Assessing the Impact of Renewable Energy Consumption, Economic Growth and Foreign Direct Investment on Carbon Emission: An Empirical Study of Africa Using Dynamic Panel Data Estimations and Panel Vector Autoregression Model Impulse Response Function

Author's Details: [1] Kingsley Anfom [2] Xu Xiaoyang
[1] [2] Jiangsu University-School of Finance and Economics

Abstract
our study adopts panel data methodologies to empirically examine the impact of renewable energy consumption per capita, GDP per capita and foreign direct investments on carbon emissions for a panel of 33 African countries for the period 2000 – 2014. The long run estimates of the variables confirm that renewable energy consumption per capita is negatively related to carbon dioxide emission; renewable energy reduces the pollution that results from carbon emission. Economic growth showed positive impact on carbon emission and foreign direct investment showed negative or an inverse relationship with carbon emissions in our samples. We recommend that the use of renewable energy consumption should be prompted in Africa in order to develop carbon free economies and also mitigate the activities of pollutants in the premise of regulations

Keywords: *Carbon emission; Renewable energy consumption; Economic growth; FDI; dynamic panel estimation; impulse response function*

1. Introduction

Carbon emission has been pinpointed as a determinant of global warming or climate change. Many recognized agencies such as international organizations and governments from developed and developing countries as well as environmental practitioners have fingered carbon emission as a highest contributing factor of global warming. In order to control carbon emissions, some relevant factors to carbon emission should be adopted in the first instance. Economic growth is an imperative factor that impact carbon emission (Zhu et al., 2016). Generally, human daily activities for survival has been observed as contributing factor to the increasing emission of greenhouse gases dramatically altering the world's environment and leading to intensified climate change. The fundamental nature of global warming which is mostly caused by greenhouse gas has been widely perceived among economists and policy makers as an issue that requires international cooperation across the globe (Chung-Pin et al, 2019).

According to the World Health Organization (WHO) about 18% of carbon dioxide (CO_2) emissions in the world emanates from energy use; also the residential consumption of fuel. Emphatically, the continuous increase of emissions from greenhouse gas posed serious health implications on the environment and human health. However, the considerate effort to coil this menace has been the adoption of cleaner technologies like the production of renewable energy (solar, biogas, wind, geothermal, etc.) can significantly mitigate emissions of pollutants such as greenhouse gases and carbon dioxide in the climate by about 0.4 to 0.9 billion tons of CO_2 emissions between the period of 2010 and 2020 (Nicholas et al. 2018).

To attract foreign direct investment, many developing countries may ignore environmental issues through "relaxed or non-enforced regulations"; in economic theory, this phenomenon is known as "the pollution haven hypothesis". However, the narrative will be different when FDI flows into the service industry or incorporate advanced technologies which have low-carbon production features. This as a result will make the relationship between FDI and carbon emission inverted becaused the introduction of low-carbon technologies will significantly reduce the emission caused by greenhouse gases. Many foreign firms consciously utililze high expertise in management and the adoption of sophisticated or high level technologies contributing to campaign against global warming and moreover contribute to clean environment of FDI recipient countries which is theoretically known as the "halo effect hypothesis" (Zarsky, 1999).

Scores of environmental practitioners have developed two hypotheses which are contradictory regarding the environment. Firstly, the “pollution haven hypothesis” (PHH) argues that developed countries or economies restrict their environment by enacting policies that control pollution and ensures resident firms do not pollute their environment. Moreover, due to these tighter regulations these firms intend to set up abroad to shift their polluting operations to developing countries to become “Pollution Haven”. The second hypothesis thus “Factor endowment hypothesis” (FEH) assumes that trade openness through export and import can result in trade pattern in a consistent manner. In account, this hypothesis came be traced to the “Heckscher-Ohlin- Vanek (HOV) theory of comparative advantage” and involves the “factor endowment differentials” (Saddam, 2014).

In view of existing literatures, the relationship between FDI and carbon emission is mixed; Ahmed (2015) in his studies revealed a positive relationship; therefore FDI increases carbon dioxide emission. Evidence from Yang et al. (2018) share different view and their study they that FDI and carbon emissions are negatively related. The study’s motivation stems from the divergent view of these studies thus Ahmed (2015), Yang et al., (2018) and Yang et al. (2015); howeve, we intend to investigate the relationship that exist between carbon emission and foreign direct investment. Also, we intend to find out whether renewable energy patronize will be the top-notch alternative to combat carbon emission. Most importantly, we intent to either validate or reject the findings of the above researchers and to conclude whether “Pollution Haven hypothesis” as well as the “factor endowment hypothesis” is present in Africa.

The purpose of this paper is to empirically investigate and assess the impact of renewable energy consumption, foreign direct investment, and economic growth on carbon emissions with much emphasis on foreign direct investment (FDI). It is assumed that the deletion of the ozone layer from carbon emissions heavily affect social development and also have strong impact on economic growth (Moore et al., 2016). The World Bank report (2015) avers that primary energy usage has amounted to over 60% of the world carbon dioxide emissions resulting to a rise in global warming. As the matter of interest this problem has motivated the researchers to conduct this study to establish the fact if renewable energy consumption can be the best alternative to coil this global problem. However, the “Environmental Kuznets Curve (EKC) hypothesis” states that economic growth proactively propagates carbon emissions; furthermore, when economic stages rise at a turning point, economic growth will decrease carbon emissions, which can be referred to as that an “inverted U-shaped” relationship exist between economic growth and carbon emissions. Zhu et al. (2016) argues that economic growth is a contributing factor of carbon emissions. In order to achieve economic growth sustainably devoid of carbon emission, this paper is motivated to establish the statistical coefficients at which economic growth and carbon emissions are related in order to recommend to policy makers. Moreover, the paper has an interest in testing for the EKC hypothesis to ensure whether it exists in Africa to be more precisely; the high GDP per capita countries and low GDP per capita countries.

Unlike other African literatures, the contribution of our study is to examine the impact of renewable energy consumption, foreign direct investment and economic growth on carbon emissions in panel study of 33 African countries in dynamic analysis or methodologies. In addition, the study adopts three panel econometric models to affirm the robustness of the study and to ensure the cross-section dependence, heterogeneity and homogeneity in data analysis for a panel study. The three econometric models are; dynamic panel data estimations (Arellano-Bond GMM), Panel Vector autoregression model and Panel homogenous causality test. Notably, our findings could contribute to policy making decision on carbon emission reduction; for example, increase in renewable energy consumption or more/less reliance on FDI.

