of intercept and the trend is denoted in Model C.

$$\text{DU}_\text{t} = \begin{cases} 1 \ldots\ldots\ldots\ldots if\ t > TB \\ 0 \ldots\ldots\ldots\ldots if\ t < TB \end{cases} \text{ and } \text{DT}_\text{t} = \begin{cases} t - TB \ldots\ldots if\ t > TB \\ 0 \ldots\ldots\ldots\ldots if\ t < TB \end{cases} \tag{4}$$

3.3.2. NARDL

In the present study, we applied the nonlinear ARDL suggested by [35] to assess the favorable and unfavorable effect of international trade and economic growth on CCO_2 emissions. The NARDL is illustrated as follows:

$$\begin{aligned} \Delta CCO_{2_t} = \beta_0 + \beta_1 CCO_{2_{t-1}} \quad & + \beta_{2(+)} GDP_{t-1(+)} + \beta_{3(-)} GDP_{t-1(-)} + \beta_{4(+)} EXP_{t-1(+)} \\ & + \beta_{5(-)} EXP_{t-1(-)} + \beta_{6(+)} IMP_{t-1(+)} + \beta_{7(-)} IMP_{t-1(-)} \\ & + \sum_{i=1}^{t} \theta_1 \Delta CC0_{2t-i} + \sum_{i=1}^{t} \theta_2 \Delta GDP_{t-i(+)} + \sum_{i=1}^{t} \theta_3 \Delta GDP_{t-i(-)} \\ & + \sum_{i=1}^{t} \theta_4 \Delta EXP_{t-i(+)} + \sum_{i=1}^{t} \theta_5 \Delta EXP_{t-i(-)} + \sum_{i=1}^{t} \theta_5 \Delta IMP_{t-i(+)} \\ & + \sum_{i=1}^{t} \theta_5 \Delta IMP_{t-i(-)} + \varepsilon_t \end{aligned} \tag{5}$$

From Equation (5), in both the long-term and short-term, β_i and θ_i are used to represent both the positive (+) and negative (−) shifts. Multi-collinearity will not be a problem with this method since it allows the optimal lag length selection. This approach also deals with fractional integration as well as addresses endogenous and autocorrelation problems. Asymmetries between long (β = β+ = β− and short term (θ = θ+ = θ−) must be taken into account during estimate, and this may be determined by using the Wald test. To determine the model's optimal lag for CO_2 and its regressors, this research used the Akaike information criteria (AIC). The partial sums of favorable and unfavorable changes in regressors are estimated simultaneously.

$$ge_{t(+)} = \sum_{k=l}^{t} \Delta ge_{k(+)} = \sum_{k=l}^{t} max(\Delta ge_k, 0)\ and\ ge_{t(-)} = \sum_{k=l}^{t} \Delta ge_{k(-)} = \sum_{k=l}^{t} min(\Delta ge_k, 0) \tag{6}$$

A long-run co-integration with the concern variables is assessed using the bounds tests of Pesaran et al. (2001) [59], which is based on F-statistic and the null hypothesis guarding it is stated as β(+) = β(−) = β = 0. $ge_{t(+)}$ and $ge_{t(-)}$ are used to denote the positive (+) and negative (−) adjustments of regressors (GDP, EXP, IMP). When using long-term co-integration bounds tests, there is no method to confirm the findings. The bounds test is based on F-statistic and the null hypothesis. In addition, the long-run coefficients of favorable ($LA_i = \beta_{(+)}/\gamma$) and negative ($LA_i = \beta_{(-)}/\gamma$) changes are used to estimates the asymmetric coefficients.

