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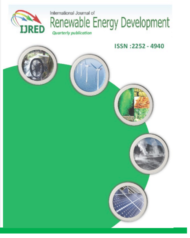

Research Article

Determinants of CO_2 Emissions in Emerging Markets: An Empirical Evidence from MINT Economies

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ABSTRACT. CO_2 emission is one the major contributor to climate change that the top CO_2 emitting countries are always trying to mitigate. In an attempt to fill the gap in energy and environmental literature, this study explores the interaction between economic growth, energy usage, trade and urbanization on CO_2 emission for MINT economies using the time coverage from 1980 to 2018, providing new perspectives into the literature by employing panel data analysis. Aiming to create robust outcomes, this paper deployed both conventional and modern econometric techniques. The panel co-integration test revealed evidence of the co-integration between CO_2 and its determinants in the MINT economies. In order to explore the linkages between CO_2 and its determinants, the ARDL PMG model was utilized in MINT economies. Findings based on the ARDL PMG reveals; (i) positive interconnection between CO_2 emissions and energy usage; (ii) no significant link was found between CO_2 and economic growth; (iii) urbanization influence CO_2 positively while a negative link was found between CO_2 and trade. Furthermore, the Dumitrescu-Hurlin Causality test revealed; (i) uni-directional causality from CO_2 to urbanization; (ii) GDP growth cause CO_2 while CO_2 causes energy usage. Based on these findings, recommendations were put forward. ©2020. CBIORE-IJRED. All rights reserved

Keywords: MINT, CO_2 Emissions, Urbanization, Energy consumption, Trade, Economic growth, Granger causality

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1. Introduction

Recently, environmental degradation, climate change and ecological distortions have been the major problems caused by the increase in the exploitation of natural resources and the production of goods and services (Ayobamiji & Kalmaz, 2020). The primary goal of developed countries is to expand their economy further, therefore there is a significant concern on the part of the environmentalists and policymakers to minimize the side-effect of this expansion. The side effect of this growth is the accumulation of greenhouse gases (GHGs), which is generated from the production or extraction of natural resources. There has been a consensus that the significant GHGs contributing to anthropogenic climate change is CO_2 emissions, which accounts for about 60% of the greenhouse effects when compared to other GHGs (Özturk and Acaravci 2010). The primary sources of CO2 emissions are fossil fuel generated from the increasing energy consumption, which accounts for about 32804.7 million tons of CO_2 emissions globally (BP, 2020). The energy usage in terms of kg of oil equivalent per capita increased from 1,896.271 to 1,922.714 in 2014 due to pressure triggered by economic expansion, urbanization and trade liberalization, etc. (World Bank, 2020). These pressures have created a rapid increase in energy demand over the years, causing a terrific challenge that relates to environmental pressure. However, efforts have been made through several intergovernmental pacts (Kyoto Protocol and Paris Agreement) to mitigate the GHGs level, which has not been fruitful.

This study's primary motive is to investigate the connection between economic growth, urbanization, trade liberalization and energy consumption on CO_2 emissions, using the panel dataset for MINT economies covering the period from 1980 to 2014. The MINT countries were coined in 2012 by Jim O'Neill, the former chief economist of Goldman Sachs, which consists of Mexico, Indonesia, Nigeria, and Turkey (MINT). These countries are generally emerging economies with similar features; the first characteristics of the MINT countries are that they

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have a large and growing population with favorable demography; secondly, these countries are geographically placed in an advantageous position (Balsalobre-Lorente, 2019). For example, Mexico and Indonesia are firmly close to the United States of America (USA) and China, respectively (the two biggest global markets). At the same time, Turkey is a strategical place within two continents Asia and Europe. While Nigeria is situated in a favorable location where she is gifted with productive natural assets (crude oil, natural gas, coal), making her one of the highest exporters of crude oil and natural gas (Adebayo, 2020). These countries (excluding Nigeria) are members of the G20 group of countries. Due to these features, these economies are becoming a center of attraction, which provides them with an essential role in the international economic and political relations. With these opportunities, specific challenges such as political instability and corruption are being experienced by the economies.

Prior studies believed that rapid urbanization and financial development also contributes to environmental pollution (Heidari *et al.,* 2015; Wang et al., 2018; Bakirtas & Akpolat, 2018; Usman, Akadiri, & Adeshola, 2020). According to Wang *et al.* (2018), from 1980 to 2011, the global urbanization rate has increased from 39.1% to 52.2%. Jedwab and Vollrath (2015) also stated that urbanization places a significant role in any nation's economic development and also improves the per capita income because most urbanized areas tend to turn into an industrialized and specialized area. Therefore, they contribute largely to the increase in the nation's economic growth; this growth tends to be induced by the energy consumed from heavy machines. Moreover, urbanization increases the consumption of industrial and residential energy, changing production structures into industrial areas, and increasing the technologically oriented production (Odugbesan & Rjoub, 2020). Examples of such urbanized cities are Lagos, Istanbul, Mexico City and Jakarta. It is expected that the trend in the movement of people from rural to urban regions will persistent in the next three decades (United Nations, 2014). The MINT countries are not also excluded from the trend, for example from the year 1995 to 2016, it was recorded that there has been an increase in percentage with regards to several people living in urban centers in Mexico, Indonesia, Nigeria, and Turkey experiencing about 47.1%, 98.4%, 160.3%, and 62.2% respectively (World Bank, 2019). MINT economies account for 4.1% of the total world GDP globally, 4.8% of the energy consumption, 4.4% leading to global CO_2 emission (World Bank, 2019). The main objective of this study is to examine the effect of these macroeconomic variables: economic growth, energy consumption, trade, and urbanization on CO_2 emission for MINT economies, an emerging economic block. Nevertheless, it is clear from the literature evaluated that there are numbers of weaknesses: firstly, it is evident that there are no studies examining the linkages between economic growth , energy usage, CO_2 emissions and urbanization in MINT economies as a group, despite their prospective status in the global economy, combined with the difficulties developing countries are facing; Secondly, the incorporation of urbanization in this interconnection has not been thoroughly explored, particularly in the MINT nations as an emerging economic bloc. Thirdly, no past research utilized panel data to analyze the effect of energy use, trade, economic growth and urbanization on CO_2 emissions for MINT economies. Therefore, the main contribution of this paper to the literature is utilizing the westerlund cointegration test proposed by Westerlund (2008) which is a second generation test to explore the long-run cointegration in the MINT economies. The structure of this research is as follows: Literature review segment contains the review of related studies done in regards to our subject matter; the data and method section showcases the data, description of data and model employed in our study; empirical methodology with findings section explains the empirical methodology utilized in this research and also discourses the outcomes or results. The concluding remark section entails the conclusion, limitation of the study, and policy implication.