The paper is organized as follows; Section 1 contains the introduction, Section 2 outlines the literature review and section 3 includes the methodology and data. The results are presented in Section 4, and key findings are summarized. Finally, some key conclusions and policy recommendations are drawn in Section 5.

2. Review of literatures

2.1 Renewable energy consumption and carbon emissions

The attention of many researchers in Africa have directed towards the need for possible means to address the problem of carbon emission which causing climate changes in the world; moreover these strategies are to ensure sustainable economic growth (Maji and Sulaiman, 2019). Scores of researches have opined that the proactive way toward carbon emission reduction is to adopt renewable energy to coil carbon emissions from the use of fossil fuels (Maji, 2015; Rafinadai and Ozturk, 2016; Ozturk and Bilgili, 2015; Adewuyi and Awodumi, 2017a, b).

Ben Jebli et al. (2015) examined the relevance of renewable energy consumption in the fight against carbon emissions. These authors considered a panel of 24 sub-Saharan Africa nations and employ panel cointegration methodologies in their analysis. They proposed that the benefit from technology transfers through trade exchanges are very good course to increase their renewable energy use and reduce carbon emissions levels.

2.2 Foreign direct investment and carbon emissions

In prior studies, some researchers have found that foreign direct investment inflow has consistent, direct and positive linkgage with carbon emissions in the long run (Samuel & Vladimir, 2019; Ahmed, 2015; Yang et al., 2018). Researches in relation to the "pollution haven hypothesis" (Zakarya et al., 2015; Behera & Dash, 2017; Solarin et al., 2017) confirm the existence of this phenomenon. Solarin et al. (2017) examined the " pollution haven hypothesis" for Ghana which he employed autoregressive distributed lag (ARDL) bounds testing method. From his findings, he posits that the "pollution haven hypothesis" exist in Ghana. Sun et al. (2017) investigated the effect of FDI inflows on CO_2 emissions with consideration of other variables like urbanization impact, economic growth and development, trade openness, financial independence and energy use. Their study used ARDL method; however, their findings support the "pollution haven hypothesis" in China.

Nonetheless, FDI inflows stems from the massive contribution of manufacturing sector, mining and energy sub-sector that are transferred from the developed countries. Behera and Dash (2017) concluded their study that FDI inflows significantly and strongly affect carbon emissions in their adoption of FMOLS and DOLS econometric models. Their study incorporated electricity consumption in their model to ascertain the sharp effect. The foucs of the study was on 17 South-east and South Asian countries. Consequently, their findings confirming the "pollution haven hypothesis". A panel study of Brazil, Russia, Russia,China and India by Zakarya et al. (2015) identified a long-run relationship consistently between FDI inflows, energy consumption and carbon emissions. Also, they confirmed the "pollution haven hypothesis" by applying panel causality test and FMOLS regression. A section of scholars share contradictory view (Zhu et al., 2016; Zhang & Zhou, 2016; Yang et al., 2015); in their submissions, they opined that the relationship that exist between FDI and carbon emissions are inversely related.

2.3 Economic growth and carbon emissions

Carbon emission has become a global phenomenon which is costing the world trillions of dollars to curb this problem. Most of the carbon emissions emanate from the use of fossil fuels and other human activities. In a recent study, Liu et al. (2019) affirmed that the correlation and long run relationship between carbon emissions and economic growth emanates from two divergent views.

Firstly, enormous literatures on the subject-matter are on the consensus that the linkage between economic growth and carbon emissions is apt and significant (Liu et al., 2019; ; Salahuddin & Gow, 2014; Ang, 2007; Apergis & Payne, 2009b). Secondly, some studies have been conducted based on the hypothesis of "U-shaped Environmental Kuznet curve" (EKC) proposed by Grossman and Krueger (1995). Cheng et al., (2019) have the view that economic growth and carbon emissions do not support EKC hypothesis in the OECD countries. There have been some inconsistent studies with regards to the EKC hypothesis (Auffammer & Carson, 2008; Pao & Tsai, 2010; Iwata et al., 2010). These studies employed data analysis and econometric techniques such as GMM, VAR, panel quantile, ADRL and cointegration FMOLS, DOLS and OLS regression models. However, most adopted carbon emission (which is the largest contributor to global warming amongst all known greenhouse gases) as the environmental quality variable. We consider six variables thus CO_2 emission per capita, renewable energy consumption per capita, population, export, gross domestic product per capita and foreign direct investment inflows to examine and investigate the influence on carbon emissions.

3. Methodology and Data

3.1 Data

Our study's data consist of panel data of carbon emissions per capita, renewable energy consumption per capita, gross domestic product per capita, foreign direct investment inflows, population and export of goods and services in 33 African countries. The 33 African countries sample was drawn from the 54 African countries. The data are obtained from the World Bank Database (World Development Indicators). Our data covers the period from 2000 to 2014. Further details and definition of the variables used in our study can be found below:

- Dependent variable: CO_2 emissions (tonnes/capita) per capita (CO_2EPC): it is defined as the units of CO_2 emissions from the utilization of fossil fuels divided by population.
- Independent variable: Renewable energy consumption per capita (REPC): it is the equivalent production of renewable energy of primary energy (measured in thousand tonnes of oil equivalent), such as the hydro energy, solar energy, wind energy, geothermal energy, tide energy, biofuels energy and wave energy consumed in one year divided by the total population
- Independent variable: Foreign Direct Investment inflows (million US dollars) (FDI): it is defined as the net foreign direct investment, which is defined as the net increase and decrease in foreign direct investment inflows and outflows in a year.
- Independent variable: Gross Domestic Product per capita (million US dollars at constant 2011 PPP): It refers to the total outputs of goods and services in an economic period specifically a year divided by population of a country in real terms.
- Control variable: Population (million): it refers to the total number of persons/citizens living a particular country.
- Control variable: Export (million US dollars: it refers to the total export of goods and services from a country to the world.

3.2 Methodology

We embark on a panel study therefore we utilitised panel regression models and methodolodies such as unit root tests, correlation matrix, Pedroni and Kao cointegration tests, Arellano & Bond (1991) dynamic panel data estimations, panel vector regression impulse response function analysis and homogeneous causality test methods to study the effect of renewable energy consumption per capita, economic growth thus GDP per capita and FDI on carbon dioxide emission per capita in 33 African countries. By using these methods, we can examine the underlying factors contributing to carbon emission in African countries in the long run estimations through the independent variables chosen.

