THE IMPACT OF ENERGY USE AND REAL PER CAPITA INCOME ON CARBON DIOXIDE EMISSIONS IN BRICS COUNTRIES: A PANEL REGRESSION APPROACH

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ABSTRACT

Using panel data covering the period 1989 – 2016 for BRICS countries, this study applied the pooled regression, fixed effects and random effects models in an attempt to analyze the impact of energy use and real per capita income on CO_2 emissions amongst the BRICS countries. Post-estimation diagnostic tests revealed that the fixed effects model was the most appropriate model and that it was not suffering from serial correlation and cross-sectional dependence. The results of the study indicated that both real income and energy use have a positive and significant impact on carbon dioxide emissions among the BRICS member countries over the period under consideration. This is in line with the hypothesis of the Environmental Kuznets Curve which postulates a positive relationship between income growth and carbon dioxide emissions in the growth of economies in the short run. Relevant policy prescriptions have been put forward for consideration by BRICS governments.

Keywords: - *BRICS countries, CO_2 Emission, Economic Growth, Energy Use*

1. Introduction

Energy use, a well-known determinant of economic growth (Cassim *et al*., 2004; Odularu & Okonkwo, 2009; Ozturk *et al*., 2010; Ighodaro, 2010; Adhikari *et al*., 2012; Apergis & Danuletiu, 2012) is a burning issue among policy makers and economists. There is no doubt, exhaustion or reduction of any type of energy can disrupt the economy. However, energy use can be detrimental to the environment in the sense that the use of more energy can produce more carbon dioxide (CO_2) emissions and thus affect air quality, particularly by resulting in greenhouse effects and subsequently causing global warming (Vo *et al*., 2019; Shaari *et al*., 2020; Manta *et al*., 2020). While the subject matter under investigation has been explored across the globe, for example, Ang (2007), Bozkurt & Akan (2014), Vo *et al*. (2019), Manta *et al*. (2020) and Shaari *et al*. (2020); it is ironic to note that such studies are scanty within the BRICS countries. Hence, this study seeks to fill-up this informational gap.

2. Methods & Materials

For the investigation of the impact of real income and energy use on carbon dioxide emissions in the BRICS, real per capita income given by real GDP per capita (RGDPP), Openness to trade (Tr) calculated as the summation of exports and imports divided by GDP, energy use (EU) and carbon dioxide emissions (CO2) are used of which openness to trade is the control variable. These variables are expressed in their natural logarithms to minimise chances for heteroskedasticity. This data was obtained from the World Bank Database. The five BRICS member countries are Brazil, Russia, India, China and South Africa. The data covers the period 1989 to 2016.

Real Per Capita Income (RGDPP)

Per capita GDP at 2010 constant USD prices was used as a measure of real income per person. Real income growth is initially expected to have a positive impact on carbon emissions due to intensive production emitting high volumes of pollutants up to a certain real income threshold, beyond this threshold carbon emissions are expected to fall with further income increases due to environmentally friendly production methods and technologies as well as the need for quality life as hypothesised by the Environmental Kuznets Curve.

Energy Use (EU)

This refers to use or consumption of primary energy before transformation to other end use fuels and it is measured in kilograms of oil equivalent per capita. Increased energy consumption is expected to have a positive impact on carbon emissions since intensified and prolonged use of energy to achieve higher levels of production and consumption imply increased emission of pollutants into the atmosphere.

Openness to trade (Tr)

This refers to the intensity of free trade and globalisation brought about by removing barriers to free trade and is measured as the summation of imports and exports divided by GDP. Tr's impact on carbon dioxide emissions is ambiguous because intensification of export production to achieve growth may positively impact carbon emissions whilst importation of environmentally friendly and smart technologies of production and reallocation of resources to areas where they are efficiently used as hypothesised by the absolute and comparative advantage trade theories can have a negative impact on carbon dioxide emissions.

Carbon Dioxide Emissions (CO_2)

These refers to carbon emissions emanating from burning of fossil fuels and production of cement thus all carbon dioxide emitted during consumption of solid, liquid or gaseous fuels. These are measured in metric tonnes per capita.

