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Of Economic Development, Urbanization, Human Capital and Environmental Pollution in the BRICS and MINT Countries: Application of the PMG-ARDL Model

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Abstract. This research explored the link between economic development, urbanization, human capital and CO_2 emission among the BRICS and MINT countries. To unravel the reliability of the study outcomes, second generation econometric models that are robust to cross-sectional dependence were utilized. Findings of the study showed that the panel series were cross-sectionally dependent. Again, the study variables were not stationary at levels, but after the first difference, stationarity was evidenced. To examine the long-run equilibrium of the study variables, the pooled mean group autoregressive distributed lag (PMG-ARDL) estimator was used. The results revealed that GDP decreased CO_2 emission in the whole and BRICS panels but increased CO_2 emission in the MINT panel. Urbanization increased CO_2 emission whereas human capital reduced environmental pollution across all the study panels. Moreover, the Dumitrescu-Hurlin granger test was employed to access causalities within study variables but the outcomes were dissimilar across the study panels. Based on the findings, policy recommendations are given.

Keywords: Economic development; environmental pollution; BRICS; MINT; PMG-ARDL

Introduction

Over the past decades, the world has gone through series of challenges which have affected livelihoods and economic development due to climate change. For this reason, several researches have been conducted to ascertain the menace of environmental pollution and how to avert or minimize the impact (Shahbaz et al., 2019; Musah et al., 2019). This study is grounded on the link between environmental pollution, economic growth, urbanization and human capital in Brazil, Russia, India, China, and South Africa (BRICS), and Malaysia, Indonesia, Nigeria, and Turkey (MINT). Several studies have shown that economic growth is a critical contributor of environmental pollution, and more importantly, the concept of environmental kuznet curve (EKC) by Grossman and Krueger (1995). According to Dauda (2020), the EKC signpost that low-income economies encounter environmental issues at the initial stages of economic development until it reaches a level that innovative infrastructure that harness environmental quality are employed.

Studies have also shown that urbanization has diverse impact on the environment. That is, while Charfeddine and Mrabet (2017) found urbanization to reduce emission of CO_2, Wang et al. (2018) reported that urbanization is a substantial driver of environmental pollution. It is important to note that, countries such as China, Brazil, India, Nigeria, among others have lots of people in the urban areas. As stated by Anwar et al. (2020), countries with high population in the urban centers contribute extensively to environmental pollution, and the BRICS and MINT countries are not exception.

Furthermore, human capital, is the skills and knowledge that people acquire through education, training and job experience. Human capital has been found as a variable that contribute to reducing environmental pollution in several studies (Desha et al., 2015; Bano et al., 2018). That is, as people are educated on the need and importance of using innovative technologies, the adoption of energy intensive equipment leading to emission of CO_2 into the

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atmosphere is minimized. In view of that, Yao et al. (2019) highlighted in their study that human development promotes environmental awareness and decrease pollution. Also, Ma et al. (2019) stated that, increase in people' level of education, and creation of environmental awareness contribute of sustainable environmental quality. For this reason, Ponce et al. (2019) concluded that, to increase in innovation capabilities, human capital in all sectors of an economy should be harnessed. Although urbanization, human capital and environmental pollution are on the surge, limited research has explored the comparative analysis of the aforementioned relationships within the BRICS and MINT countries. The aim of this study, therefore, is to explore the impact of economic development, urbanization, and human capital on environmental pollution in the BRICS and MINT countries.

The remaining sections of the study are organized as follows: section 2 explains the methodology and source of data for the study; section 3 briefs the results and discussions; and section 4 offers the conclusion and policy recommendation of the study.

