Review Paper

Economic Growth and Environmental Pollution in Brunei: ARDL Bounds Testing Approach to Cointegration

ABSTRACT

Aims: This study examine the short run and long run dynamic relationship between economic growth and environmental pollution in Brunei. The study adopts the framework of Autoregressive Distributed Lag (ARDL) model to scrutinize the existence of the Environmental Kuznets Curve (EKC) among the studying variables, using time series data cover the period of 1974 to 2014.

Methodology: The ARDL bound test reveals the existence of long-run relationship among the integrated variables when CO_2 chosen as a dependent variable**.**

Results: The results support the existences of EKC hypotheses in the long-run whereas in the short-run an invested U-shaped curve was not confirmed between GDP and CO2 in Brunei. The results of granger causality based on VECM analysis have shown unidirectional causality runs from economic growth to CO2 in the short run. Further analysis through stability test indicates the coefficients in the model are stable and do not suffers with structural break within the time taken in the study.

Conclusion: The government of Brunei should proceeds to target the sustainable means of production which has environmental friendly and consumes less energy to enhance economic growth and maintain environmental quality in the long run.

Keywords: Carbon dioxide, Economic growth, ARDL, Granger causality, EKC, VECM, Brunei

1. INTRODUCTION

In recent years, many countries around the world have started to focus on an alternative means of production as the drastic actions to reduce alarming rate of environmental degradation. Similarly, it is well known that the poor productive capacities of a nation and severe climatic change have been the results of higher level of CO_2 emission (Abdoul & Hammami, 2017). The emission of carbon dioxide gas has grown severely due to various human activities, related to the expansion of land utilization as well as the rapid use of fossil fuels as a source of energy. Since the constant supply of energy is needed among the heavier industries in order to maintain the maximum production level, improving the human life and guarantee the strong economic growth among the nations (Salahuddin et al. 2015). Indeed, the rapid use of fossil fuel for production process has led the magnificent increases of CO_2 and other greenhouse gases in the atmosphere. These emitted substances not only destroy the natural environment but also bring the negative impacts to human life that are considered to be among the world's greatest environmental threats (Zahidul Islamet al.2013).

The economy of Brunei Darussalam mostly supported by the oil and gas industry which an account for 60 percent of Gross Domestic Product (GDP) and 90 per cent of the total exports in 2017 (OECD, ERIA, 2018, p. 206). "Brunei Darussalam is the fourth-largest oil producer in South-East Asia and the ninth-largest exporter of liquefied natural gas (LNG) in the world" (APEC, 2017). Although the Brunei Darussalam implemented some key actions directed to reduce CO2 emissions from fuel combustion that effectively begun in 2010. The overall amount of carbon dioxide emissions had increased from 63.2 percent in 2010 to 67.5 percent in 2014, while the Methane gas (CH4) had declined from 36.4 per cent in 2010 to 32.1percent in 2014 (UNFCCC, 2017). The CO_2 is the biggest contributor of Green House Gases in the country which comes from the burning of fossil fuels that is widely used in the electricity generation (48.7 per cent) and end-use sectors. Methane gas also has been recorded to contribute significantly share to the total emission of GHGs, which generated from the irregular releases of gas from industrial activities and land transportation accounts for 12.6 percent and 34.5 percent respectively (UNFCCC, 2017). The strategies to reduce the excessive uses of energy consumption in Brunei were due to the problem of increasing energy efficiency. This might reduce the economic growth associated with collapse of primary industries that depend mostly on combustion of fossil fuels like oil. Therefore, the investigation of the relationship between energy consumption, urban population, economic growth and CO2 emissions is significant towards the implication of energy policies in Brunei.

2. LITERATURE REVIEW

This study tends to adopt the fundamental work of Simon Kuznets in 1955, whose study is undertaken to investigate the inverse relationship between environmental quality and economic growth (Kuznets, 1955). Environmental Kuznets Curve (EKC) hypothesizes that there is a positive relationship between per capital income and environmental degradation which is consistent up to the turning point, where the relationship overturned, that is to say, at the initially stage, the environmental quality tends to decline as the economic growth rises and eventually at the turning point it starts to improve with per capital [Saboori et al., 2012]. The environmental Kuznets curve draw the conclusion to either support the existence of EKC hypotheses based on an inverted U-shaped or reject the hypotheses when results portrays N-shaped EKC curve. The first empirical study on EKC hypotheses was conducted by Grossman and Krueger in 1995 and 1993. In there an investigation employed specific random city model and observed an Inverted U-shaped curve between various indicators of environmental degradation (such as carbon dioxide emission) and GDP per capital [Palamalai S. et al, 2015].

Moreover, there are numerous studies have been conducted to examine the linkages between carbon dioxide emissions, economic growth and other controlled variables using different econometric techniques to test the validity of EKC hypothesis and ended up with strong evidences to either support or not the existence of EKC hypothesis. Balibey (2015) examined the relationships between CO_2, economic growth and Foreign Direction Investment (FDI) between 1974 and 2011, using 'VECM estimation' model. His results verified the existence of EKC in Turkey. Furthermore, results of this study also demonstrated the unidirectional granger causality runs from economic growth to environmental degradation. Sambrano et al (2018) examine the existence of an inverted U-shaped of EKC curve in Singapore using ARDL based on time series data over the period of 1971-2011. The empirical results support the EKC hypothesis both in long run and short run phenomenon. Alabdulrazag and Alrajhi (2016) examine the relationship between economic growth, CO_2, energy consumption and population density using ARDL bounds test to cointegration and verify the validity of EKC hypothesis in KSA. Their results also support the existence of inverted u-shaped in both short and long run.