3.3.3. Gradual Shift Causality

This study also employed a non-linear causality approach solely to evaluate the causal association between CCO_2 and the regressors. The Fourier Toda–Yamamoto causality was developed by [60]. This approach accounts for structural modification during estimation. The construction of this approach is based on VAR (p + d), which is as follows:

$$y_t = \alpha(t) + \beta_1 y_{t-1} + \ldots + \beta_{p+dmax} y_{t-(p+dmax)} + \varepsilon_t \tag{7}$$

For Equation (9), the intercept of the VAR model is represented as α, whereas y_t and β are denoted as matrices parameter and variable of concern (CCO_2, GDP, EXP and IMP) separately. From Equations (8) and (9) provides the required definition of the Fourier Toda–Yamamoto causality. To detect the structural modification, the need for the Fourier approximation is required which can be defined in Equation (8) as:

$$\sigma(t) = \sigma_0 + \gamma_1 sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 cos\left(\frac{2\pi kt}{T}\right) \tag{8}$$

where: the frequency size and number is depicted as γ_{1k} and s; the frequency for approximation is indicated as k, whereas, the frequency modification can be measured with γ_{2k}. This method is derived in the Equation (9) by substituting Equation (8) into the Equation (7), producing this:

$$y_t = \sigma_0 + \gamma_1 sin\left(\frac{2\pi kt}{T}\right) + \gamma_2 cos\left(\frac{2\pi kt}{T}\right) + \beta_1 y_{t-1} + \ldots + \beta_{p+d} y_{t-(p+d)} + \varepsilon_t \tag{9}$$

According to this method, the null hypothesis is (H0: β1 = βϴ= 0) and the alternate hypothesis is (H0: β1 ≠ βϴ≠ 0) when using the Wald statistic.

4. Findings and Discussions

The study commenced by testing variables integration order. These tests are necessary because time-series data is renowned for its unpredictability, which makes scientific analysis of the data challenging. Therefore, the present research applied traditional PP and ADF unit root tests initiated by [61,62] to capture the stationarity characteristic of the series. The outcomes of the PP and ADF tests are presented in Table 3 and the result disclosed that all the series are I [1]. Most of the time, traditional techniques such as ADF and PP fall short in the presence of structural breaks that might have had a significant influence on the motion of the variables used to examine an economy. Such a fundamental rupture in the economy always seems to have a long-term influence (shift) or break. The global financial crises in 2007/2008, the current COVID-19 pandemics, Asia financial crisis in 1997, for instance, are an illustration of a structural disruption that has had a significant influence on the world economy. As a result, the present research utilized the Zivot and Andrew (ZA) test initiated by [58] to catch variables stationarity and single break simultaneously. The results of the ZA are presented in Table 4.

Table 3. ADF, PP and ZA Unit root Tests.

	ADF		PP		ZA			
	Level	**Δ**	**Level**	**Δ**	**Level**	**Break**	**Δ**	**Break**
Countries				**Consumption-based Carbon Emissions (CCO_2)**				
Mexico	−2.7043	−5.4187 *	−2.7043	−5.9975 *	−4.2336	2001	−5.1392 **	2002
Indonesia	−1.9509	−6.9326 *	−1.9509	−14.263 *	−4.1076	1998	−6.4796 *	2000
Nigeria	−2.7043	−4.8610 *	−2.6715	−5.5404 *	−4.3398	2001	−6.4796 *	2000
Turkey	−2.7834	−6.9654 *	−2.7028	−7.1955 *	−6.6078 *	2004	−5.8157 *	2006

The shock periods were all well absorbed over the research period, 1990–2018. During these timeframes, two significant structural changes (global financial crisis and energy shock) surfaced, which has the potential to leave a lasting shock to the several nation's economies, such as Mexico, Nigeria and Turkey, as well as the Asia financial crisis in 1997, which had a massive effect on Indonesia's economy can influence the research variables. The Kuwait invasion a fellow OPEC nation by Iraq in the 1990 produced another short-lived energy crisis before the energy crisis of the 2000s [41,63]. Furthermore, the fears of an energy crisis in the 2000s were mostly generated by Middle East tensions, China's overwhelming oil demand, and the weakening of dollar. From 2003 to 2008, there was a general huge rise in oil prices. Another significant structural shift was the introduction of the United States' monetary policy, which influenced its internal economy as well as the economies of foreign nations that linked their exchange rates to the US dollar.

The MINT countries (Mexico, Indonesia, Nigeria and Turkey) were among the culprits of the United States' structural changes and monetary policy, which have the potential to affect the stationarity of the variables concerned. All of these disruptions resulted to structural shift in the MINT nations, which might jeopardize the economic indicators stability. Table 3 shows the results of both the standard unit root test and the structural shock. Furthermore, we assess the series nonlinearity by utilizing the BDS test initiated by [64]. The outcomes of the BDS test is presented in Table 3 and the outcomes disclosed that all the series are nonlinear. Therefore, using the linear techniques such as FMOLS, DOLS, VECM, and ARDL will yield misleading outcomes.