Methodology

Model Specification

This research follows recent empirical studies (Bano et al., 2018; Dauda, 2020) to explore how economic growth, urbanization, and human capital influence environmental pollution in the BRICS and MINT countries from 1990 to 2016. The explained variable is environmental pollution and it is measured using CO_2 emission as a proxy. The explanatory variables are economic growth measured as GDP, urbanization (URB), and human capital (HC). The proposed environmental pollution model that conforms to previous studies is constructed as follows:

$$CO_2 = GDP + URB + HC \quad (1)$$

Where CO_2 indicate environmental pollution, GDP, URB, and HC denote gross domestic product, urbanization, and human capital. In order to reduce heteroscedasticity, the study variables were converted into natural logarithm and the new model for the study is specified as:

$$lnCO_{2it} = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 lnURB_{it} + \beta_3 lnHC_{it} + \varepsilon_{it} \quad (2)$$

Where β_0 is the unobserved time-invariant singular effect; $\beta_1 - \beta_3$ signpost the impact of GDP, URB, and HC on CO_2, i represent the number of sampled countries; t indicates the period of study; and ε_{it} is the error term.

Econometric Approach

Prior to estimating the model according to Eq. (2), a panel data is prepared to go through a series of steps before achieving the study's goals. As a result, econometric tests are used in the following order: first, Pesaran (2004)'s cross-sectional dependence test is employed to check the problem of residual cross-sectional dependencies. Second, as the period of the panel data used is fairly enormous, it is ideally assumed that the research variables will be defined by a unit root method (Sun et al., 2021). Thus. to assess the series' stationarity, acceptable panel unit root measures, such as the cross-sectional IPS (CIPS) and cross-sectional augmented Dickey-Fuller by Pesaran (2007) are used. The main estimator used to explore the long-term relationships between the selected variables is the pooled mean group – autoregressive distributed lag (PMG-ARDL) which possess an error correction term with strength in generating both short-run and long-run relationships amid the study series. In estimating the model, the number of observations is stated as 1, 2, 3, 4 ……N. The long-run estimation of the PMG-ARDL model factoring the fixed lag order is computed as follows:

$$\Delta lnco_{2it} = \alpha_{0i} + \emptyset_{1i}\left[lnCO_{2it-1} + \theta_{1i}(lnGDP_{it} + URB_{it} + lnHC_{it)}\right] + \sum_{a=0}^{c-1} \delta_{ia}\Delta lnGDP_{it-a} + \sum_{a=0}^{c-1} \rho_{ia}\Delta lnGDP_{it} + \sum_{a=0}^{c-1} \rho_{ia}\Delta lnURB_{it-a} + \sum_{a=0}^{c-1} \rho_{ia}\Delta lnHC_{it-a} + \varepsilon_{it} \quad (3)$$

Where $\emptyset$ is the error correction term that measures the speed of adjustment in the long-run relationship, ρ is the short-run estimated parameters, and *i* is the long-run equilibrium amid environmental pollution, economic growth, urbanization, and human capital. The PMG-ARDL (1,1,1,1) offers the long-run effects of the independent variables where the fixed lag length is indicated as $\sum$ for the differenced term. Furthermore, a heterogeneous panel granger causality test by Dumitrscu and Hurlin (2012) which also accounts for residual cross-sectional dependence is used to check the path of causal affiliations among the study variables (Figure 1).

Data Source

This study investigates the role of economic growth, urbanization, and human capital on environmental pollution in Brazil, Russia, India, China, and South Africa (BRICS) and Malaysia, Indonesia, Nigeria and Turkey (MINT) from 1990 to 2016. Data for this study is retrieved from the World Bank Development Indicators (WDI), and Penn World data version 9.0. The variables used in this study include CO_2 emission as a proxy for environmental pollution, gross domestic product representing economic development, urbanization and human capital. The study variables are converted into natural logarithm to minimize the issue of heteroscedasticity. The countries (BRICS and MINT), timeframe, and variables were purposively selected to achieve the aim of the study. The study variables, units of measurement, and source of data are found in Table 1.

Table 1. Study variables and data source

Variable	Unit of measurement	Data source
CO_2 emission	Kilotons (kt)	World bank development indicators
Gross domestic product	Constant 2010 US $	World bank development indicators
Urbanization	Urban population (total)	World bank development indicators
Human capital	Years of schooling and returns to education	Penn World Table version 9.0

Empirical Results and Discussions

Cross Sectional Dependence Test Results

This empirical study began with a cross-sectional dependence test. The outcome showed that there were dependencies in the panels under study. Therefore, the null hypothesis of no cross-sectional dependence is rejected at 1% significant value. For this reason, econometric techniques that are robust to cross-sectional dependencies such as the cross-sectional IPS (CIPS), and cross-sectional augmented Dickey Fuller (CADF) were employed for the study's further empirical analysis. The result of the cross-sectional dependence test is shown in Table 2.