Firstly, the unit root tests are computed to find out the stationarity status of the variables. However, we adopted these methods; Levin, Lin & Chu test (LLC) by Levin et al. (2002), Maddala and Wu (1999) tests thus PP-Fisher and ADF-Fisher, and Im-Pesaran & Shim test (IPS) by Im et al. (2003). We considered these unit root tests due to their effectiveness and capability to check for the problem of homogeneity and heterogeneity in our sample data. In effect, Im et al. (2003) proposed the following model for that function;

$$y_{it} = \rho_i y_{i,t-1} + \sigma_i x_{it} + \varepsilon_{tt} \quad (1)$$

In the equation (1), x_{it} denotes the combination of all the regression variables; ρ_i stands for the elasticities of the autoregression, ε_{it} denotes the residual term whilst $_i$ and $_t$ stands for the time period of 2000 - 2014. Im-

Pesaran test (IPS) paves way for serial correlation in order of different levels (Im et al., 2003; Apergis & Payne, 2010) and subsequently uses the augmented dickey Fuller (ADF) normal averaging (Inglesi-Lotz, 2016). This model can be described by the equation below (see. Maji & Sulaiman, 2019).

$$\varepsilon_{it} = \sum_{j=1}^{n=1} \theta_{ij} \varepsilon_{i,t-1} + \varepsilon_{it} \tag{2}$$

Substituting Eq. (1) into Eq. (2) yield the following:

$$y_{it} = \rho_i y_{i,t-1} + \sigma_i x_{it} + \varepsilon_{it} + \sum_{j=1}^{n=1} \theta_{ij} \varepsilon_{i,t-1} + \varepsilon_{it} \tag{3}$$

In the resulting eqn. (3), ρi denotes the number of lags in the regression of Augumented Dickey-Fuller test. The null hypothesis of the panel unit root tests is that each variable has a unit root and the alternate hypothesis reports that at least one of the variables is stationary in series in the panel.

Secondly, after the estimation of the unit root test and all the variables prove stationary then it allows for the cointegration test. The regression of time series panel data requires either stationarity or cointegration. Cointegration tests examines the consistency in residuals of non-stationary status of the variables to confirm the Null hypothesis (H_o) of no cointegration then the residuals will be an I(1) process. To finally infer that the variables are cointegrated then the alternative hypothesis (H_1) of the residuals is an I(0) process. Pedroni (1999, 2004) and Kao (2000) tests and approaches allow more than one exogeneous variable. The dynamic panel long run estimation or model can be derived as (D.-W. Kim et al., 2018):

$$co2epc_{it} = \sum_{j=1}^{p} a_j \ln.co2epc_{i,t-j} + \beta_1 \ln repc_{it} + \beta_2 \ln gdppc_{it} + \beta_3 \ln fdi_{it} + \beta_4 \ln \exp_{it} + \beta_5 \ln pop_{it} + v_i + \varepsilon_{it} \iota = 1,\ldots,N, t = 1,\ldots,T_i \tag{4}$$

In the equation (4), $i = 1, \ldots, N$ represents the cross sectional observation, $t = 1, \ldots\ldots, T$ represents the time period. CO_2EPC refers to carbon emissions per capita, REPC represents renewable energy consumption per capita, j refers to the time lag that will be determined by "Arellano-Bond test for serial correlation", FDI refers to foreign direct investment, GDPPC stands for gross domestic product per capita represents economic growth, and EXP connotes export values. The symbol v_{it} represents the panel level effects and $\mathcal{E}_{it}$ represents the "independent and identically distributed" (i.i.d) over the whole data sample with variance σ_ε^2. The error term is expected to be identically distributed and normally with zero mean and constant variance, therefore, the symbol μ_{it} represents the error term.

An evidence that the variables are cointegrated paves way for the next step thus to run dynamic panel data estimations (GMM methodology) to ascertain the coefficients of the variables. We will emphasize on the GMM two-step method for our estimations due to the effect of less propensity of an effect by heteroskedasticity than the one-step method; even though we will use the one-step method for cross-check. Furthermore, Sargan test checks for the significant validity of instruments used in the regression process. Again, AR(1) and AR(2) test is also performed to check for autocorrelation of the residuals; the value of AR(2) depicts that the hypothesis of zero second order serial correlation existing among the variables cannot be rejected (Lingyun and Xiaolu, 2018).

Subsequently, panel vector autoregression methodology is applied to data. Even though, the dynamic panel estimation present dynamic effects of renewable energy consumption major factors on carbon emissions; the assessment of dynamic causality, direction and timing about the variables will not be enough information hence the use of panel vector autoregression. Perhaps, vector autoregression methodology is more suitable for time series data but to use for panel study is appropriate to use the panel vector autoregression methodology which is transformed version of VAR methodology. According to Kim et al.

(2018) and Love & Zicchino (2006), this methodology or approach combines the VAR method of incorporating all variables as "endogenous variables" and controls the panel for heterogeneity. The model for PVAR is as follows:

$$Y_{it} = c + \sum_{s=1}^{m} A_s Y_{i,t-s} + \eta_i + d_{c,t} + e_t \quad (5)$$

In the equation, Y_{it} consists of six vectors thus co2epc, lnrepc, lngdppc, lnfdi, lnexp and lnpop, $d_{c,t}$ are country-specific time dummies and will be determined based on serial correlation test of co2epc for all 33 countries (Arellano-Bond, 1991). The assumption is that all panel samples have the equal structure if the VAR approach using panel data is applied hence the inclusion of η_i in the equation to consider the fixed effects due to the dependent variable that is lagged. Consequently, fixed effects in consideration will correlate with the predicators or regressors and will in effect create an estimation of biased coefficients. In order to resolve this bottleneck or bias, the "forward mean-differencing" is used in that effect (Arellano and Bover, 1995; D.-W. Kim et al., 2018). This method ensures the "orthogonality" between altered variables and predictors or regressors (Love & Zicchino, 2006). Furthermore, impulse response function is estimated to ascertain the complete perspective on dynamic relationships between carbon emissions and renewable energy consumptions, economic growth (gross domestic product per capita) and foreign direct investments (FDI) in the continent of Africa for our sample of 33 countries.