The empirical model undertaken by the researchers, in line with Shaari *et al*. (2020), is built upon the precepts from the Environmental Kuznets Curve which postulates a positive relationship between real income growth and carbon dioxide emissions during initial stages of development of an economy in which agriculture and manufacturing are the key sectors. However, at a certain higher income threshold, further increases of income causes carbon emissions to fall as the economy becomes more reliant on services and use of smart technologies, hence the EKC is hypothesised to be an inverted U shaped. This implies that countries are encouraged to focus on policies that enhance economic growth and ignore the associated problems of carbon emissions in their early stages of growth and development with a view that in the long run growth in income will eradicate problems of carbon emission.

An unbalanced panel data analysis with 130 observations made up of five cross sectional BRICS countries and 28 time periods from 1989 to 2016 was used. This study utilises panel data regression as a tool for analysis because of the need to regress data of 5 different countries over a 28 years' time period. Panel data regression involves pooling of observations of different variables for different cross-sectional units over a specific time period, hence it combines both time series and cross-sectional features of data. This implies that panel data regression is a hybrid data analysis tool because it allows for more degrees of freedom, increases variability, reduces the omitted variable bias, it is highly efficient and more informative than time series or cross-sectional regression. Therefore, panel data regression enhances an empirical analysis better than solely using time series or cross-sectional data.

2.1 Model Specification

Panel data regression is made up of three models of estimation namely, the random effects model (REM), the fixed effect model (FEM) and the pooled ordinary least squares (OLS) model. This study will summarise all these three models in the context of the impact of real per capita income and energy use on carbon dioxide emissions among BRICS member countries before undertaking econometric procedures to determine the best model of estimation.

The Pooled OLS Model

This model assumes that all cross-sectional units are homogenous and it does not take into cognisance time series aspects (Gujarati 2004). It assumes a single constant intercept and slope coefficients which are both time and cross-sectional invariant. It overlooks cultural and technological differences amongst cross sectional units.

The specific equation for the pooled OLS model on the impact of RGDPP and EU on carbon emissions with openness to trade as a control variable is given by equation 1 below:

$$lnCO_{2it} = \beta_0 + \beta_1 lnRGDPP_{it} + \beta_2 lnTr_{it} + \beta_3 lnEU_{it} + \mu_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..(1)$$

$$with\ i = 1,2,3,4\ \&5\ for\ Brazil, Russia, India,\ China\ \&\ South\ Africa\ respectively$$

$$t = 1989, 1990, \dots, 2016\ and\ i\ stands\ for\ BRICS\ member\ country$$

This model's major merit is its plainness to undertake though it has been condemned due to its lack of realism by not appreciating that cross sectional units are heterogeneous and that time dynamics play an important role in determining these economic variables.

Fixed effect model

This model allows for some heterogeneity and individuality among the cross-sectional units. It appreciates that cross sectional units are different in terms of culture, education and religion as well as the fact that differences in time dynamics due to technological and policy changes impacts on economic variables differently. These differences then lead to a unique coefficient for each cross-sectional unit which is however time invariant. These differences are then incorporated into economic functions through both cross sectional and time dummies. Equation 2 has a coefficient to show that each country has a unique coefficient due to various country differences mentioned above. Equation 3 is an expansion of equation 2 and has both state and time dummies.

Equation 2 & 3 below gives the model specification for the impact of real income and energy use on carbon dioxide emissions in the BRICS assuming the FEM.

$$lnCO_{2it} = \propto_{0i} + \propto_1 lnRGDPP_{it} + \propto_2 lnTr_{it} + \propto_3 lnEU_{it} + U_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

$$lnCO_{2it} = \propto_0 + \propto_1 lnRGDPP_{it} + \propto_2 lnTr_{it} + \propto_3 lnEU_{it} + \beta_2 D_{2i} + \beta_3 D_{3i} + \cdots + \beta_5 D_{5i} + \delta_1 DUM_{90} + \cdots + \delta_{16} DUM_{16} + U_{it} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

$D_{2i}, \dots, D_{5i}$ *are BRICS countries' dummies and* $DUM_{90}, \dots, DUM_{17}$ *are time dummies for* 1989 to 2016

$$D_{ji} = \begin{cases} 1, & if\ i = j \\ 0, & otherwise \end{cases}, DUM_{90} = 1\ for\ observation\ in\ 1990\ \&\ 0\ otherwise$$

Dummies for country 1 *and year* 1989 (D_{1i} *and* D_{89}) *have been excluded to avoid a dummy trap*

The major strengths of this model are that it is more practical since it appreciates the heterogeneity or differences in individual cross-sectional units due to special characteristic features specific to each cross-sectional unit. However, this model has been criticised since increases in both cross sectional and time dummies used will cause losses in degrees of freedom and these summative and multiplicative dummies as well leads to dummy traps.