Table 2. Cross-sectional dependence test result

Variable	Whole panel		BRICS Panel		MINT Panel	
	CD test value	*P* value	CD test value	*P* value	CD test value	*P* value
$LnCO_2$	19.888***	0.000	30.89***	0.000	36.556 ***	0.000
LnGDP	28.937***	0.000	38.69***	0.000	41.801***	0.000
LnURB	19.522***	0.000	40.12***	0.000	50.984***	0.000
lnHC	27.625***	0.000	31.07***	0.000	50.573***	0.000

Results for Unit Root Test

Using stationarity tests of CIPS and the CADF, the integration order of the study variables was examined. According to the research results as shown in Table 3, the null hypothesis of no stationarity was accepted at levels for all series but after the first difference, they were all rejected. This means that the entire variables were I(0) at levels, and I(1) at first difference. This is an evidence that the sampled variables possess a long-run unit root, and thus, forms the basis for applying the PMG-ARDL for model estimation.

Table 3. Panel unit root test result

		Level		1st Difference	
Income level	**Variable**	**CIPS**	**CADF**	**CIPS**	**CADF**
Whole panel	$LnCO_2$	-2.220	-2.181	-3.592***	-4.679***
	LnGDP	-2.036	-2.483	-3.575***	-3.594***
	LnURB	-2.430	-1.672	-4.273***	-2.800**
	lnHC	-2.453	-2.290	-2.815***	-2.221***
BRICS	$LnCO_2$	-2.191	-2.593	-3.613***	-3.170***
	LnGDP	-3.060	-1.228	-2.971***	-3.304***
	LnURB	-1.497	-2.135	-2.429**	-3.124**
	lnHC	-2.819	-1.513	-3.081**	-4.128***
MINT	$LnCO_2$	-2.864	-1.916	-5.231***	-4.481***
	LnGDP	-2.374	-2.228	-4.171***	-3.683***
	LnURB	-2.254	-2.144	-3.077***	-5.635***
	lnHC	-1.987	-2.700	-4.754***	-2.974***

Note: ***, **, and * indicate significant levels at 1%, 5%, and 10% respectively

Empirical Results and Discussion of the PMG-ARDL Estimation

Results of the PMG-ARDL estimations with respect to the long-run equilibrium amid environmental pollution, economic growth, urbanization, and human capital in the BRICS and MINT countries are shown in Table 4. From the PMG-ARDL estimations, GDP had significant negative influence on CO_2 emission in the main (BRICS-MINT), and the BRICS panels, but a significant positive impact was witnessed in the MINT panel. The significant negative influence of GDP on CO_2 indicates that a surge in economic growth have a substantial impact on the environmental quality of the BRICS-MINT countries. This outcome supports that of Shabaz et al. (2017) who reported that CO_2 emission in China had reduced during the study period due to economic growth. Similarly, Zou and Zhang (2020) reported that economic growth reduced environmental pollution in China during their study period (2000 and 2017).

However, this outcome contradicts Aye et al. (2017) who identified economic growth to increase CO_2 emission in 31 developing countries.

The significant and positive effect of GDP on CO_2 emission implies that as economic activities increase in the MINT countries, more greenhouse gases are emitted into the atmosphere resulting in pollution of the atmosphere. This finding aligns with Anwar et al. (2020) who found economic growth to have a positive influence on CO_2 emission in the Far East countries between the period, 1980 to 2017.