2. Literature Review

CO_2 emissions research has been conducted extensively in the literature. However, mixed results were reported concerning the relationship between CO_2 emission, energy consumption, economic growth, trade, and urbanization. These mixed results are due to differences in the time range, econometric methodology, and countries or regions employed. The following studies (Dinda & Coondoo, 2006; Lee & Lee, 2009; Narayan & Narayan 2010) explored the nexus between GDP growth and CO_2 emission. Dinda and Coondoo (2006) study on 88 Countries revealed a two-way causality link between GDP growth and CO_2 emission. Ghosh (2010) reveals that there is a bidirectional link between GDP growth and CO2 emission in the short run, which corresponds with the findings of Govindaraju & Tang (2013) and Khoshnevis & Dariani (2019). Wang et al. (2011) study revealed a unidirectional relationship moving from GDP growth to CO_2 emissions, which was corroborated in a recent study done by Farhani et al. (2014) and Ertugrul *et al.* (2016). However, in a recent study done by Akadiri & Akadiri (2020) which was concentrated on Middle East countries, a unidirectional relationship was established moving from CO_2 emission to GDP growth. Zaidi *et al.* (2017) showed that GDP growth tends to reduce CO_2 emissions while in a recent study done by Ayobamiji & Kalmaz (2020) revealed that energy and GDP growth increase CO_2 emissions.

Several studies investigated the link between economic growth, energy consumption and CO_2 emissions (Salahuddin & Gow, 2014; Apergis & Payne, 2009; Lean & Smyth, 2010; Akadiri & Akadiri, 2020; Zaidi *et al.*, 2017; Gorus & Aydin, 2018; Pao & Tsai, 2010; Wang *et al.*, 2011). Lean and Smyth's (2010) study on ASEAN confirmed a long-run relationship between energy consumption, economic growth, and CO_2 emissions. Apergis & Payne, (2009) conducted a study on 6 Central American Countries and found a unidirectional moving from energy usage to CO_2 emission. A study conducted on 28 provinces in China by Wang *et al.*, (2011) also corroborated this finding. Salahuddin and Gow, (2014) findings revealed a bi-directional causality interconnection between energy usage and CO_2 emissions. Pao & Tsai (2010) reveal that the link between energy consumption and GDP growth is bi-directional, which is contrary to the study done by Gorus & Aydin (2018).

Akin (2014), Ertugrul *et al.* (2016); Ayobamiji and Kalmaz, (2020) and Farhani *et al.* (2014) explores the nexus between economic growth, energy consumption, Trade and CO_2 emissions. Akin (2014) revealed that there is an uni-directional relationship running from CO_2 emission and trade while Ertugrul *et al.* (2016) study shows that there is an uni-directional relationship running from trade and CO_2 emission. Several studies have included urbanization in their model (Khoshnevis & Dariani, 2019; Abbas, 2020; Kasman & Duman, 2015; Odugbesan & Rjoub 2020). Khoshnevis & Dariani (2019) reveal that the link between urbanization and GDP growth is bi-directional while Abbasi *et al.* (2020) researched 8 Asian countries and finding revealed a bi-directional relationship between urbanization and energy consumption.

Recently, Odugbesan & Rjoub (2020) utilize the time series data set to examine the link between economic growth, energy consumption, urbanization and CO_2 emissions on MINT economies. Contrary to Odugbesan & Rjoub (2020), this study employed the panel data set to examine the relationship between economic growth, energy consumption, urbanization and CO_2 emissions. Also, trade was incorporated into the model, which will help in filling the gap in energy and environmental literature concerning countries with similar features such as MINT. Table 1 shows the author(s), countries, the variables used, time coverage, the techniques employed and finding.