Random Effects Model

This model assumes that the intercepts for cross sectional units are randomly drawn from the population with a constant mean value that is the 5 BRICS countries are drawn from a huge population and have a common mean for $\propto_0$. Differences in the cross-sectional values for each country are shown in the error term, w_i as shown by equation 4 below:

$$lnCO_{2it} = \propto_0 + \propto_1 lnRGDPP_{it} + \propto_2 lnTr_{it} + \propto_3 lnEU_{it} + z_{it} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (4)$$

where $z_{it} = w_i + u_{it}$, w_i *is the cross section error component with zero mean and var,* σ_w^2

u_{it} *is a combination of both cross sectional and time series error components*

The assumption is that there is a maximum number of N cross sectional units (5 BRICS member countries) as well as T time periods (28 years from 1989 to 2016). Variables in the specific models above are:

$lnRGDPP$= natural logarithm of Per capita real Gross Domestic Product

$lnCO_2$ = natural logarithm of Carbon Dioxide Emissions

$lnEU$ = natural logarithm of Energy Use

$lnTr$ = natural logarithm of Openness to Trade

3. Data Presentation, Analysis & Interpretation

The descriptive statistics of all these variables are shown on table 1 below:

Table 1: Descriptive Statistics

Description	DLNCO2	DLNRGDPP	DLNTR	DLNEU
Mean	0.016176	0.031942	0.023362	0.016236
Median	0.024012	0.033220	0.023527	0.017902
Maximum	0.158647	0.127833	1.437791	0.127233
Minimum	-0.516217	-0.157455	-0.475986	-0.133693
Std. Dev.	0.070820	0.047934	0.167173	0.039862
Skewness	-3.431289	-0.919002	4.537676	-0.390603
Kurtosis	27.20783	5.000590	43.22781	4.811160
Jarque-Bera	3271.089	38.13319	8786.632	20.10135
Probability	0.000000	0.000000	0.000000	0.000043
Sum	2.005770	3.960805	2.896925	2.013213
Sum Sq. Dev.	0.616902	0.282613	3.437477	0.195447
Observations	124	124	124	124
Cross sections	5	5	5	5

The Jarque-Bera (JB) Statistic is a normality test made up of skewness and kurtosis measures. Generally, a variable with a JB value below 5.99 imply that it follows a normal distribution whilst a JB value in excess of 5.99 suggest non normal distribution. Skewness measures the distribution of the variable and has three aspects, symmetric (when skewness = zero), negatively skewed (when skewness < zero) and positively skewed (when skewness > zero). Kurtosis measures the extent to which the distribution is heaped. It also has three aspects which are mesokurtic (if kurtosis = 3), platykurtic (if kurtosis <3) and leptokurtic (if kurtosis >3). A normal distribution should be both symmetric and mesokurtic. Below is a summary of descriptive statistics for the variables under consideration.

The average values for DLNCO2, DLNRGDPP, DLNTR and DLNEU are 0.016176, 0.031942, 0.023362 and 0.016236 respectively. Their respective maximum: minimum values are 0.1586: -0.5162; 0.1278: -0.1575; 1.4378: -0.4760 and 0.1272: -0.1337. The ranges for all variables are less than 2 meaning that maximum and minimum values are closer to each other hence chances for the existence of outliers is minimised. There is evidence of low data variability in all variables since all variables have small standard deviations which are all below 0.5.

Evidence suggests that all variables are not normally distributed since all their JB values of greatly exceed a JB value of 5.99. DLNCO2, DLNRGDPP and DLNEU are all negatively, skewed with their respective measures of skewness of -3.4313, -0.919 and -0.3906 whilst DLNTR has a positive skewness of 4.5377. All variables are leptokurtic since their kurtosis measures exceed 3.

3.1 Panel Unit root test

A panel unit root test for variables under consideration was conducted. There is need for stationarity of variables so that OLS can produce unbiased results. The results in Table 2 below indicate that there is evidence to fail to reject the null hypothesis of unit roots in favour of the alternative for both individual intercept and individual intercept and trend scenarios when in level since all p-values for different tests are greater than 0.05 hence they are not stationary in levels. All panel variables only became stationary after first differencing for both scenarios since the p-values are now less than 0.05 hence we reject the null of unit root implying that the panel is integrated of order 1.