Also, the effect of URB on CO_2 emission was vital and positive in all the panels. That is, a unit increase in URB increases CO_2 emission in the whole, BRICS, and MINT panels by 2.685770, 2.467696, and 4.165430 respectively. The positive impact of URB on CO_2 across all the panels is an evidence that, the more people migrate into the urban centers, industries as well as other socio-economic activities in the BRICS and MINT countries release more greenhouse gases that harm the environment. This outcome of the study coincides with Ali et al. (2019) whose finding revealed that urbanization increased CO_2 emission in Pakistan. Soheila and Anahita (2019) also recorded a harmful impact of urbanization on CO_2 in Asian countries during the study period, 1980-2014.

Finally, the results of the study showed that human capital had a substantive negative effect on the environmental quality of all the three panels. All other things being equal, a unit increase in human capital reduced CO_2 emission in the whole, BRICS, and MINT panels by 21.365, 19.559, and 14.746 respectively. The economic implication is that, as more people are being educated in schools, and experts in innovative technology increase through economic cooperation and research and development, less carbon intensive products are produced in the BRICS and MINT countries. This in turn, reduces the quantity of emissions exerted into the atmosphere. This outcome of the study is in line with Saleem et al. (2019). This outcome also supports Sinha and Sen (2016) who found human development to reduce CO_2 emission in the BRICS countries between 1980 and 2013.

The null hypothesis of heteroscedasticity amid the panels is rejected in favor of the alternative (presence of homoscedasticity) because the outcome of the heteroscedasticity tests was statistically insignificant. This is an indication that the results of this study is reliable and valid for policy recommendation. Specifically, from the PMG-ARDL estimation results across all the estimated panels, the study variables which include gross domestic products, urbanization, and human capital are statistically significant and consistent with the error correction term's adjustment rate of 0.190, 0.261, and 1.156 units for the whole, BRICS, and MINT panels correspondingly. This indicates that each variable in the study panels speedily responds to deviations in the long-run relationship.

Table 4. PMG-ARDL long-run estimation results

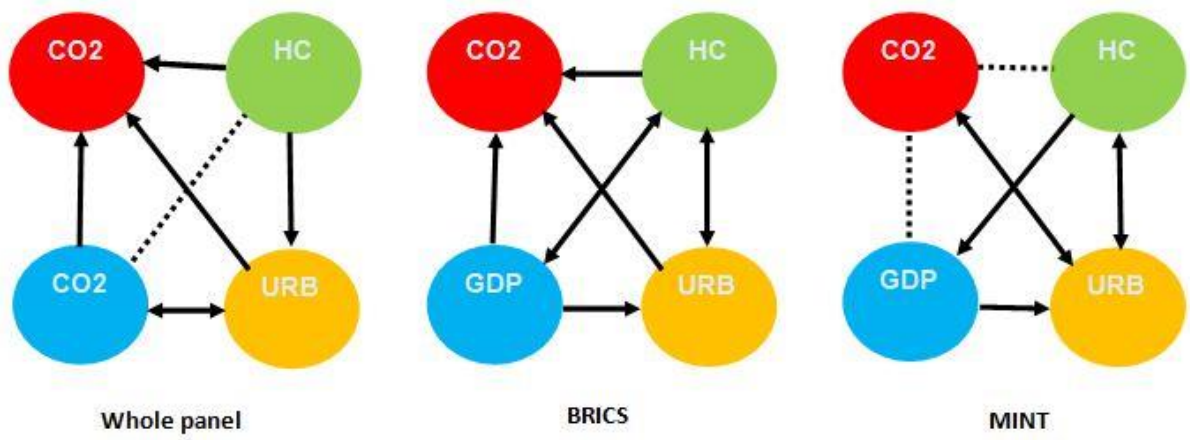
Dependent variable	CO_2 emission					
Independent variables	Main panel	Prob	BRICS	Prob	MINT	Prob
lnGDP	-0.267983	0.0000^{***}	-0.143188	0.3906	6.029465	0.0627^{**}
lnURB	2.685770	0.0000^{***}	2.467696	0.0000^{***}	4.165430	0.0771^{**}
lnHC	-21.36494	0.0000^{***}	-19.55944	0.0000^{***}	-14.74615	0.0903^{*}
Heteroscedasticity	7.234		5.690		4.8063	
ECT	-0.019024	0.050^{**}	-0.026153	0.0847^{*}	-0.115624	0.0048^{***}