Table 1
Synopsis of the related studies

Author(s)	Country(s)	Variables	Period	Technique employed	Findings
Salahuddin & Gow (2014)	GCC Countries	CO_2, Y, EN	1980-2012	Pedroni Coint., Granger Causality test	$CO_2 \leftrightarrow EN$
Akin (2014)	85 Countries	CO_2, Y, EN, TO,	1990-2011	Panel Coint., Granger Causality	$Y \rightarrow CO_2$ $CO_2 \rightarrow TO$
Apergis & Payne (2009)	6 Central American Countries	CO_2, Y, EN	1971-2004	Pedroni Coint., FMOLS, Granger Causality	$Y \rightarrow CO_2$ $EN \rightarrow CO_2$ $Y \leftrightarrow EN$
Dinda & Coondoo (2006)	88 Countries	CO_2, Y	1960-1990	IPS, Granger Causality	$CO_2 \leftrightarrow Y$
Ertugrul *et. al.* (2016)	10 biggest emitters among emerging natons	CO_2, Y, EN, TO	1971–2011	Bounds Coint., Granger Causality	$Y \rightarrow CO_2$ $EN \rightarrow CO_2$ $TO \rightarrow CO_2$
Lean & Smyth (2010)	ASEAN	CO_2, Y, EN	1980–2006	Johansen Fisher Coint., Granger Causality Test	$EN \rightarrow CO_2$
Lee & Lee (2009)	109 nations	CO_2, Y	1971–2003	Panel Regressions	Differing Results
Narayan & Narayan (2010)	43 Developing countries	CO_2, Y	1980-2004	Pedroni Coint.,	Differing Results
Abbas (2020)	8 Asian countries	CO_2, Y, EN, TO, URB, FD	1982-2017	Panel Coint., Granger Causality Test	$URB \leftrightarrow EN$ $EN \rightarrow CO_2$
Kasman & Duman (2015)	EU new member and candidate nations	CO_2, Y, EN, TO, URB	1992–2010	Panel Coint., and Panel Granger Causality Test	$EN \leftrightarrow CO_2$
Akadiri & Akadiri (2020)	Middle East	CO_2, Y, EN	1995–2014	Panel Coint., and Panel Granger Causality Test	$EN \leftrightarrow CO_2$ $CO_2 \rightarrow Y$
Zaidi *et al.* (2017)	29 countries	CO_2, Y, EN	1960-2008	The Hausman test, Inverse function Regression analysis	Y reduces CO_2
Odugbesan & Rjoub (2020)	MINT	CO_2, Y, EN, URB	1993-2017	ARDL and Granger causality	Differing results
Gorus & Aydin (2018)	8 MENA Countries	CO_2, Y, EN	1975-2014	Panel Granger causality analysis	$EN \leftrightarrow CO_2$ $Y \rightarrow EN$
Ayobamiji & Kalmaz (2020).	Nigeria	CO_2, Y, EN, TO, FDI, FD	1971-2014	ARDL	Y & EN increases CO_2
Pao & Tsai (2010)	BRIC	CO_2, Y, EN	1971-2005	Panel co-integration tests, & Panel Granger causality test	$EN \leftrightarrow CO_2$ $EN \leftrightarrow Y$
Farhani *et al.* (2014)	Tunisia	CO_2, Y, EN, TO	1971-2008	Bounds Coint., Granger Causality Test	$Y \rightarrow CO_2$ $EN \rightarrow CO_2$
Khoshnevis & Dariani (2019)	Asian countries	CO_2, Y, EN, TO URB	1980–2014	Panel co-integration tests, & Panel Granger causality test	$URB \leftrightarrow CO_2$ $Y \leftrightarrow CO_2$
Wang *et al.* (2011)	28 provinces in China	CO_2, Y, EN,	1995–2007	Panel co-integration and Panel VECM	$Y \leftrightarrow EN$ $Y \rightarrow CO_2$ $EN \rightarrow CO_2$

↔ represents bi-directional; → represents uni-directional, GCC represents Gulf Cooperation Council; ASEAN represents Association of Southeast Asian Nations; CO_2 denotes Carbon Emissions; EN illustrates Energy usage; GCCC represents Gulf Cooperation Council countries; Y represents Economic Growth; TO represents Trade; FDI portrays Foreign Direct Investment; FD mirrors Financial development.

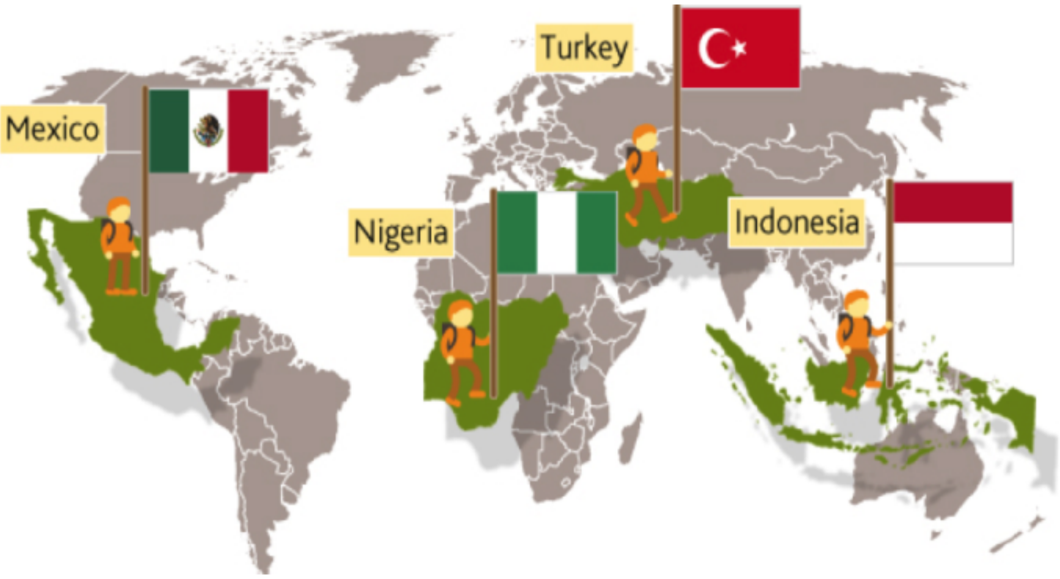

Fig. 1 Map Showing the MINT Economies

3. Data and Model

3.1. Data

This study utilized a panel dataset of the MINT economies covering the period between 1980 and 2018. The dependent variable is CO_2 emissions obtained from the OECD database, whereas its determinants are GDP growth, energy usage, trade, and urban population, which are obtained from the World Bank database. Table 2 depicts the deployed variables descriptive statistics by looking at the minimum, maximum, mean, and standard deviation. The Figure 1 illustrates the MINT in the global map while Figure 2, 3, 4, 5 and 6 respectively depicts the trends in CO2 emissions, energy consumption, economic growth, trade and urbanisation among the MINT economies.

Table 2
Descriptive Statistics of MINT Economies

	Variables	**Mean**	**Min**	**Max**	**SD**
Mexico	CO_2	3.630864	4.455658	4.455658	0.230774
	Y	8601.606	9839.050	8601.606	768.0262
	ENE	1517.257	1361.721	1698.585	90.38297
	TR	44.62708	22.11727	65.76725	14.15267
	URB	2.239998	1.650556	3.496340	0.531058
Indonesia	CO_2	1.256667	0.642835	2.564189	0.507522
	Y	2193.953	1231.195	3692.973	697.7811
	ENE	643.3624	377.7884	883.9183	173.2781
	TR	54.72970	2.611211	5.720043	9.805307
	URB	4.188858	2.611211	5.720043	1.079698
Nigeria	CO_2	0.610522	0.325560	0.928241	0.183979
	Y	1687.40	1324.297	2563.900	387.4704
	ENE	715.5344	665.4360	798.6302	36.17605
	TR	33.51019	9.135846	53.27796	13.02374
	URB	4.816867	4.054265	5.850712	0.585230
Turkey	CO_2	3.090933	1.722847	4.479773	0.803481
	Y	8104.783	4986.681	13277.76	2287.473
	ENE	1112.435	704.7910	1583.634	265.1794
	TR	40.37831	2.057651	6.201874	1.310665
	URB	3.165265	2.057651	6.201874	1.310665