Table 2 : Panel Unit Root Results for BRICS member countries

Panel Unit Root Test Statistic	LEVEL				1st DIFFERENCE			
	Intercept		Intercept & Trend		Intercept		Intercept & Trend	
	Stat	Prob	Stat	Prob	Stat	Prob	Stat	Prob
Levin, Lin & Chu t*	-0.6867	0.2461	-0.0972	0.4613	-9.892*	0.0000	-7.767*	0.0000
Breitung t-stat	_	_	2.4148	0.9921	_	_	-5.142*	0.0000
Im, Pesaran & Shin	2.1812	0.9854	0.0884	0.5352	-12.19*	0.0000	-10.864*	0.0000
ADF-Fisher Chi-square	46.0881	0.2350	41.7598	0.3942	212.63*	0.0000	179.197*	0.0000
PP-Fisher Chi-square	41.8055	0.3923	47.9906	0.1805	241.98*	0.0000	439.947*	0.0000

NB * signifies significance at 1%

The researchers then estimated the model in first difference assuming pooled OLS, random effects and fixed effects methodologies and undertook the following econometric tests in order to decide on the best fitting, efficient model

3.2 Correlated Random Effects Hausman Test

The researchers use this test to identify or determine whether or not random effects are affecting the model results. The hypothesis to be tested and the decision rule are given on Table 3 below:

$H_0: random\ effects\ model\ is\ appropriate$

$H_1: fixed\ effects\ model\ is\ appropriate$

$reject\ H_0\ if\ the\ p - value\ < 0.05$

Table 3: The Hausman Test

Correlated Random Effects - Hausman Test			
Pool: BRICS2			
Test cross-section random effects			
Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	11.921126	3	0.0077

The p-value is less than 0.05 hence we reject the null hypothesis and conclude that the random effects are not influencing our study results hence the fixed effects model is more appropriate. This implies that fixed effects and not random effects are determining the impact of real income and energy use on carbon dioxide emissions in the BRICS region

3.3 The redundant fixed effects likelihood ratio and the F-test

Having decided that fixed effects are appropriate in our model, it is important to determine whether both cross sectional and time fixed effects are necessarily influencing our study results by using the redundant fixed effects likelihood ratio hence a choice between the fixed effect model and the pooled OLS model will be made.

It is important to determine the model that better explains the effect of real income and energy use on carbon dioxide emissions in the BRICS. Several econometric procedures are therefore undertaken to make this decision. One of the procedures is performing the F-Test for the joint significance of all variables under consideration (Gujarati, 2004). F calculated is found by:

$$F = \frac{(R^2_{UR} - R^2_R)/(n-1)}{(1-R^2_{UR})/nT - n - K} \ldots\ldots\ldots (5)$$

$H_0: The\ efficient\ estimator\ is\ pooled\ least\ squares\ method$

$H_1: The\ efficient\ estimator\ is\ the\ unrestricted\ model$

$reject\ H_0\ iff\ F_{calculated} > F_{critical}\ or\ p_{value} < 0.05$

$where\ UR\ is\ the\ unrestricted\ model\ with\ common\ effects\ whilst\ R\ is\ the\ poooled\ model$

K is the number of estimated parameters in the common effects model, m is the total number of excluded parameters.

3.4 The redundant fixed effect likelihood ratio

A hybrid test to determine the efficient estimator between the pooled least squares method and the fixed effects model called the Redundant Fixed Effect Test has been used. Consider Table 4 below:

Table 4: The Redundant Fixed Effects Test

Redundant Fixed Effects Tests			
Pool: BRICS2			
Test cross-section and period fixed effects			
Effects Test	Statistic	d.f.	Prob.
Cross-section F	3.311337	(4,92)	0.0140
Cross-section Chi-square	16.678705	4	0.0022
Period F	1.057386	(24,92)	0.4068
Period Chi-square	30.206971	24	0.1780
Cross-Section/Period F	1.351930	(28,92)	0.1439
Cross-Section/Period Chi-square	42.733192	28	0.0369

This test has been used to determine whether fixed effects are necessary or not in determining the impact of real income and energy use on carbon dioxide emission in the BRICS region. The chi-square statistics for the combined cross section and period effects are significant at 5% hence we reject the null hypothesis that fixed effects are redundant and conclude that the efficient estimator is the fixed effect (unrestricted) model.

After realising the need to determine whether both cross sectional and time period fixed effects influence our model results, the redundant fixed effect test has further been used.