Table 4. BDS Test Outcomes.

	Mexico	Indonesia	Nigeria	Turkey
	Consumption-based Carbon Emissions (CCO_2)			
	Z-stat [*p*-value]	Z-stat [*p*-value]	Z-stat [*p*-value]	Z-stat [*p*-value]
M2	12.773 *	20.363 *	15.416 *	16.892 *
M3	12.973 *	20.352 *	15.803 *	16.943 *
M4	13.927 *	20.289 *	15.962 *	16.963 *
M5	15.771 *	20.404 *	16.096 *	17.149 *
M6	17.365 *	21.862 *	16.506 *	17.897 *
	Export (EXP)			
M2	7.4547 *	5.4087 *	12.948 *	5.7665 *
M3	7.8080 *	4.5381 *	13.629 *	6.8405 *
M4	8.5657 *	2.9154 *	13.779 *	7.5088 *
M5	9.6666 *	2.2312 *	14.678 *	8.1398 *
M6	11.171 *	2.3661 *	14.350 *	8.7539 *
	Import (IMP)			
M2	11.120 *	2.2117 *	4.5426 *	10.218 *
M3	11.319 *	0.2035 *	5.5921 *	10.619 *
M4	10.667 *	−2.2163 *	7.0517 *	11.130 *
M5	12.010 *	−3.7727 *	7.9781 *	11.459 *
M6	14.354 *	−3.8840 *	8.7830 *	11.962 *
	Economic Growth (GDP)			
M2	13.633 *	19.866 *	19.360 *	18.012 *
M3	13.687 *	19.246 *	19.271 *	18.172 *
M4	14.557 *	18.959 *	18.996 *	18.140 *
M5	15.641 *	18.781 *	19.115 *	18.128 *
M6	16.895 *	18.676 *	19.462 *	18.484 *

Note: * denotes $p < 0.01$.

The present research proceeds by assessing the long-run association between consumption-based carbon emissions and import, export and economic growth in the MINT nations which is presented in Table 5. The F-statistics for Mexico is 5.415862 which is more than the critical value (lower and upper). Therefore, the null hypothesis of "no co-integration" is rejected at significant level of 1%. Furthermore, the F-statistics for Indonesia is 9.274899 which is more than the critical value (lower and upper). Therefore, the null hypothesis of "no co-integration" is rejected at significant level of 1% for Indonesia. Moreover, the F-statistics for Nigeria is 5.110351 which is more than the critical value (lower and upper). Therefore, the null hypothesis of "no co-integration" is rejected at significant level of 1% for Nigeria. Finally, the F-statistics for Turkey is 6.581693which is more than the critical value (lower and upper). Therefore, the null hypothesis of "no co-integration" is rejected at significant level of 1% for Turkey.

After the co-integration between CCO_2 and the independent variables is confirmed in all the MINT nations, we proceed by assessing the asymmetric influence of GDP, import and export on CCO_2 emissions in the MINT nations (Mexico, Indonesia, Nigeria and Turkey). The outcomes of the NARDL for each MINT nations are presented in Table 6. In all the MINT nations, favorable shock in GDP triggers CCO_2 emissions positively. This implies that keeping other factors constant, 1% upsurge in GDP caused CCO_2 to increase by 2.2462% in Mexico, 1.0954% in Indonesia, 2.4518% in Nigeria and 0.5010% in Turkey.