Note: ***, **, and * indicate significant levels at 1%, 5%, and 10% respectively

Causality Test Results of the Panel Groups

As a result of cross-sectional dependence that existed amid the study panels, the Dumitrescu and Hurlin (2012) causality test was used to explore the causal relations among the study variables, and summary of the results is found in figure 1. According to the results of the entire panels (whole, BRICS and MINT), a unidirectional causality was found between CO_2 and the sampled variables (GDP, URB, and HC) in the whole panel. This outcome of the study indicates that as economic growth associated with urbanization and human capital increases in the BRIC-MINT countries, the environmental quality is affected negatively. This result aligns with Halkos and Gkampoura (2021) who found a uni-direction between GDP and CO_2 for 119 countries in the world. While a bi-direction existed between GDP and URB, a uni-direction was found between URB and HC. However, no there was no causal link between GDP and HC. This finding implies that GDP and URB are correlated while human capital causes urbanization but does not have any causal link with GDP.

With the BRICS panel, an evidence of uni-direction was witnessed between CO_2 and the sampled variables (GDP, URB, and HC), and between GDP and URB. The uni-direction causal link from URB to CO_2 emission is consistent with Ali et al. (2019) for Pakistan over the period 1972-2014. Nonetheless, a bi-direction was found between GDP and HC, and between URB and HC which means that the just mentioned variables are correlated. For the MINT panel, a bi-direction was found between CO_2 and URB, and URB-HC, while a uni-direction existed between GDP-URB, and GDP-HC. On the other hand, the study found no causal link between CO_2 and GDP, and CO_2-HC. The bi-direction between CO_2 and URB agrees with Salahuddin et al. (2019).



Conclusion and Policy Recommendations

This research explored the link between economic development, urbanization, human capital and environmental pollution in the BRICS and MINT countries from 1990 to 2016. To unravel the reliability of the study outcomes, second generation econometric models that are robust to cross-sectional dependence were utilized. Findings showed that the panel series were cross-sectionally dependent. Again, the study variables were not stationary at levels, but after the first difference, stationarity was evidenced. To examine the long-run equilibrium of the study variables, the pooled mean group autoregressive distributed lag (PMG-ARDL) estimator was used. The results revealed that, GDP had a negative influence on CO_2 emission in the whole and BRICS panels but a positive impact was found in the MINT panel. Urbanization had a positive impact on CO_2 emission whereas human capital reduced environmental pollution across all the study panels.

Pesaran's heteroskedasticity and the ECT confirmed that the study model was valid and free from heteroskedasticity. Finally, the D-H causality test which was used to access the causality amid the study variables revealed a uni-directional causality between CO_2 and the independent variables in the whole and BRICS panels. However, a bi-direction was found in between CO_2 and URB in the MINT panel although no causal link was found between CO_2 and GDP, and CO_2 and HC. The causal link amid the other variables were diverse across the study panels. Based on the results and discussion of the study, the following policy recommendations are made:

Since GDP had a significant positive influence on environmental pollution in the MINT countries. Authorities should formulate and put into action policies that would harness economic growth and at the same time, reduce emission of harmful gases into the atmosphere. This can be in the form of purchasing innovative equipment that emit less CO_2 but produce more goods and services.

Authorities in the in the BRICS and MINT countries should pay critical attention to the pace of urbanization. That is, policies that concern urban growth such are building regulations, transportation, and health should be restructured, and strictly implemented in order to harness environmental quality. For instance, the use of electric vehicles can be promoted and sold at affordable prices to reduce the consumption of non-renewable fossil fuel.

Furthermore, since human capital reduced emission of CO_2 across all the study panel, this study recommends that authorities in the BRICS and MINT countries should continue developing their people in all sectors of production towards reduction the reduction of CO_2 emission. This can be in the form of increasing research and development, and foreign direct investment which is often associated with technology and knowledge spillovers in the host countries.