3. Empirical Analysis and Key findings

Table 1 Descriptive Statistics

	CO2EPC	LNREPC	LNGDPPC	LNFDI	LNEXP	LNPOP
Mean	5.945	3.556	8.488	9.441	14.520	16.435
Median	8.653	4.338	7.852	2.489	4.130	16.472
Maximum	12.600	4.588	23.575	23.172	30.979	18.989
Minimum	0.049	-2.679	6.092	-3.823	0.000	13.328
Std. Dev.	4.892	1.384	2.805	9.458	12.264	1.186
Skewness	-0.105	-1.838	4.327	0.199	0.200	-0.331
Kurtosis	1.186	6.099	23.024	1.134	1.075	2.847
Jarque-Bera	68.748	476.980	9814.413	75.045	79.692	9.515
Probability	0.000	0.000	0.000	0.000	0.000	0.009
Observations	495	495	495	495	495	495

Table 1 exhibits the summary statistics of the variables adopted for the study. From the table, the mean and median of the variables are very close and the standard deviations are similar confirming that all the variables are homogenously related. Again, the statistical figures posit that the variables are positively skewed and leptokurtic as well as in normal distribution. Notably, the average annual growth rate of the economy of our sample for Africa stood at 8.488%, foreign direct investment grew at 9.441%, the consumption of renewable energy grew at 3.556%, export of goods and services grew at 14.520% . However, carbon emission for the sample year grew annually at an average rate of 5.945%.

3.1 Panel unit root tests

To avoid useless regression, we aimed at finding stationarity in the study's variables hence the adoption of Im-Pesaran & Shim test (2003: IPS), Fisher tests from Maddala & Wu (1999: including Fisher-ADF test and Fisher-PP test) and Levin, lin & chu test (Levin et al. 2002) and the results are shown in Table 2. From the table, lnfdi is stationary with all the tests at level form, lnexp and lnrepc are stationary with LLC test and PP-Fisher test, co2epc is stationary with Fisher PP test whiles lngdppc is stationary with LLC, ADF-Fisher and PP-Fisher tests, and lnpop is stationary at LLC and ADF-Fisher all at level form. We found no existence of unit root in our study's variables.

Table 2 Panel Unit root tests

	co2epc	lnrepc	lngdppc	lnfdi	lnexp	lnpop
Level Form						
LLC	0.133	-1.641**	-7.143***	-4.114***	-3.114***	-14.018***
IPS	1.955	1.596	1.653	-2.817**	-0.417	-0.365
ADF - Fisher	65.964	74.903	87.131**	100.859**	76.683	126.292***
PP - Fisher	93.890**	81.787*	107.164***	99.989**	105.274**	64.175
First Difference						
LLC	-14.523***	-13.381***	-11.610***	-20.731***	-16.427***	-9.070***
IPS	-12.158***	-10.331***	-9.120***	-17.676***	-12.618***	-8.051***
ADF - Fisher	265.155***	222.095***	211.957***	363.221***	265.465***	223.458***
PP - Fisher	327.792***	251.969***	242.312***	477.300***	357.283***	75.014

Note: 1. All tests are based on the model with a constant. 2. Lag lengths are chosen from 0 to 1 based on Schwarz Information Criterion. ***Denotes statistical significance at 1% level. **Denotes statistical significance at 5% level. *Denotes statistical significance at 10%. Co2epc=carbon emission, lnrepc=renewable energy consumption per capita, lngdppc=economic growth, lnfdi=foreign direct investment inflows, lnexp=export of goods and services, lnpop-population. LLC=Levin, Lin & Chu test, IPS=Im-Pesaran & Shim test, ADF-Fisher and PP-Fisher=Maddala & Wu tests.

3.2 Pedroni and Kao cointegration tests

Upon checking out for the presence of cointegration relationship in the variables we adopted; Kao and Chiang (2000) and, Pedroni (1999, 2004) conitegration tests; Table 4 shows the results. In account, the tests conducted with Pedroni tests for all the variables portrayed that four (4) out of seven (7) statistics from both "within and between-dimensions" are statistically significant hence cointegrated. Moreover, Kao tests also showed statistically significance thus cointegrated. At 5% significance level, the assumption is that the null hypothesis should not be accepted; statistically we reject the null hypothesis at 1% significance level.

Table 3 Pedroni and Kao Panel Cointegration Test

Alternative hypothesis: common AR coefs. (within-dimension)				
	Statistic	Prob.	Weighted Statistic	Prob.
Panel v-Statistic	0.066	0.474	-4.350	1.000
Panel rho-Statistic	1.601	0.945	5.167	1.000
Panel PP-Statistic	-11.25902	0.000***	-4.117	0.000***
Panel ADF-Statistic	-10.72897	0.000***	-4.504	0.000***
Alternative hypothesis: individual AR coefs. (between-dimension)				
	Statistic	Prob.		
Group rho-Statistic	6.966	1.000		
Group PP-Statistic	-6.291	0.000***		
Group ADF-Statistic	-5.966	0.000***		
Kao Cointegration test	t-statistics	Prob.		
ADF	-12.355	0.000***		

* Probabilities are computed using asymptotic Chi-square distribution
Notes: "***" indicates statistical significance at 1% level, "**"indicates 5% significance level.

3.3 Results of Long-run panel estimates (dynamic panel data estimations)

Table 4 displays the results of the analysis using dynamic panel data methodology thus Arellano-Bond (1991). We adopted generalized method of moments one and two-steps approaches or methods. Moreover, lnrepc showed negative and statistical significant impact on carbon emissions (co2epc) at coefficient of -0.88 in all the three models in table 4. At coefficient of 0.06, economic growth (lngdppc) showed positive and statistical significant impact on carbon emissions in all models. In view of this result, it can reported that economic growth significantly add up to the burgeon rise in carbon emissions in Africa at 0.06%. At constant level in one step estimation method, lnfdi showed negative and insignificant impact on carbon emission but subsequenting the elimination of constant term and also considering constant with the two step method confirmed that foreign direct investment (lnfdi) has negative and statistical significant impact on carbon emissions. In this regard, FDI seems not to contribute to the increase in carbon emissions but rather decreases carbon emissions which the study tends to support or confirm existence of the "halo effect hypothesis" and also reject the "pollution haven and factor endowment hypothesis". Relatively, population growth of African do not significantly contribute to the rise in carbon emissions, evidence from table 4 confirms that population activities decreases carbon emissions by 0.33%. As lnpop showed negative and statistical significant impact on co2epc with coefficient of -0.33. However, lnexp (export) significantly promote the increment in carbon emissions by 0.33% as lnexp showed positive and statistically significant coefficient of 0.33 with co2epc. In conclusion, the results from our regression analysis confirm that a percentage increase in renewable energy consumption, economic growth, foreign direct investment, exports and population will lead to -0.88%, 0.06%, -0.08%, 0.33% and -0.33% effect on carbon emissions.