Furthermore, unfavorable shift in GDP has insignificant influence on CCO_2 emissions in the all the MINT nations. The CCO_2-GDP outcomes imply that Mexico, Indonesia, Nigeria and Turkey have sacrificed the quality of the environment at the expense of economic growth. This result is connected to the basic conundrum of the growth–development dichotomy, which is discussed in [65] report. The widespread pro-growth attitude in emerging nations is reflected in the contexts of Mexico, Indonesia, Nigeria and Turkey, and this issue may be related to the Mexican, Indonesian, Nigerian and Turkish economies' fossil fuel-driven development pattern. The study of [27] on the determinants of CCO_2 emissions neglected favorable and unfavorable shifts in export, import and economic growth. Therefore, the outcomes from this study might have major policy ramifications for MINT economies economic expansion trend readjustment. This trend of ecologically unsustainable economic growth has been found in a number of other countries as well [66]. Likewise, GDP is a gauge of an economy's health and includes many elements such as investment, net exports, government spending, and consumption. Since consumption accounts for the majority of GDP, rising consumption is positively linked with CCO_2 emissions [3,24].

Table 5. NARDL Co-integration.

Countries	F-Statistic	Lower Bound 95%	Upper Bound 95%	Decision
Mexico	5.4158 *	3.15	4.43	Co-integration
Indonesia	9.2748 *	2.79	4.10	Co-integration
Nigeria	5.1103 *	3.15	4.43	Co-integration
Turkey	6.5816 *	4.29	5.61	Co-integration

Note * stands for $p < 0.01$. AIC is utilized for optimum lag length.

Table 6. NARDL Long- and Short-Run Outcomes.

Long-Run Outcomes								
	Mexico		Indonesia		Nigeria		Turkey	
Variables	Coefficient	T-Prob	Coefficient	T-Prob	Coefficient	T-Prob	Coefficient	T-Prob
GDP (+)	2.2462	3.2558 *	1.0954	2.9222 ***	2.4518	1.8935 ***	0.5010	2.826 ***
GDP (−)	−0.2295	−0.5326	0.3524	1.5625	−2.4599	−0.7976	−0.3728	−1.3685
IMP (+)	0.8622	2.2792 **	0.6844	4.3300 ***	0.1239	3.4775 *	0.2754	3.8105 *
IMP (−)	−0.2919	−2.0879 ***	−1.1286	−2.6982 **	−0.3556	−2.1450 ***	−0.2143	−5.8619 *
EXP (+)	−0.4697	−2.0086 ***	−1.0779	−1.8283 ***	−0.2510	−4.9991 *	−0.5025	−8.4306 *
EXP (−)	0.2084	−0.3488	1.3091	2.6699	−0.4369	−2.0855 ***	−0.2775	−4.391 *
Dummy	0.1208	1.3135	0.2403	1.8558 ***	0.2067	3.7366 *	1.5934	1.4521
C	1.1091	3.8893	2.0736	4.6304	2.1859	3.6451	2.5293	7.4473
Short-Run Outcomes								
Variables	Coefficient	T-Prob	Coefficient	T-Prob	Coefficient	T-Prob	Coefficient	T-Prob
GDP (+)	0.1839	4.8365 **	3.3524	2.4804 **	2.4518	2.8206 **	0.5010	4.4580 *
GDP (−)	0.1967	1.1139	0.6844	2.6685 **	−4.4599	−2.2061 **	−1.5934	−1.3263
IMP (+)	0.6785	6.152*	1.8518	2.1591 ***	3.5135	3.1035 *	0.5788	7.4219 *
IMP (−)	−1.2680	−3.3445 *	−2.0203	−5.4797 *	−0.1279	−0.9870	−0.2143	−8.3428 *
EXP (+)	−0.4697	−9.7456 *	−1.3910	−1.2360	−0.1283	−1.2173	−0.5025	−10.643 *
EXP (−)	1.2680	6.7677 *	2.7024	5.9162 *	0.4369	3.1457 **	0.2765	3.1036 **
ECT (−1)	−0.6193	−7.9162 *	−0.8478	−7.4353 *	−0.4307	−5.3803	−0.4793	−4.6377 *
C	1.5936	5.9686	2.0736	4.3718	2.1859	5.4310	3.5293	4.5235

Note: *, ** and *** stands for $p < 0.01$, $p < 0.05$ and $p < 0.10$ respectively.

Furthermore, when income levels in oil-producing nations rise, it is possible that not only the government, but also companies and people, would consume more, leading an upsurge in emissions. According to this result, meeting SDG 13 objectives will be difficult in Mexico, Indonesia, Nigeria and Turkey. This outcome is in line with the study of [11] for Chile which established that a favorable upsurge in GDP triggers CCO_2 while negative shock in GDP does not impact CCO_2 in Chile. Nonetheless, this outcome contradicts the research of [67] who established that favorable (unfavorable) shifts in GDP increase (decrease) environmental degradation in China.