Source: WDI (2020), OECD (2020) and Global Carbon Atlas (GSA, 2019)

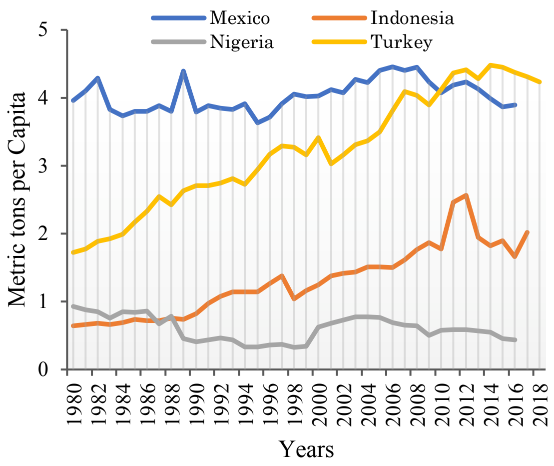

Fig. 2 CO_2 Emissions

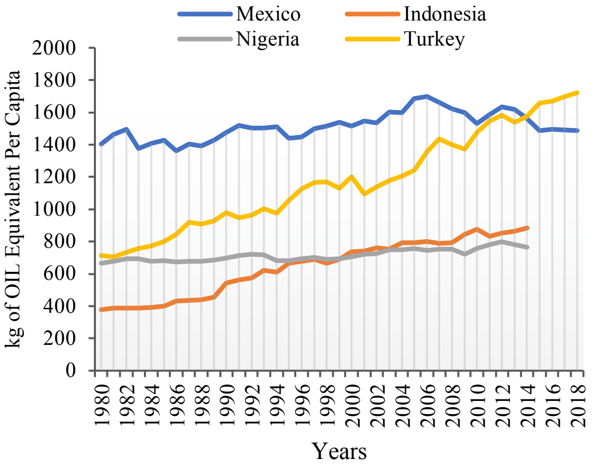

Fig. 3 Energy Consumption

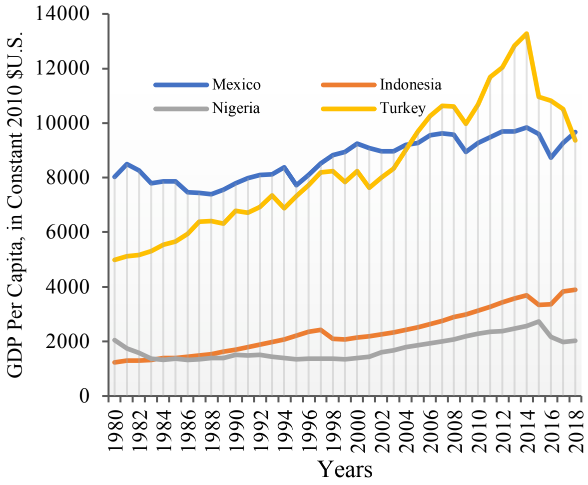

Fig. 4 Economic Growth

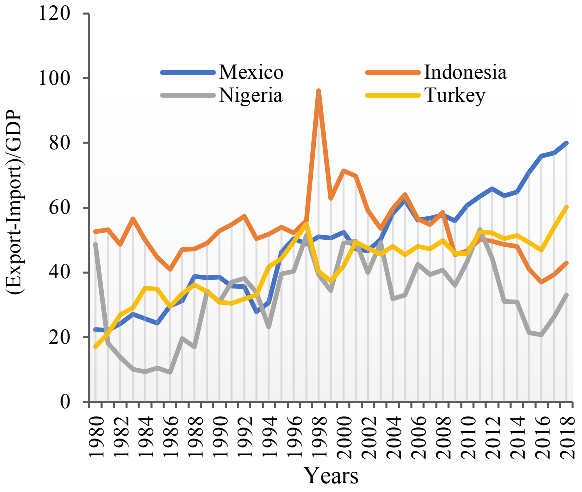

Fig. 5 Trade

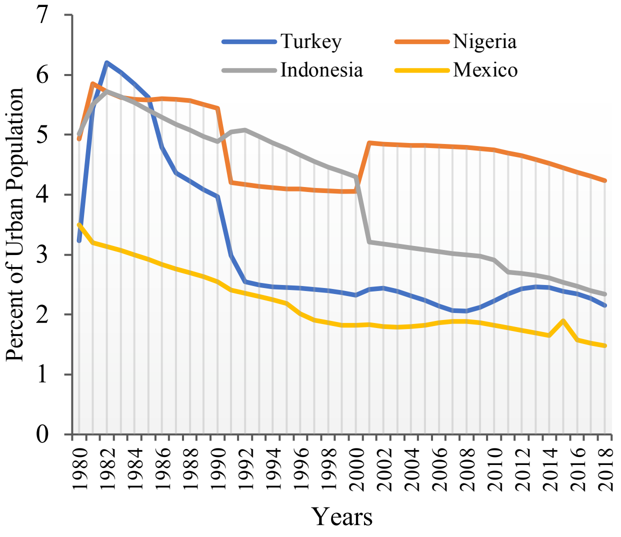

Fig 6 MINT Countries Urbanization

3.2. Model

The investigators utilized the STIRPAT framework to explore the interconnection between CO$_2$ emission and urbanization based on previous studies (Martınez-Zarzoso et al.2007; Poumanyvong & Kaneko, 2010; Khoshnevis et al. 2019). Ehrlich and Holdren (1971) created this model, which is premised on Influence, Population, Affluence, and Technology (IPAT). According to Chertow (2001), the IPAT identity illustrated in the equation is frequently utilized as the foundation for examining the different factors influencing CO$_2$ emissions.