Table 4 Results of dynamic panel data estimation using Arellano-Bond method

	One step method	Two step method	Two step method
co2epc	0.30	0.29	0.30
L1	(9.28)***	(28.32)***	(28.32)***
lnrepc	-0.89	-0.88	-0.88
	(-14.17)***	(-50.77)***	(-50.77)***
lngdppc	0.06	0.06	0.06
	(1.91)**	(36.63)***	(36.63)***
lnfdi	-0.08	-0.08	-0.08
	(-1.01)	(-3.87)***	(-3.87)***
lnexp	0.33	0.33	0.33
	(5.51)***	(21.39)***	(21.39)***
lnpop	-0.33	-0.33	-0.33
	(-4.18)***	(-59.17)***	(-59.17)***
constant	8.02	8.02	with constant
	(6.01)***	(7.03)***	system omitted
Wald chi2	2959.09***	61656.30***	
sargan test	345.96	14.929	
Prob	0.653	1.000	
AR(1)		-3.82***	Wald chi2
AR(2)		-1.65	61656.30***

Notes: "***", "**" and "*" indicate statistical significance at 1%, 5% and 10% levels. Z-statistics are in parentheses. Co2epc=carbon emission, lnrepc=renewable energy consumption per capita, lngdppc=economic growth, lnfdi=foreign direct investment inflows, lnexp=export of goods and services, lnpop-population.

3.4 Results from PVAR impulse response function analysis

We assessed the dynamic effects among the variables by utilising panel VAR impulse response function. Figure 1 exhibits the analysis report and by focusing on the relationship of lnrepc, lngdppc, lnfdi, lnexp and lnpop with co2epc; it can be established that lnrepc has a downward negative relationship with co2epc, lngdppc showed downward positive relationship in the short run and an upward positive relationship in the long run with co2epc. Lnfdi showed a downward positive relationship insignificantly in the short run but negative downward relationship laterally in the long run. However, export in the short run showed negative relationship with co2epc but has the tendency to rise to show positive relationship with co2epc. Lastly, lnpop showed negative and stabilized relationship with co2epc. From the results, we statistically reject the "Environmental Kuznets Curve" (hypothesis) in our samples.

3.5 Homogenous causality test

The study aimed at ascertaining the direction at which each variable causes the other and homogenous causality test (Dumistricu & Hurlin, 2012) causality test was used to check the causal relationship or effect of the variables. Table 5 reports the results and it is evidenced that there is bidirectional linkage or causality from lnpop↔co2epc, lnfdi↔lnrepc, lnpop↔lnrepc, lnpop↔lnfdi, lnpop↔lnexp, and lnpop↔lngdppc; this direction of causality or birectional homogeneous linkage confirm that variation or a change in one variable causes the other in the same direction. Moreover, there is an evidence of unidirectional linkage or homogeneous causality from lnrepc→co2epc, lngdppc→co2epc, lnexp→co2epc, lngdppc→lnrepc, lnexp→lnrepc, lngdppc→lnfdi, and lnexp→lnfdi. The unidirectional linkage or homogeneous causality confirm one way causality from the first variable to the latter.