Moreover, favorable (unfavorable) shifts in import impact CCO_2 positive (negatively). This implies that keeping other factors constant, 1% upsurge in IMP caused CCO_2 to increase by 0.8622% in Mexico, 0.6844% in Indonesia, 0.1239% in Nigeria and 0.2754% in Turkey. On the other hand, 1% decrease in import is attributed to CCO_2 emissions decrease in 0.2919% in Mexico, 1.1286% in Indonesia, 0.3556% in Nigeria and 0.2143% keeping other factors constant. From a theoretical standpoint, an increase in the level of imports of goods and services is connected to increased consumption because it is regarded as one of the important elements in any nation's overall level of consumption, which is especially true in the case of MINT nations. The MINT economies are primarily emerging nations, and their imports include a significant percentage of products and services, both intermediate and final, that are utilized by the host nations (MINT nations). This outcome corroborates the findings of [34] for MINT nations and [3] for nine oil-exporting nations.

Finally, favorable changes in export influence CCO_2 negatively in all the MINT economies. This outcome implies that a positive shift in export mitigates CCO_2 emissions. According to the hypothesis, growing exports give more goods and services for destination nations to consume while leaving less for local consumption. These empirical outcomes are similar to the outcomes of [27] for MINT nations, and [29] for nine exporting nations who established that negative interrelationship between exports and CCO_2 emissions. Furthermore, our empirical outcomes show that exports and imports have opposite signs, i.e., exports reduce CCO_2 emissions while imports trigger CCO_2 emissions.

The short-run outcomes are similar to the long-run outcomes. The ECT is negative and significant in the MINT nations (Mexico, Indonesia, Nigeria and Turkey). For Mexico, the ECT is −0.619, for Indonesia (−0.84), for Nigeria (−0.43) and for Turkey (−0.47). Furthermore, the study conducts several post-estimation tests which are presented in Table 7. The outcomes show that for all the MINT nations there is no issue of serial correlation, no problem of heteroskedasticity, no problem of misspecification and the residuals are normally distributed. The stability tests are also conducted using CUSUM and CUSUM of Square and the outcomes are presented in Table 7. The outcomes show that for all the MINT nations, the models are stable.

Table 7. Post Estimation Tests.

	Mexico	**Indonesia**	**Nigeria**	**Turkey**
R^2	0.98	0.99	0.96	0.99
Adjusted R^2	0.97	0.98	0.95	0.98
DW	2.589	2.256	2.465	2.461
J-B Normality	1.301 [0.521]	1.488 [0.475]	0.828 [0.376]	1.488 [0.475]
χ^2 LM	1.907 [0.185]	2.487 [0.138]	2.397 [0.152]	2.470 [0.154]
χ^2 ARCH	0.032 [0.858]	0.007 [0.931]	0.090 [0.755]	0.003 [0.952]
χ^2 RESET	0.404 [0.534]	0.001 [0.951]	1.001 [0.340]	0.562 [0.491]
CUSUM	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%
CUSUM of Square	Stable at 5%	Stable at 5%	Stable at 5%	Stable at 5%

The Wald test was utilized in this research to determine the significance of long-run and short-run asymmetries. Table 8 depicts the results of the WALD test. The results demonstrated that imports and exports have long-run asymmetries while economic growth does not have long and short run asymmetries for all the MINT nations.

Table 8. Long-Run and Short-Run Asymmetric (Wald) Test.