$$I = P \cdot A \cdot T \qquad (1)$$

However, various criticism has been levied on the IPAT model such as; (i) it is seen as an equation based on mathematics which is not good for testing hypothesis; and (ii) presuming non-flexible proportionality between the indicators. As a result of the above loopholes mentioned, the stochastic version of IPAT was suggested by Dietz and Rosa (1997). Therefore, utilizing the model as a backbone for this model was suggested by Dietz & Rosa (1997). Where the constant term is portrayed by a, and P, A and T are the same as stated in Equation 1. The elasticity of environment influences concerning P, A, and T is depicted by b, c, and d respectively, the error term is illustrated by ε_i, and i which is the country is indicated by the subscript. The impact is denoted by I, which is ideally calculated regarding the emission level of a pollutant. The size of the populace is represented by P. Society impact is denoted by A and technology index as illustrated by T. Hence, the IPAT model is utilized in examining factors influencing changes in the environment.

$$I_{it} = \propto_i P_{it}^{\beta} A_{it} T^{it}{}_{it}^{\delta} e \qquad (2)$$

Several researchers, such as Wang et al. (2011), Khoshnevis *et al.* (2019) and Nasrollahi et al (2020) have deployed the STIRPAT framework to explore the nexus between energy usage and CO$_2$ emission and urbanization and CO$_2$ emissions.

In Equation 2, subscript i(i=1,N) represents the country while timeframe is illustrated by i(i=1,…,T). The natural log of the variables utilizes are taken for convenient linear panel estimation. Also, the logarithm of all the variables deployed was taken in order to eliminate heteroscedastic. Therefore, equation 2 is depicted below:

$$InI_{it} = \propto_i + \beta InP_{it} + yInA_{it} + \delta InT_{it} + e_{it} \quad (3)$$

Where the size of the population is represented by P, GDP per capita is illustrated by A, technology index is depicted by A, and is calculated by industrial value-added share of GDP and the year is portrayed by t. Hence, to analyze the influence of these indicators on CO$_2$ emissions, equation 3 above is re-written below as;

$$InCO_{2it} = \propto_i + \beta InP_{it} + \delta InY_{it} + \delta InIND_{it} + e_{it} \qquad (4)$$

In equation 4 above, CO$_2$ emission is represented by CO$_2$. The size of the population is illustrated by P, economic development level is represented by PY, and the share of value-added of the industrial sector in GDP is depicted by IND. When estimating equation 4, there is a clear distinction in slope coefficients between the heterogeneous and homogenous frameworks. The standard panel ARDL regression techniques will be used if the slope coefficient is homogeneous. According to Eberhardt & Teal (2011), panel estimation frameworks with different slope coefficients is an active area. Several studies have revealed that size of the population, technological progress, and economic growth are the major determinants of CO$_2$ emissions (Ali & Nitivattananon, 2012; Raggad 2020; Andersson *et al.* 2009; Khoshnevis *et al.* 2019; Wang *et al.* 2019; Odugbesan & Rjoub 2020). To investigate the factors encompassed in the STIRPAT model that impact CO$_2$ emissions the MINT economies, equation 5 was formulated as follows;

$$InCO_{2it} = \propto_i + \beta InY_{it} + \delta InENE_{it} + \delta InTR_{it} + \varphi InURB_{it} + e_{it} \qquad (5)$$

In equation 5, I and t denote sub-index and different years, CO$_2$ represents CO2 emission, Y illustrates economic growth, ENE represents energy consumption, TR depicts trade, and urbanization represents URB and e mirrors error term.

4 Empirical Methodology with Findings

4.1. Cross Section dependence test

Data normalization is important to turn the values into similar measurement units because CO$_2$ emissions was reported as metric tons, whereas others were reported with different measurements. The transformation into a normal log thus minimizes potential disruptions of the series' dynamic properties. Panel disturbances in data are generally believed to be cross-sectionally independent, particularly when there is a large cross-sectional dimension. Nevertheless, there is clear proof that cross-sectional dependence also exists in the parameters of panel regression. The literature includes some measures for cross-section dependency. However, this study only utilized the Pesaran (2004) test for a cross-sectional dependency test. Furthermore, this study utilized Breusch & Pagan (1980), bias-corrected scaled LM, Pesaran (2004) CD, and LM, Pesaran (2004) scaled LM tests to verify the stationarity of data deployed.

$$Y_{it} = \propto_i + \beta_i X_{it} + e_{it} \qquad (6)$$

$$COV(\varepsilon_{it}, \varepsilon_{ij}) \neq 0 \qquad (7)$$

The CDLM2 test is estimated as below, which is another method to analyze the cross-sectional dependency

$$CD_{LM2} = \sqrt{\frac{1}{N(N-1)}} \left[\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} TP\hat{\rho}_{ij} \right] \sim N(0.1) \qquad (8)$$

We applied this test when N and T are great ($T \to \infty$ & $N \to \infty$) and are normally distributed asymptotically. Another test for the cross-sectional dependency is the CD LM test which is estimated using Eq. 9.

Table 3
CDS Test by Pesaran (2004)

Variables	CD-Test	Probability
InY	11.72311	0.0000*
InENE	12.15594	0.0000*
InC02	3.152256	0.0016*
InTR	5.462336	0.0000*
InURB	9.782140	0.0000*

1% significance level is portrayed by *
Source: Authors Compilation with Stata 15

$$CD_{LM} = \sqrt{\frac{2T}{N(N-1)}}\left[\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} T\hat{P}_{ij}\right] \sim N(0.1) \qquad (9)$$

It is premised on the number of cross-sectional residuals squares with a correlation coefficient. This test, which is a regular asymptotic standard distribution, is utilized if T > N and N > T. This test's null and alternative hypothesis is identical to the tests on CD LM1 and CDLM2. The Eqn. 9 mirrors this formula;

$$CD_{LM1adj} = \sqrt{\frac{1}{CD_{LM1}}}\left[\frac{(T-K)\rho_{ij}^{2}\mu T_{ij}}{\sqrt{v_{ij}^{2}}}\right] \sim N(0.1) \qquad (10)$$

This study analysis commenced by exploring the cross-sectional dependence across the affected countries. To explore the CDS, the investigators utilized the Pesaran, (2004) test illustrated in equation 9. The CSD test result shows that the cross-sections depend on each other, which is apparent from the significant statistics test. For each variable displayed, the T-stat fails to accept the null hypothesis. Thus, Table 3 depicts evidence of a high dependence among the panel variables. This pinpoints that shocks in one of the MINT economies incline to be disseminated to other economies.