Finally, the outcome of the study revealed that there exists cross-sectional dependence amid the study variables across the panels. This signpost that, what happens to countries in one panel could possibly affect countries in the other panel. For this reason, this study recommends that authorities within the BRICS and MINT countries should liaise with each other and share ideas on plans and policies that they are making to combat environmental pollution such as China that has planned to become carbon-neutral by 2060.

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Appendix

Table 5. Pairwise Dumitrescu Hurlin Panel Causality Tests for the whole panel

Null Hypothesis	W-Stat	Zbar-Stat	Prob.
LNGDP does not homogeneously cause LNCO_2	5.48956	7.90962	0.0460
LNCO_2 does not homogeneously cause LNGDP	2.20369	1.99516	3.E-15
LNURB does not homogeneously cause LNCO_2	5.41375	7.77315	0.0000
LNCO_2 does not homogeneously cause LNURB	14.6678	24.4301	8.E-15
LNHP does not homogeneously cause LNCO_2	4.38652	5.92418	0.0000
LNCO_2 does not homogeneously cause LNHP	6.04972	8.91788	3.E-09
LNURB does not homogeneously cause LNGDP	9.77437	15.6221	0.0000
LNGDP does not homogeneously cause LNURB	20.7309	35.3435	0.0000
LNHP does not homogeneously cause LNGDP	4.64720	6.39340	2.E-10
LNGDP does not homogeneously cause LNHP	4.02666	5.27645	1.E-07
LNHP does not homogeneously cause LNURB	18.6338	31.5686	0.0000
LNURB does not homogeneously cause LNHP	4.85286	6.76357	1.E-11

Table 6. Pairwise Dumitrescu Hurlin Panel Causality Tests for the BRICS panel

Null Hypothesis	W-Stat	Zbar-Stat	Prob.
LNGDP does not homogeneously cause LNCO_2	16.3119	12.6807	0.0000
LNCO_2 does not homogeneously cause LNGDP	3.49141	1.14227	0.2533
LNURB does not homogeneously cause LNCO_2	23.7792	19.4012	0.0000
LNCO_2 does not homogeneously cause LNURB	2.55922	0.30329	0.7617
LNHP does not homogeneously cause LNCO_2	14.0051	10.6046	0.0000
LNCO_2 does not homogeneously cause LNHP	7.02356	4.32120	2.E-05
LNURB does not homogeneously cause LNGDP	7.30902	4.57812	5.E-06
LNGDP does not homogeneously cause LNURB	11.9458	8.75122	0.0000
LNHP does not homogeneously cause LNGDP	6.55227	3.89704	0.0001
LNGDP does not homogeneously cause LNHP	5.10582	2.59524	0.0095
LNHP does not homogeneously cause LNURB	11.8882	8.69937	0.0000
LNURB does not homogeneously cause LNHP	13.3592	10.0233	0.0000

Table 7. Pairwise Dumitrescu Hurlin Panel Causality Tests for the MINT panel

Null Hypothesis	W-Stat	Zbar-Stat	Prob.
LNGDP does not homogeneously cause LNCO_2	5.75836	5.59563	2.E-08
LNCO_2 does not homogeneously cause LNGDP	1.38556	0.34838	0.7276
LNURB does not homogeneously cause LNCO_2	4.04494	3.53957	0.0004
LNCO_2 does not homogeneously cause LNURB	8.20785	8.53495	0.0000
LNHP does not homogeneously cause LNCO_2	4.86813	4.52738	6.E-06
LNCO_2 does not homogeneously cause LNHP	1.38766	0.35090	0.7257
LNURB does not homogeneously cause LNGDP	5.22874	4.96010	7.E-07
LNGDP does not homogeneously cause LNURB	3.70501	3.13166	0.0017
LNHP does not homogeneously cause LNGDP	4.19710	3.72216	0.0002
LNGDP does not homogeneously cause LNHP	0.57292	0.62677	0.5308
LNHP does not homogeneously cause LNURB	10.6753	11.4958	0.0000
LNURB does not homogeneously cause LNHP	2.66706	1.88615	0.0593