	Mexico				Indonesia			
	Long-run		Short-run		Long-run		Short-run	
Variables	Chi-square	*p*-value	Chi-square	*p*-value	Chi-square	*p*-value	Chi-square	*p*-value
GDP	1.212	0.297	1.068	0.322	2.005	0.156	3.233 ***	0.0722
EXP	9.560 *	0.006	7.072 **	0.016	7.204 *	0.007	3.917 **	0.0478
IMP	5.994 **	0.031	4.646 **	0.057	8.613 *	0.003	3.965 **	0.0464
	Nigeria				Turkey			
Variables	Chi-square	*p*-value	Chi-square	*p*-value	Chi-square	*p*-value	Chi-square	*p*-value
GDP	0.643	0.449	0.665	0.430	2.215	0.154	2.428	0.145
EXP	5.196 ***	0.057	0.115	0.740	5.506 **	0.037	7.436 **	0.026
IMP	8.971 **	0.011	5.806 **	0.047	6.098 **	0.027	4.448 **	0.049

Note: *, ** and *** represents $p < 0.01$, $p < 0.05$ and $p < 0.10$.

Furthermore, this study also employed the Gradual Shift Causality test, which was summarized in Table 9. Based on the result reported in Table 9, there is a unidirectional causal interconnection from GDP to CCO_2 in Mexico within the period of consideration, indicating that GDP is a major predicting factor of CCO_2. This outcome of [41] for Malaysia and [54] for China also aligns with our findings. Furthermore, there is a unidirectional causal association from CCO_2 to GDP in Turkey, suggesting that CCO_2 is a predictive factor of GDP for the case of Turkey and this outcome is consistent with the study of [43] for South Korea and [5] for Argentina. In addition, a feedback causal association was evident between CCO_2 and GDP in Indonesia and Nigeria, suggesting that both CCO_2 and GDP are predictive indicators for each other. This finding consonance with the outcome of [68] for Brazil and [40] for Latin America countries. Between CCO_2 and EXP, there is a bidirectional causal interaction between CCO_2 and EXP in Indonesia and Turkey, indicating that there is a feedback causative association between CCO_2 and EXP. This finding is in line with the study of [3] for RCEP economies.

Moreover, there is a one-way causal association from CCO_2 to EXP in Mexico, signifying that CCO_2 is a predictive factor of EXP for the case of Mexico and this outcome is in line with the study of Fatima et al. (2021) for high-emitter countries [6]. However, no causal association exists between CCO_2 and EXP in the case of Nigeria. Between CCO_2 and IMP, there is a one-way causal interaction from IMP to CCO_2 in Mexico and Nigeria, indicating that import is a predictor of CCO_2 for the case of Mexico and Nigeria. This outcome is consistent with the research of [3] for G7 Nations; and [46] for 24 sub-Saharan African nations. Finally, two-way causal interaction is evident between CCO_2 and IMP in Indonesia and Turkey, suggesting a feedback causal interaction. This outcome is not in line with the study of [55] for G7 nations and [44] for Turkey.

Table 9. Gradual Shift Causality Test.

Causality Movement	Wald-Stat	No of Fourier	p-Value	Decision Rule
		Mexico		
GDP → CCO_2	13.239 ***	2	0.066	Reject Ho
CCO_2 → GDP	3.449	2	0.841	Do not Reject Ho
EXP → CCO_2	2.054	2	0.956	Do not Reject Ho
CCO_2 → EXP	31.210 *	3	0.000	Reject Ho
IMP → CCO_2	58.420 *	1	0.000	Reject Ho
CCO_2 → IMP	10.562	3	0.158	Do not Reject Ho
		Indonesia		
GDP → CCO_2	526.162 *	2	0.000	Reject Ho
CCO_2 → GDP	29.760 *	2	0.000	Reject Ho
EXP → CCO_2	15.836 **	1	0.027	Reject Ho
CCO_2 → EXP	68.732 *	1	0.000	Reject Ho
IMP → CCO_2	96.003 *	3	0.000	Reject Ho
CCO_2 → IMP	21.308 *	3	0.003	Reject Ho
		Nigeria		
GDP → CCO_2	47.668 *	3	0.000	Reject Ho
CCO_2 → GDP	18.286 **	3	0.011	Reject Ho
EXP → CCO_2	3.907	1	0.790	Do not Reject Ho
CCO_2 → EXP	5.237	2	0.631	Do not Reject Ho
IMP → CCO_2	51.427 *	1	0.000	Reject Ho
CCO_2 → IMP	4.094	1	0.769	Do not Reject
		Turkey		
GDP → CCO_2	4.816	3	0.682	Do not Reject Ho
CCO_2 → GDP	30.531 *	3	0.000	Reject Ho
EXP → CCO_2	12.603 ***	1	0.082	Reject Ho
CCO_2 → EXP	33.399 *	1	0.000	Reject Ho
IMP → CCO_2	21.226 *	2	0.003	Reject Ho
CCO_2 → IMP	33.259 *	2	0.000	Reject Ho

Note: *, ** and *** represents $p < 0.01$, $p < 0.05$ and $p < 0.10$ respectively. → depicts causality movement.