3.5 Cross sectional fixed effects case

To determine whether cross sectional fixed effects are influencing our study results we carry out the redundant fixed effects test within a fixed cross-sectional scenario. Consider Table 5 below:

H_0: *there are no cross sectional fixed effects (cross sectional effects are redundant)*

H_1: *there are cross sectional fixed effects*

Reject the null hypothesis if p-value is less than 0.05

We reject the null hypothesis and conclude that cross sectional fixed effects are influencing our model results since the p-value is less than 0.05 and conclude that individual BRICS member countries' specific characteristics does influence our study results.

Table 5: The Redundant fixed effect Test

Redundant Fixed Effects Tests			
Pool: BRICS2			
Test cross-section fixed effects			
Effects Test	Statistic	d.f.	Prob.
Cross-section F	3.082597	(4,116)	0.0188
Cross-section Chi-square	12.526220	4	0.0138

3.6 Period fixed effects case

To determine whether period fixed effects are influencing our study results we carry out the redundant fixed effects test within a fixed period scenario. Consider Table 6 below:

H_0: *there are no period fixed effects (period fixed effects are redundant)*

H_1: *there are period fixed effects*

Reject the null hypothesis if p-value is less than 0.05

Table 6: The Redundant fixed effect Test

Redundant Fixed Effects Tests			
Pool: BRICS2			

Test period fixed effects			
Effects Test	Statistic	d.f.	Prob.
Period F	0.935289	(24,96)	0.5557
Period Chi-square	26.054487	24	0.3504

We fail to reject the null hypothesis that there are no period fixed effects influencing our model results since the p-values for both the F-Test (0.56) and chi-square (0.35) for period fixed test exceed 0.05 and conclude that various macro-economic conditions and events happening during specific years do not affect our study results.

3.7 Panel cross section dependence Test

It is often assumed that there is always panel cross sectional independence among residuals when the number of cross-sectional units is large. Existence of cross-sectional dependence can have dire consequences to the model leading to high levels of inefficient estimators and invalid results. A test to determine residual panel cross sectional dependence in the model under consideration on table 7 below show that there is no sufficient evidence to reject the null hypothesis which states that there is no panel cross sectional dependence since the p-values for various tests are all greater than 0.05 hence we fail to reject the null hypothesis.

Table 7: Residual Cross-Section Dependence Test

Test	Statistic	Probability
Breusch-Pagan LM	12.3149	0.2645
Pesaran scaled LM	-0.6004	0.5482
Bias-corrected scaled LM	-0.7046	0.4811
Pesaran CD	0.2804	0.7792

3.8 The Fixed Effect Model

This then implies that the best fit model to determine the impact of real per capita income and energy use on carbon dioxide emissions amongst the BRICS member countries. Figure 1 below gives estimated coefficients of variables under consideration assuming existence of fixed effects on the impact of $DlnRGDPP$ and $DlnEU$ on $DlnCO_2$ amongst BRICS member countries.

Table 8: Fixed Effect Model of impact of $DlnRGDPP$ and $DlnEU$ on $DlnCO_2$ amongst BRICS member countries

Dependent Variable: DLNCO2?				
Method: Pooled Least Squares				
Total pool (unbalanced) observations: 124				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.008006	0.004353	-1.839343	0.0684
DLNRGDPP?	0.310976	0.111428	2.790827	0.0061
DLNTR?	-0.152494	0.019666	-7.754230	0.0000
DLNEU?	1.097029	0.116316	9.431448	0.0000
Fixed Effects (Cross)				
BRAZ--C	0.012456			
CHIN--C	-0.014493			
IND--C	0.012037			
RUSS--C	-0.013588			
SA--C	0.003045			
	Effects Specification			
Cross-section fixed (dummy variables)				
R-squared	0.757548	Mean dependent var		0.016176
Adjusted R-squared	0.742918	S.D. dependent var		0.070820
S.E. of regression	0.035908	Akaike info criterion		-3.753372
Sum squared resid	0.149569	Schwarz criterion		-3.571418
Log likelihood	240.7090	Hannan-Quinn criter.		-3.679458
F-statistic	51.77802	Durbin-Watson stat		2.136543
Prob(F-statistic)	0.000000			

3.9 Results Analysis & Interpretation

All variables, DLNRGDPP, DLNTR and DLNEU are significant at 1% level in determining the level of carbon dioxide emissions in the BRICS during the period under review. DLNRGDPP have a positive impact on carbon emission thus a 1% increase in real income causes carbon emissions to increase by 0.3 percentage points within the BRICS. This partly concurs with the EKC hypothesis which postulates a positive relationship between real income and carbon emissions during initial stages of development implying that growth of countries within the BRICS is mainly hinged on the manufacturing and not the services industry. During this period, efforts to increase real income through intensifying production will increase the emission of pollutants hence this positive relationship. These results are consistent with a number of previous studies such as Ang *et al*. (2007), Fodha *et al* (2010), Bozkurt & Akan (2014), Dritsaki & Dritsaki (2014), Vo *et al*. (2019) and Manta *et al*. (2020).