Figure 1 Impulse response function analysis

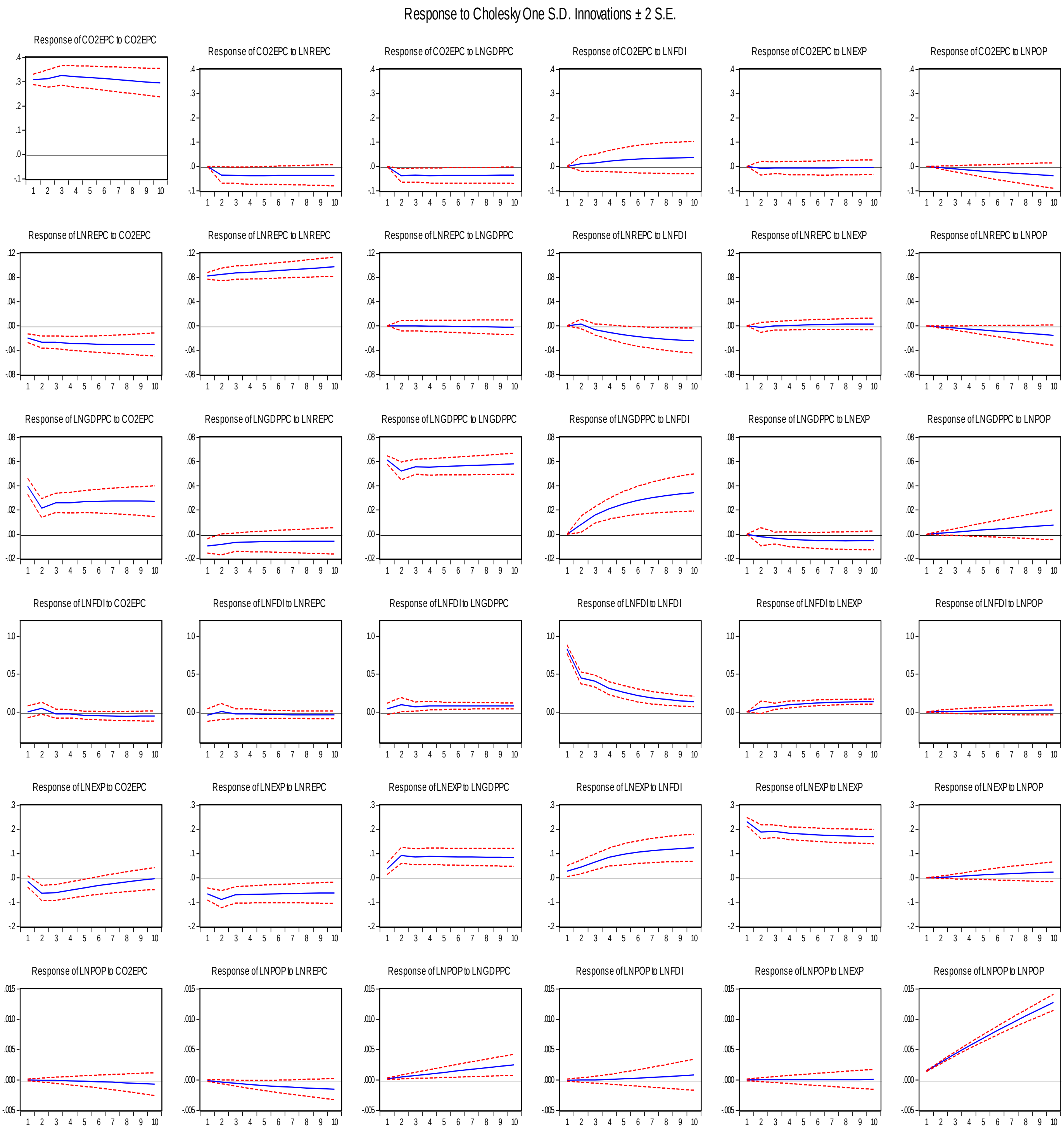

Table 5: Homogenous causality test

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.	Sig.
lnrepc does not homogeneously cause co2epc	4.866	3.351	0.001	***
co2epc does not homogeneously cause lnrepc	3.587	1.402	0.161	
lngdppc does not homogeneously cause co2epc	5.105	3.715	0.000	***
co2epc does not homogeneously cause lngdppc	2.791	0.189	0.850	
lnfdi does not homogeneously cause co2epc	2.814	0.224	0.823	
co2epc does not homogeneously cause lnfdi	3.577	1.387	0.166	
lnexp does not homogeneously cause co2epc	4.110	2.199	0.028	**
co2epc does not homogeneously cause lnexp	2.988	0.489	0.625	
lnpop does not homogeneously cause co2epc	7.334	7.109	0.000	***
co2epc does not homogeneously cause lnpop	11.085	12.824	0.000	***
lngdppc does not homogeneously cause lnrepc	4.382	2.613	0.009	**
lnrepc does not homogeneously cause lngdppc	3.313	0.984	0.325	
lnfdi does not homogeneously cause lnrepc	5.562	4.411	0.000	***
lnrepc does not homogeneously cause lnfdi	6.751	6.221	0.000	***
lnexp does not homogeneously cause lnrepc	4.063	2.128	0.033	**
lnrepc does not homogeneously cause lnexp	2.643	-0.036	0.971	
lnpop does not homogeneously cause lnrepc	6.025	5.116	0.000	***
lnrepc does not homogeneously cause lnpop	18.111	23.526	0.000	***
lnfdi does not homogeneously cause lngdppc	3.607	1.432	0.152	
lngdppc does not homogeneously cause lnfdi	3.949	1.953	0.051	**
lnexp does not homogeneously cause lngdppc	4.639	3.005	0.003	**
lngdppc does not homogeneously cause lnexp	3.994	2.022	0.043	**
lnpop does not homogeneously cause lngdppc	8.664	9.135	0.000	***
lngdppc does not homogeneously cause lnpop	31.963	44.626	0.000	***
lnexp does not homogeneously cause lnfdi	5.140	3.768	0.000	***
lnfdi does not homogeneously cause lnexp	3.565	1.368	0.171	
lnpop does not homogeneously cause lnfdi	6.344	5.601	0.000	***
lnfdi does not homogeneously cause lnpop	4.912	3.420	0.001	***
lnpop does not homogeneously cause lnexp	6.965	6.547	0.000	***
lnexp does not homogeneously cause lnpop	11.004	12.699	0.000	***

Note: *** indicates 1% significance, ** indicates 5% significance, * indicates 10% significance. Co2epc=carbon emission, lnrepc=renewable energy consumption per capita, lngdppc=economic growth, lnfdi=foreign direct investment inflows, lnexp=export of goods and services, lnpop-population.

5. Conclusion and Policy recommendation

We critically looked into the impact on carbon emissions per capita by renewable energy consumption per capita, economic growth and foreign direct investment in a panel study from 2000 to 2014 of 33 African countries. To achieve the study's objective, we employed the use of panel methodologies such as "Arellano-Bond dynamic panel data estimations and panel VAR impulse response function as well as panel homogeneous causality test".

From the results, it is established that all variables are cointegrated. The three dynamic panel estimation methodologies thus one step, two step with constant and two step without constant infer that renewable energy consumption reduces the level of carbon emissions whiles FDI have consistent negative or inverse relationship with carbon emissions in the long run, hence the rejection of the "pollution haven hypothesis" and "factor endowment hypothesis". Economic growth showed consistent relationship thus a strong and significant positive effect on carbon emissions; however, the positive relationship exists in the short run effect and long run effect but the "inverted U-shaped curve" did not prevail in our findings. In this regard, the "Environmental Kuznets Curve" (EKC) hypothesis is rejected in the study. Population showed a negative impact on carbon emissions; an increase in population showed a decrease in carbon emissions and vice versa, which can otherwise mean that the activities that cause carbon emissions mostly the population need to be considered in order to curb the menace of carbon emissions. The widely participation of the populace in an actionable plan to coil the problem is highly beneficial to the fight against carbon emissions.

Upon consideration from the econometric outcomes from the panel of countries in terms of socioeconomic development, the following policy recommendations are proposed:

1. The renewable energy utilization should be encouraged in Africa and also transform the energy system to one that is cleaner and less dependent on coal and other fossil fuels. The use of hydropower and solar which are in abundance in Africa should be encouraged and subsides for the households and firms to patronize in order not to leave no one behind in the war against carbon emissions.

2. Regulators and policy makers should increase the capacity of vehicles fuel consumption and embark on other solutions that will limit oil use. With much emphasis on foreign direct investments should be green investments with aim of safeguarding the environment or climate from pollution through carbon emissions. As Africa is on the path of economic emancipation and industrialization, adoption of clean technologies should be encouraged in order not to fall for the halo effect and factor endowment hypothesis.

The policy recommendations may not be fully implemented due to the economic constraints of African countries because the continent aims to witness an astronomical boom in its economic growth. The limitation that the study observed stems from the data analysis with Arellano-Bond dynamic GMM two-step method; we observed that in the method that constant or intercept was included the model the system omitted it but in the model that constant or intercept was not included the model was fit as the diagnostic tests performed to check for the fitness of the method showed accuracy.