5. Conclusions and Policy Directions

5.1. Conclusions

Global warming is a legitimate issue in today's society. Global warming has put the lives of millions of people and animals in jeopardy. As a result, the issue has gotten a lot of interest from scholars and researchers all around the globe [6,7,31,69–73]. Carbon (CO_2) emissions are the major cause of global warming or climate change, according to the literature. As a result, an accurate carbon emission assessment is critical for developing an appropriate climate strategy to address ecological issues. Therefore, the current research employed NARDL technique, which is an innovation of [35] to investigate the asymmetric effects of economic growth, exports and imports on CCO_2 emissions in MINT economies between 1990 and 2018. The NARDL method enables us to evaluate the bifurcated (i.e., favorable and unfavorable) influence of the explanatory factors on CCO_2. However, the study also incorporated a dummy variable representing the series break into the CCO_2 function. Furthermore, we utilized the BDS test to determine whether or not the variables under examination are linear or not. The BDS results outcomes shows that variables of study are nonlinear, necessitating the use of non-linear approach such as NARDL.

The outcomes of the NARDL highlights that (i) a positive shock in GDP triggers CCO_2 positively in the MINT economies, whereas a negative shock in GDP has insignificant influence on CCO_2; (ii) positive (negative) shock in import increase (decrease) CCO_2 in the MINT economies; (iii) favorable (unfavorable) shock in export decrease (increase) CCO_2 for only Nigeria and Turkey. The study also employed the Gradual Shift Causality test and the outcomes indicate that: (i) a unidirectional causal interconnection from GDP to CCO_2 in Mexico and from CCO_2 to GDP in Turkey, whereas, a feedback causal association was evident between CCO_2 and GDP in Indonesia and Nigeria; (ii) a bidirectional causal interaction between CCO_2 and exports in Indonesia and Turkey, and a one-way causal association from CCO_2 to exports in Mexico; (iii) a one-way causal interaction from IMP to CCO_2 in Mexico and Nigeria, and a two-way causal interaction is evident between CCO_2 and imports in Indonesia and Turkey.

5.2. Policy Directions

Based on the research findings, the research proposes that, in order to lessen the influence of imports and economic expansion on CCO_2 emissions, there is need to target domestic consumption, particularly those sectors which consume more energy; thereby causing emissions of CO_2. Imports that are emissions-oriented should also be managed by non-restrictive trade policies that exclusively aim to reduce CO_2. The import structure of these countries is mostly production machinery and transportation, so these countries should focus on importing environment-friendly production machinery, which shall not only reduce the effect of imports on emissions but also shall help in declining the externality effect caused by exports through trade. Policies related to consumption-based carbon emissions and international trade shall realize the effect of government policies to absorb it fully. Finally, policymakers in the MINT nations should focus appropriate policy interventions on export industries, which are less polluting yet vital to economic expansion. Only by increasing exports while keeping import growth steady can CCO_2 emissions be reduced.

5.3. Study Limitation and Future Research Directions

Although the present research utilized a new metric for environmental degradation, the policy suggestions are limited to the variables utilized and the group of countries analyzed. Therefore, future studies should investigate other determinants of CCO_2 emissions such as technological innovation, renewable energy consumption and globalization in their analysis. In addition, future research that covers the most recent changes such as oil price drops and COVID-19 recession would be worth considering. Furthermore, the dataset for consumption-based carbon emissions covers the period from 1990 to 2018; therefore, it is not possible to add more variables considering the small period of analysis. This is a dynamic model and suitable lag length is also used. Addition of more variable will make our results unreliable. Therefore, future studies should use quarterly data in their investigation. The authors intend to focus their research activity on other groups of countries such as the European Union given the efforts of member countries in the transition to low carbon economy.

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