4.2. Unit root tests

There is a similarity between time series data and panel data unit root testing. The panel ADF data model can be represented as;

$$\Delta y_{it} = \varphi_i \delta y_{it-1} + \sum_{i=1}^{M} a_i \Delta y_{t-1} + x_{it}\beta + \varepsilon_{it} \qquad (11)$$

Where Δy_{it} denotes the variable utilized i=1,2…..,N units cross-section throughout a period t=1,2.,….T, X_{it} Describes the exogenous variables column vector, such as fixed effects or trends of individual, coefficient of the mean-reversion is portrayed by φ_i, the autoregressive process lag length is depicted by φ and the error term which is presumed to be mutually dependent is illustrated by ε_{it}. To analyze the integration order of the various variables, this research utilizes the ADF test, which was suggested by Maddala. & Wu (1999), PP test introduced by Choi (2001), Levin, Lin & Chu (2002), IPS unit root suggested by Im, Pesaran & Shin (2003). The null hypothesis was tested utilizing the above unit root tests. The outcomes of all the unit root tests in Table 4 revealed that the variables utilized are integrated at a mixed level that is I(0) and I(1). Although these outcomes of all unit root tests are alike. In addition, the research equation encompasses trend and drift. The order of variables in mixing integration allows us to use Pedroni co-integration test.

4.3. Co-Integration test

This study utilized the heterogeneous panel co-integration test suggested by Pedroni, (2004) and Westerlund cointegration test suggested by Westerlund (2008) which is a second generation cointegration test to explore the co-integration amongst the variables. The co-integration is depicted in Eq. 12

$$CO2_{it} = \delta_{it} + \theta_i t + \alpha_{1i}Y_{it} + \alpha_{2i}ENE_{it} + \alpha_{3i}TR_{it} + \alpha_{4i}URB_{it} + \varepsilon_{it} \qquad (12)$$

Table 4
Unit Root Table

Variables	Levin, Lin & Chu	Order	IPS-Wstat	Order	ADF-Fisher	Order	PP-Fisher	Order
Panel T: At Intercept								
InCO2	-1.70**	I(0)	-7.30*	I(1)	61.9*	I(1)	105.0*	I(1)
InY	-2.37*	I(0)	-5.07*	I(1)	40.5*	I(1)	40.5*	I(1)
InENE	-1.56***	I(0)	-6.81*	I(1)	56.7*	I(1)	100.9*	I(1)
InTR	- -1.31***	I(0)	-7.70*	I(1)	65.6*	I(1)	105.8*	I(1)
InURB	-1.36***	I(0)	-4.62**	I(1)	37.1*	I(1)	82.1*	I(1)
Panel M: At Intercept & Trend								
InCO2	-7.04*	I(1)	-6.22*	I(1)	47.9*	I(1)	98.1*	I(1)
InY	-5.35*	I(1)	-3.79*	I(1)	28.6*	I(1)	56.9*	I(1)
InENE	-4.89*	I(1)	-5.81*	I(1)	44.4*	I(1)	88.4*	I(1)
InTR	-6.70*	I(1)	-1.91***	I(0)	18.1**	I(0)	20.41**	I(0)
InURB	-2.40*	I(1)	-3.90*	I(1)	29.8*	I(1)	306.7*	I(1)

Significance level are 1%, 5% & 10% correspondingly
Source: Authors Compilation with Stata 15

Table 5
Cointegration Result by Pedroni (2004)

Model: InCO2=f(InY InENE InTR InURB)				
	Statistic	PV	Weighted Stat	PV
Panel v-Stat	0.101	0.459	0.1330	0.4471
Panel rho-Stat	-0.810	0.208	-1.3530	0.088***
Panel PP-Stat	-3.150	0.000*	-3.5478	0.000*
Panel ADF-Stat	-2.627	0.004*	-2.3530	0.009*
Group rho-Stat	-0.4901	0.312		
Group PP-Stat	-4.110	0.000*		
Group ADF-Stat	-2.594	0.004*		

1% Significance level is denoted by *, InCO$_2$: CO2 emission, InY: Economic Growth, InENE: Energy Usage, InTR: Trade, InURB: Urbanization

Table 6
Cointegration Result by Westerlund (2008)

Model: InCO2=f(InY InENE InTR InURB)			
Statistic	Value	Z-value	P-value
Gt	-4.555	-5.010	0.000*
Ga	-17.382	-2.110	0.017**
Pt	-6.229	-2.364	0.009*
Pa	-12.582	-1.769	0.038**

* &** portrays 1% and 5% level of significance
Source: Authors Calculation with Stata 15

The common time factors and permits for heterogeneity are taken into consideration when utilizing the panel co-integration tests. Table 5 and 6 depict Pedroni (2004) and Westerlund (2008) panel co-integration tests respectively. Pedroni (2004) tests the existence of co-integration in the long-run between CO$_2$ emission (CO$_2$) and economic growth (Y), energy consumption (ENE), trade (TR), and urbanization (URB). Based on the seven tests carried out, there are 11 outcomes. Out of the eleven outcomes, seven are significant, meaning that the null hypothesis can be rejected and accept that there is a co-integration between CO2 emissions and its determinants.

Four tests are incorporated in the Westerlund ECM panel cointegration test. It consists of four statistics (Gt, Ga, Pt and Pa). The alternative hypothesis that the panel is cointegrated as a whole is tested by the first two tests whereas cointegration of at least one unit is tested by the other two tests (Odugbesan & Rjoub, 2019). The result obtained from Table 6 illustrates acceptance of the alternative hypothesis of cointegration in the group panel as shown by all the four tests.

4.4. Hausman Test

The Hausman test statistics is depicted in Table 7 for all the four predictor variables utilized in this research. The hypotheses for the Hausman test indicates that MG and PMG estimates are not statistically different; PMG more efficient while the alternative hypothesis shows that null hypothesis is not true.