References:

i. *Adewuyi, A.O., Awudomi, O.B., 2017a. Biomass energy consumption, economic growth and carbon emissions: Fresh evidence from West Africa using a simultaneous equation model. Energy 119, 453 – 471.*

ii. *Adewuyi, A.O., Awudomi, O.B., 2017b. Renewable and non-renewable energy-growth-emissions linkages: Review of emerging trends with policy implications. Renewable and Sustainaibility Energy Review. 69, 275 – 291.*

iii. *Ahmed, S., 2015. Variance Decomposition of Emissions, FDI, Growth and Imports in GCC countries: A Macroeconomic Analysis. International Journal of Management Science and Business Administration 1 (6), 118-126.*

iv. *Amponsah, N.Y., Troldborg M., Kington, B., Aalders, I., Hough, R.L., 2014. Greenhouse gas emissions from renewable energy sources: a review of lifecycle considerations. Renewable and Sustainable Energy Review 39, 461–475.*

v. *Ang, J.B., 2007. CO_2 emissions, energy consumption, and output in France. Energy Policy 35 (10), 4772 – 4778.*

vi. *Apergis, N., Payne, J.E., 2009b. Energy consumption and economic growth: evidence from the common wealth of independent states. Energy Economics 31 (5), 641 – 647.*

vii. *Arvesen, A., Hertwich, E.G., 2012. Assessing the life cycle environmental impacts of wind power: a review of present knowledge and research needs. Renewable and Sustainable Energy Review 16, 5994 – 6006.*

viii. Auffhammer, M., Carson, R.T., 2008. Forecasting the path of China's CO2 emissions using province−level information. Journal of Environmental Economics Management 55 (3), 229–247.

ix. Behera, S.R., Dash, D.P., 2017. The effect of urbanization, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (south and south East Asian) region. Renewable and Sustainable Energy Review 70, 96–106. https://doi.org/10.1016/j.rser.2016.11.201.

x. Ben Jebli, S. M., Ben Youssef, I. Ozturk., 2015b. The Role Of Renewable Energy Consumption And Trade: Environmental Kuznets Curve Analysis For Sub-Saharan Africa Countries. African Development Review 27, 288 - 300.

xi. Cheng C., Xiaohang R., Zhen W., 2019. The impact of renewable energy and innovation on carbon emission: An empirical analysis for OECD countries. Energy Procedia 158, 3506 - 3512.

xii. Chung-Ping C., Minyi D., Bo S., Yin C., 2019. Driving forces of global carbon emissions: From time- and spatial-dynamic perspectives. Economic Modelling 77, 70 - 80

xiii. Dai-Won, K., Jung-Suk, Yu, Hassan, M. K., 2018. Financial inclusion and economic growth in OIC countries. Research in International Business and Finance 43, 1 – 14.

xiv. Dong K., Sun R., Hochman G., 2017. Do natural gas and renewable energy consumption lead to less CO2 emissions? Empirical evidence from a panel of BRICS countries. Energy 141, 1466–1478.

xv. Dumitriscu, E.I., Hurlin, C., 2012. "Testing for Granger non-causality in heterogeneous panels". Econometric modelling 2, 1450 -1460.

xvi. Grossman, G.M., Krueger, A.B., 1995. Economic growth and the environment. Quarterly Journal of Economics 110 (2), 353–377.

xvii. Furlan C., Mortarino C., 2018. Forecasting the impact of renewable energies in competition with non-renewable sources. Renewable and Sustainable Energy Review 81, 1879–1886.

xviii. Hertwich E., Gibon T., Bouman E.A., Arvesen A., Suh S., Heath G.A., Bergesen J.D., Ramirez A., Vega M.I., Shi, L., 2015. Integrated life-cycle assessment of electricity supply scenarios confirms global environmental benefit of low-carbon technologies. PNAS 112, 6277 – 6282.

xix. Hong L., Zhou N., Fridley D., Raczkowski C., 2013. Assessment of China's renewable energy contribution during the 12th Five Year Plan. Energy Policy 62, 1533–1534.

xx. Ito, K., 2017. CO2 emissions, renewable and non-renewable energy consumption, and economic growth: evidence from panel data for developing countries. Journal of International Economics151, 1 – 6.

xxi. Im, K.S., Pesaran, M.H., Shin, Y., 2003. Testing for unit roots in heterogeneous panels. Journal of Econometrics 115, 53 – 57.

xxii. Inglesi-Lotz, R., 2016. The impact of renewable energy consumption to economic growth: A panel application. Energy Economics 53, 58 – 63.

xxiii. Iwata, H., Okada, K., Samreth, S., 2010. Empirical studyon the environmental kuznet curve for CO_2 in France: the role of nuclear energy. Energy Policy 38, 4057 – 4063.

xxiv. Julian K., Frauke U., 2018. Technology Transfer and Cooperation For Low Carbon Energy Technology: Analysing 30 Years of Scholarship and Proposing A Research Agenda. Energy Policy 119, 600 – 609.

xxv. Kao, C., 1999. Spurious regression and residual-based tests for cointegration panel data. Journal of Econometrics 90 (1), 1 – 44.

xxvi. Kao, C., Chiang, M.H., 2000. On the estimation and inference of a cointegrated regression in panel data. Advanced Econometrics 15, 179 – 222.

xxvii. Levin, A., Lin, C.F., Chu, C., 2002. Unit root tests in panel data: asymptotic and finite sample properties. Journal of Econometrics 108, 1 – 24.

xxviii. Lingyun H., Lihong Z., Zhangqi Z., Deqing W., Feng W., 2019. Green credit, renewable energy investment and green economy development: Empirical analysis based on 150 listed companies of China. Journal of Cleaner Production 208(20), 36 3- 372

xxix. Lingyun H., Xiaolu Z., 2018. Impact of financial development on trade-embodied carbon dioxide emissions: Evidence from 30 provinces in China. Journal of Cleaner Production 198, 721 – 736

xxx. Liu, Q., Lei, Q., Xu, H., Yuan, J., 2018. China's energy revolution strategy into 2030. Resource Conservation and Recycling 128, 78–89.

xxxi. Liu, Z., 2015.Steps to China's carbon peak. Nature 522, 279.

xxxii. Maddala, G.S., Wu, S., 1999. A comparative study of unit root tests with panel data and a new simple test. Oxford Bulletin of Economics and Statistics 61, 631 – 652.