DLNEU as well has a positive impact on carbon emissions showing that a 1% increase in energy use causes carbon dioxide emissions to increase by 1.1 percentage points. This is so because carbon emissions are bi-products of energy use thus an intensified use of energy imply more carbon emissions as economies increase their production levels. The same results were found by several previous studies, for example, Lean & Smith (2005) as well as Ang (2007).

On the other hand, DLNTR has a negative impact on carbon emissions with a 1% increase in openness to trade causing carbon emissions to fall by 0.15 percentage points. This might be caused by the importation of smart and environmentally friendly production technologies as well as efficient resource use since free trade ensures that goods are produced where there are high levels of efficiency. Another reason is that free trade is associated with countries forming trade blocs and economic integration arrangements and such blocs might have clauses that force member countries to be signatories of environmental conservation treaties requiring countries to observe certain pollution guidelines. These results were also found by Sohag *et al* (2017). However, Managi *et al* (2009) in estimating the effect of trade on environmental quality in both non advanced and advanced economies found that trade increases emissions in non-advanced countries.

The results above show an average common intercept for all BRICS member countries, c, with a value of -0.008. There are also country specific intercepts for all BRICS member countries arising from the fact that these countries are heterogeneous and each have its own unique special characteristics (cross sectional fixed effects). Country specific intercepts are given as deviations from the average common intercept. A high adjusted R^2 of 0.743 shows that 74.3% of the variation in carbon dioxide emissions can be explained by all exogenous variables under consideration. The DW statistic of 2.1 shows that there is no serial correlation among error terms.

4. Conclusion & Recommendations

4.1 Conclusion

The aim of the study was to examine the impact of real income and energy use on carbon dioxide emissions among the BRICS member countries over the period 1989 to 2016 using panel data analysis. Variables under consideration were converted into their natural logarithms to minimise variability and were first differenced to get rid of the unit root problem. Openness to trade was used as the control variable. The Hausman test was employed to decide on the efficient model to use between the fixed effect and the random effect model. the fixed effect model was selected, the fixed effect redundant test was employed to choose between the pooled OLS model and the fixed effect model and also to determine whether both cross sectional and period fixed effects are necessary. The best of fit model was the fixed effects model with cross sectional fixed effects only. The cross-sectional dependence test was carried out and the results revealed that the panel variables did not exhibit cross-sectional dependence. The results show that both real income and energy use have a positive and significant impact on carbon dioxide emissions among the BRICS member countries over the period under review. This is in sync with the hypothesis of the Environmental Kuznets Curve which postulates a positive relationship between income growth and carbon dioxide emissions in the growth of economies in the short run.

4.2 Recommendations

Given the negative health and environmental impacts of increased carbon dioxide emissions, Governments of all BRICS member countries are faced with a difficult decision since enacting laws that penalise carbon emissions may lead to falling real incomes. However, the only viable solution to this predicament is to replace old, high carbon producing machines and technologies with new smart and environmentally friendly technologies such that production will not be disrupted hence the economy grows whilst carbon dioxide emissions fall. Thus, they should invest in such technology and encourage firms to replace old technologies with new smart technologies by offering them incentives such as reduction of import duties on new technologies. They should also invest in research and development in their tertiary institutions such that advancement will be done to produce environmentally friendly technologies. These governments should also invest in the replacement of non-renewable high pollutant containing energy sources such as coal and fossil fuels with renewable environmentally friendly energy sources such as solar, biogas and hydro-electricity. Governments may partner with the private sector through private-public partnerships to ensure efficiency and accountability in undertaking these investments. Direct controls on carbon emissions such as production permits, carbon taxes and total ban in the form of laws and regulations may be effective in reducing these emissions however they might have dire consequences on economic growth, therefore the solution should encourage polluters to switch to less pollutant producing technologies.

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