The study utilized the PMG since the *p*-value > 0.05. Therefore, the null hypothesis of homogeneity cannot be rejected. Thus, the PMG estimator is supported by the model. The next thing is to conduct the pool mean group method.

Table 7.
Hausman Test

	PMG	MG	PMG/MG
InY	-1.346	-1.425	
InENE	3.562	3.183	
InTR	-8.113	-12.55	
InURB	6.841	8.272	
Hausman Test			0.80

Source: Authors Calculation with Stata 15

4.5. Pooled Mean Group method

The research used the pooled mean group (PMG) estimator created for dynamic heterogeneous panels to explore the presence of equilibrium in the long-run between CO$_2$ emissions and its determinants. The PMG is an intermediary method between the MG estimator and DFE. Since it includes averaging (the MG estimator) and pooling (which depicts the DFE). The PMG estimator enables for differences between the coefficients in the short-run and the error variances; however, the long-run coefficients are restricted to be similar (Khoshnevis & Dariani, 2019). Estimating the interaction in the long-run between variables is based on the co-integrating link between non-stationary variables. The maximum-likelihood PMG estimator for heterogeneous dynamic panels that fit into the ARDL model is proposed by Pesaran *et al.* (1999). Therefore, this can be defined as an equation for the error correction to improve economic understanding. An ARDL model for error correction (ECM) is outlined below;

Table 8
Long-run & Short-run estimation

Dependent Variable: $\ln CO_2$			
Long-run estimation results PMG			
Regressors	Coefficient.	T-stat	PV
InY	0.1544	1.4659	0.1454
InENE	2.1606	19.950	0.0000*
InTR	-0.4691	-2.9309	0.0041*
InURB	0.4109	3.8195	0.0002*
Short-run estimation results PMG			
ECM (-1)	-0.4344	-2.0455	0.0431
ΔInY	0.1850	0.4919	0.6237
ΔInENE	1.7972	1.4695	0.2018
ΔInTR	0.1960	1.5890	0.1148
ΔInURB	-0.3552	-0.7359	0.4633

Note * and ** represents 1% and 5% significance level respectively

Source: Authors Calculation with Stata 15

$$\Delta(CO_2)_{it} = \theta(CO_2)_{i,t-1} + \vartheta' X_{i,t-1} + \sum_{m-1}^{t-1} \lambda ij\Delta(CO_2)_{i,t-j} + \sum_{t-1}^{s-1} \lambda\, ij\Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \qquad (13)$$

Where the determinants of CO_2 emission are depicted by X; the long-run dynamics is represented by ϑ'; the error correction term is denoted by θ and dynamics in the short run is depicted λ_{ij} (Khoshnevis & Dariani, 2019). The next phase is calculating the long-run interaction between the CO_2 emissions and its predictors. The best econometric analysis that best fits the features of our panel results is chosen. Thus, the panel data is estimated based on PMG. The result of the PMG model is depicted in Table 8.

All coefficients calculated were explained as long-run elasticity with the form of the natural logarithm of variables utilized are taken. PMG is utilized to check the relation between CO_2 emissions and its determinants in the long run and short-run. The coefficient of variables is significant and negative at 1%. This indicates that the short-run adjustment speed to enter equilibrium is significant in the long run. The ECM is significant, statistically indicating a quicker return to equilibrium in the event of an imbalance. This term illustrates the speed of the adjustment process to go back to equilibrium. Furthermore, there is no proof of significant interaction between GDP growth and CO_2 emissions in the MINT economies. This indicate no support for the EKC hypothesis in the MINT. The coefficient of energy usage is 2.16, suggesting a 1% increase in energy consumption will lead to 2.16% in CO_2 emissions when other variables are held constant. This finding concurs with past studies (Farhani *et al.* 2014; Ayobamiji & Kalmaz, 2020). There is an increase in CO_2 emissions due to an increase in production and consumption of energy. Though the impacts of change in technology, productivity, and energy consumption efficiency are causing a decrease, this finding corresponds to the outcomes of Wang *et al.* (2011), Farhani *et al.* (2014), and Khoshnevis & Dariani (2019). 0.46% decrease in CO_2 is a result of a 1% increase in trade when other variables are kept constant. The urbanization coefficient is 0.14, which suggests that when other variables are kept constant, a 1% increase in urbanization will lead to a 0.14% increase in CO2 emissions. This finding is in support of the urban environmental transition theory. The theory claims are based on the following: one of the characteristics of urban cities is rapid industrialization, which is a significant cause of emissions. The pattern of consumption of residents in urban cities is mainly carbon intensive compared to their counterparts living in rural areas. These claims confirm the experience of MINT countries over the last two decades with massive urban growth. Major cities such as Lagos, Istanbul, Jakarta, and Mexico City are presently in the post-industrial phase. A large amount of energy has been consumed due to an increase in the use of automobiles and residential houses, public utility services such as public transport, and high electricity usage. In contrast, in small cities, industrialization's gradual development is the primary source of a large amount of energy consumption. This large amount of energy consumption will consequently lead to high emissions. This finding aligns with the findings of Ali *et al.* (2016), Khoshnevis & Dariani (2019), Andersson, (2019) and Wang *et al.* (2019). However, in the short-run, no significant relationship exists between CO_2 emissions and it determinants.

4.6. Causality analysis

The Dumitrescu-Hurlin causality was also utilized to determine the path of causality between CO2 and its determinants in the MINT economies. The equation below depicts the panel causality equation.

$$y_{it} = \sum_{k-1}^{k} y\, i^{(k)} y_{i,t-k} + \sum_{k-1}^{k} \beta\, i^{(k)} x_{i,t-k} + \varepsilon_{i,t} \qquad (14)$$

The lag length is depicted by k, stands for the lag length, autoregressive parameter id portrayed by $yi^{(k)}$, and the regression coefficient pitch depicted by $\beta i^{(k)}$, can change between groups. Beyond these, there is no random mechanism for the tests.