xxxiii. Maji, I. K., 2015. Does clean energy contributes to economic growth? Evidence from Nigeria. Energy Report 1, 145 – 150.

xxxiv. Maji, I. K., Sulaiman, C., 2019. Renewable energy consumption and economic growth nexus: A fresh evidence from West Africa. Energy Report 5, 384 – 392.

xxxv. Moore J.C., Chen Y., Cui X., Yuan W., Dong W., Gao Y., Shi, P., 2016.Will China be the first to initiate climate engineering? Earth's Future 4, 588–595.

xxxvi. Mu Y., Wang C., Cai W., 2018. The economic impact of China's INDC: distinguishing the roles of the renewable energy quota and the carbon market. Renewable and Sustainable Energy Review 87, 2055 –2966.

xxxvii. Nicholas A., Mehdi J., Slim Y., 2018. Does Renewable Energy Consumption And Health Expenditures Decrease Carbon Dioxide Emissions? Evidence for Sub-Saharan Africa Countries. Renewable Energy 127, 1011 – 1016.

xxxviii. Ozturk F. B., 2015. Biomass Energy and Economic Growth Nexus In G7 Countries: Evidence From Dynamic Panel Data. Renewable and Sustainability Energy Review 49, 132 - 138.

xxxix. Ozturk, I., Bilgili, F., 2015. Economic growth and biomass consumption nexus: Dynamic panel analysis for Sub-Sahara African countries. Applied Energy 137, 110 – 116.

xl. Pan, X.Z., Chen, W.Y., Clarke, L.E., Wang, L., Liu, G., 2017. China's energy system transformation towards the 2 °C goal: implications of different effort-sharing principles. Energy Policy 103, 116–126.

xli. Pao, H.T., Tsai, C.M., 2010. CO_2 emissions, energy consumption and economic growth in BRIC countries. Energy Policy 38 (12), 7850 – 7860.

xlii. Pedroni, P., 1999. Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxford Bulletin of Economics and Statistics 61, 53 -70.

xliii. Pedroni, P., 2004. Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis: New results. Economic Theory 20, 597 – 627.

xliv. Qi, T., Zhang, X., Karplus ,V.J., 2014. The energy and CO2 emissions impact of renewable energy development in China. Energy Policy 68, 60–69.

xlv. Rafindadi, A.A., Ozturk, L., 2016. Impact of renewable energy consumption on the german economic growth: Evidence from combined conitegration tests. Renewable and Sustainable Energy Review (2016), in the press.

xlvi. Saddam, A., 2014. Trade and Foreign Direct Investment: Impact on Economic Growth and Emissions in Gulf Cooperation Council Countries. Economics University of Malaya Ph.D: 374.

xlvii. Salahuddin, M., Gow, J., 2014. Economic growth, energy consumption and CO_2 emissions in gulf cooperation council countries. Energy 73, 44 – 58.

xlviii. Samuel, A. S., Vladimir, S., 2019. Effects of foreign direct investments, economic development and energy consumption on greenhouse gas emissions in developing countries. Science of the Total Environment 646, 862-871.

xlix. Solarin, S.A., Al-Mulali, U., Musah, I., Ozturk, I., 2017. Investigating the pollution haven hypothesis in Ghana: an empirical investigation. Energy 124, 706–719. https://doi.org/ 10.1016/j.energy.2017.02.089.

l. Sun, C., Zhang, F., Xu, M., 2017. Investigation of pollution haven hypothesis for China: an ARDL approach with breakpoint unit root

li. Song J., Yang W., Higano Y., Wang X., 2015. Introducing renewable energy and industrial restructuring to reduce GHG emission: application of a dynamic simulation model. Energy Conversation Management 96, 625–636.

lii. Sun, X., Zhang B., Tang, X., McLellan, B.C., Höök, M. 2016. Sustainable Energy Transitions in China: renewable Options and Impacts on the Electricity System. Energies 9, 980. http://dx.doi.org/10.3390/en9120980.

liii. Toda, Y.H., Yamamoto, T. 1995. Statistical inference in vector autoregressions with possibly integrated processes. Journal of Econometric 66, 225–250.

liv. *World Bank report, 2015. World bank's world development indicators. Available at http://www.worldbank.org/. dataset.*

lv. *Xie H., Yu Y., Wang W., Liu Y., 2017. The substitutability of non-fossil energy, potential carbon emission reduction and energy shadow prices in China. Energy Policy 107, 63–71.*

lvi. *Xie, Y., Dai, H., Dong, H., 2018. Impacts of SO2 taxations and renewable energy development on CO2, NOx and SO2 emissions in Jing-Jin-Ji region. Journal of Cleaner Production 171, 1386 –1395.*

lvii. *Yamada, H., Toda, Y.H., 1998. Inference in possibly integrated vector autoregressive models: some finite evidence. Journal of Econometrics 86, 55–95.*

lviii. *Yang Z., Jintao F., Ying K., Rui W., 2018. How Foreign Direct Investment Influences Carbon Emissions, Based on the Empirical Analysis of Chinese Urban Data. Sustainability MPDI.*

lix. *Zapata, H.O., Rambaldi, A.N., 1997. Monte Carlo evidence on cointegration and cau-sation. Oxford Bullutin of Economics and Statistics 59 (2), 285–298.*

lx. *Zarsky, L., 1999. Havens, halos and spaghetti: untangling the evidence about foreign direct investment and the environment. Foreign Direct Investment and the Environment, 47-74.*

lxi. *Zhao X., Cai Q., Zhang S., Luo K., 2017. The substitution of wind power for coal-fired power to realize China's CO2 emissions reduction targets in 2020 and 2030. Energy 120, 164–178.*

lxii. *Zakarya, G.Y., Mostefa, B., Abbes, S.M., Seghir, G.M., 2015. Factors affecting CO2 emissions in the BRICS countries: a panel data analysis. Procedia Economics and Finance 26, 114–125.*

lxiii. *Zhang, C., Zhou, X., 2016. Does foreign direct investment lead to lower CO2 emissions? Evidence from a regional analysis in China. Renewable and Sustainable Energy Review 58, 943–951.*

lxiv. *Zhu, H., Duan, L., Guo, Y., Yu, K., 2016. The effects of FDI, economic growth and energy consumption on carbon emissions in ASEAN-5: evidence from panel quantile regression. Econometric Modelling 58, 237–248. https://doi.org/10.1016/j.econmod.2016.05.003.*