Table 9
Dumitrescu Hurlin Panel Causality Test

Null Hypotheses	W-Stat.	Zbar-Stat.	Prob.	Decision
Y → CO_2	5.927	3.558	0.000*	Reject Ho
CO_2 →Y	1.153	-0.859	0.389	Do Not Reject Ho
ENE → CO_2	2.674	0.450	0.652	Do Not Reject Ho
CO_2 → ENE	0.230	-1.656	0.097***	Reject Ho
TR → CO_2	0.834	-1.137	0.255	Do Not Reject Ho
CO_2 → TR	3.859	1.500	0.133	Do Not Reject Ho
URB → CO_2	2.268	0.112	0.910	Do Not Reject Ho
CO_2 → URB	5.544	2.969	0.003*	Reject Ho

*, and ***signifies 1%, and 10% level of significance

Source: Authors Calculation with Stata 15

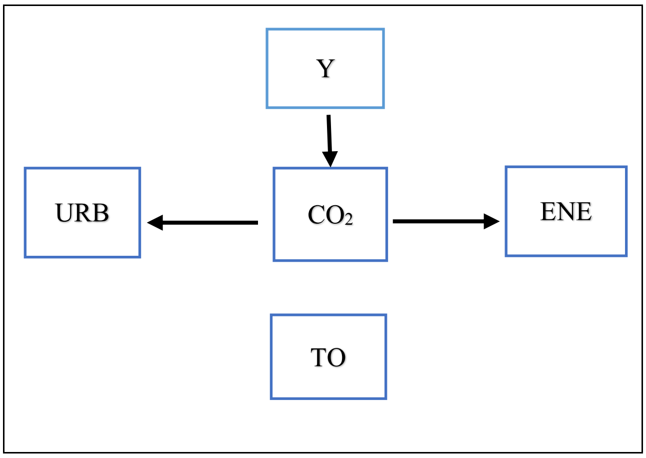

Fig. 7 Representation of DH Panel Causality Tests

The Dumitrescu Hurlin causality test has a formula that has a coefficient that is fixed. Besides this, the individual remainders are independent for each cross-sectional unit. Additionally, the individual remainders are distributed independently amongst the groups. The Dumitrescu Hurlin causality is illustrated by Equation 15.

$$W_{N.T}^{H\,NC} = \frac{I}{N}\sum_{i=1}^{N} Wi,t \qquad (15)$$

Where $W_{i,t}$ depict the distinct Wald stat values for the unit of the cross-section. The average statistic is depicted by $W_{N.T}^{H\,NC}$

Table 9 and Figure 7 depict the findings from the DH causality test revealed that changes in economic growth granger cause CO_2 emission in MINT economies. The empirical result uncovered that GDP growth is the main contributor to CO_2 emission. The outcome aligns with previous studies (Lean & Smyth, 2010; Hossain, 2011; Govindaraju & Tang, 2013; Cowan, 2014; Farhani & Ozturk 2015). No causality was found between trade and CO_2 emissions. The result complies with the study of Hossain, (2011), however, it is in contrast to the studies of Halicioglu (2009) and Sebri & Ben-Salha (2014). Furthermore, CO_2 emissions granger cause urbanization at a 1% significance level. The empirical finding exposed that CO_2 emission is a significant contributor to urbanization. The outcome agrees with past studies (Shahbaz *et al.* 2018; Odugbesan & Rjoub, 2020). Lastly, a causality was found running from CO_2 emissions to energy usage in the MINT economies. It indicates that CO_2 emissions have predictive power over energy consumption in the MINT economies. The finding concurs with previous studies (Soytas & Sari, 2009; Wang *et al.* 2018; Khoshnevis & Dariani, 2019; Odugbesan & Rjoub, 2020).

5. Conclusion

This study empirically investigates the interconnection between CO_2 and its determinants (GDP growth, trade openness, urbanization, and energy usage utilizing) in the MINTS economies as we utilized the yearly data spanning between 1980 and 2014. Various unit root tests were utilized, and findings show that the deployed variables are cointegrated at a mixed level i.e. I(0) and I(1). The co-integration test revealed that there is evidence of co-integration between CO_2 and its determinants in the MINT economies. In order to explore the linkages between CO_2 and its determinants, the ARDL PMG model was utilized in MINT economies. Findings based on the ARDL PMG revealed that the ECM is negative and significant statistically indicating a quicker return to equilibrium in the event of an imbalance. Furthermore, a positive interconnection was found between energy usage and CO_2 emissions while no significant connection exists between economic growth and environmental pollution. Furthermore, there is evident of negative link between trade and CO_2 emissions and urbanization significantly influence environmental pollution. Also, findings from the Dumitrescu Hurlin Panel Causality test revealed that economic growth granger cause CO_2 emission in MINT economies. This empirical result uncovered that GDP growth is the main contributor to CO_2 emissions. Additionally, CO_2 emissions granger cause urbanization and causality was found running from CO_2 emissions to energy consumption in the MINT economies. Based on our findings, we recommend that policymakers in these countries should continue with their trade policies since trade has a detrimental effect on CO_2 emissions. Also, it is necessary for the MINT economies to adopt energy efficiency initiatives that will boost their economic growth. This approach will be directed towards the reduction of CO_2 emissions. In this respect, structural reforms are needed to enhance the quality of the environment, as well as economic growth. Additionally, the MINT economies need to improve their energy efficiency by enacting green technologies and promoting renewable energy usage. Also, strong reliance on fossil fuels should be replaced by renewable energy, as fossil fuels are the major contributor to GHGs. In addition, MINT countries need to turn their economies into a sustainable economy, which is the best way to overcome ecological issues arising from economic growth. The nations in the MINT will implement their environmental protection rules and regulations in order to put greater focus on environmental safety. Finally, in order to attain sustainable urbanization in MINT economies, efficient energy, economic and environmental measures will direct urban development growth in those nations without sacrificing economic growth and ensuring a reduction in CO_2 emissions in order to accomplish a quality environment. Urban planning policy makers in the MINT states will strive to reduce the pace of urbanization by pursuing efficient land use to promote green and efficient urbanization, which will, to some degree, boost the impact of urbanization on environmental degradation. Further studies should utilize quarterly data. Although this paper allows for sound analytical outcomes and fills gaps in literature using Westerlund cointegration, PMG, and Dumitrescu Hurlin Panel Causality techniques, further research should be undertaken in the future to assess this link in the various developing countries and blocs that will enrich existing literature.

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