In addition, Javaid and Zulfiqar (2017) investigate the links between CO_2, economic growth, energy consumption, urban population and trade openness in Pakistan, based on time series data between 1971 and 2010. Applying ARDL bound test to cointegration approach and VECM to verify the existence of EKC curve in long run and short run phenomena respectively. Their results support the Environmental Kuznets curve (EKC) between CO_2 and economic growth in long run as well as short run. In addition to that, other studies revealed the similar results of supporting EKC hypotheses. [Osabuohien et al. 2014; Muftau O et al. 2014; Xiongling T (2016); Zahidul Islam et al. 2017; Kebede, S 2017; Aye and Edoja, 2017; Bildiric M (2017); Naminse and Zhuang, 2017]

However, some other studies failed to admit the inverted U-shaped relationship with real-life data in fact their results do not support EKC. Pandey and Mishra (2015) employ both dynamic and static framework to examine the causality between CO_2 emissions and economic growth using panel data cover the period between 1972 and 2010. The results of this study failed to support the EKC hypothesis in SAARC countries. However the results from VECM indicated the unidirectional granger causes from economic growth to carbon dioxide. Linh and Lin (2014) examine the dynamic relationship between carbon dioxide emission, economic growth, FDI and energy consumption between 1980 and 2010 using granger causality and cointegration approach to verify the existence of EKC in Vietnam. However their empirical results do not support EKC theory.

Furthermore, Muftau et al (2014) investigate the link between CO2 and economic growth in West Africa. Using fixed effect model to time series data cover the period between 1970 and 2011. The results indicate the N-shaped relationship between CO_2 and economic growth which do not support the EKC theory in West Africa. Other previous studies failed to admit EKC hypothesis Alam and Janifar, 2014; Ali A et al., 2015; Lacheheb et al (2015); Marsiglio et al. 2016; and Jardón et al., 2017]. With respect to related reviews, it have been clearly shown the contradiction in an existence of EKC hypotheses based on different techniques run from individual to multilateral countries (cross sectional countries). To the best of our knowledge, no study has conducted directly to examine the environment-growth nexus in the context of Brunei using ARDL framework, Bound cointegration, Granger Causality test and Sensitivity Analysis.

3. METHODOLOGY

3.1 Theoretical Methodology

Referring to the pioneering work of Grossman and Krueger in 1995, which is translated the idea of EKC theory that explore the relationship between environmental degradation by means of polynomial equation of per capita income. The standard estimation model can be expressed as follows and it has been recently used by very other scholars include Saboori et al (2012) and Lacheheb et al (2015).

$$\boldsymbol{E = f(Y, Y^2, Y^3, Z)} \qquad \textbf{(1)}$$

Where E represents as environmental degradation as a function of Income (***Y***), Income squared (**Y^2**), cubic square (**Y^3**) and a set of control variables (Z). In order to provide clear interpretation of the coefficients, all variables converted into logarithm forms and plug into an econometric model and therefore, the estimation model (1) will be:-

$$\boldsymbol{In(CO2) = \alpha_0 + \alpha_1 InY_t + \alpha_2 (InY_t)^2 + \alpha_3 (InY_t)^3 + \alpha_4 (InZ_t) + \varepsilon_t} \qquad \textbf{(2)}$$

Where In (CO2) represents as environmental degradation as a proxy of carbon dioxide emission metrics tones per capital, Carbon dioxide has been used widely as explanatory variables (such as the study of Pandey and Mishar, 2015; Chen Lu, 2017; Ali et al, 2015; Jordan et al (2017); and Shaari et al (2017). Y as a GDP per capital, income squared (Y^2), income cubic (Y^3) are indicators of economic growth; and Z refers to others independent variables that may influence environmental pollution, ε stands as disturbance term, and *t* is a time series, α_s represent the elasticity of Y, Y^2, $Y^3$and Z respectively. This study included urban population and energy consumption as control variables. The inclusion of income (Y) and its exponential values as the determinants of environmental degradation into estimation model, may lead the model to suffer with perfect Multicollinearity (Usama *et al*., 2016). In econometric theories, the presence of multicollinearity in the model leads to increases standard errors and further affects the hypothetical decision rules criterion. This circumstance has prompt researchers to test the possibility of presence of multicollinearity problem between income, income squares, income cubic and other control variables.

Table (01) indicates the results of correlation matrix among the proposed variables which intend to be included in the estimation model. The results in the table below depict the perfect correlation (strong correlation) between income (InY), squared income (InY^2) and cubic Income (InY^3), and hence the decision to include them as key variables in the estimation model can creates the multicollinearity problem.

Table 01: Correlation matrix

	INCO2	INEC	INPOP	INY	INY2	INY3
INCO2	1.000000	.430549	.232410	-.364343	-.364641	-.364935
INEC	.430549	1.000000	.628180	-.472051	-.472591	-.473123
INPOP	.232410	.628180	1.000000	-.801483	-.802541	-.803587
INY	-.364343	-.472051	-.801483	1.000000	.999992	.999968
INY2	-0.364641	-0.472591	-0.802541	0.999992	1.000000	0.999992
INY3	-0.364935	-0.473123	-0.803587	0.999968	0.999992	1.000000

Therefore our estimated model will drop all highly correlated variables and remained the rest of other explanatory variables. Therefore the model (2) will include InCO2, InENC, InPOP and InY and expressed as follow:-

$$\boldsymbol{In(CO2) = \alpha_0 + \alpha_1 InY_t + \alpha_2(InENC_t) + \alpha_3(InPOP_t) + \varepsilon_t} \quad \textbf{(3)}$$

Therefore, in order to avoid the inclusion of multicollinearity problem in the estimation model between income and its polynomial terms, Narayan and Narayan (2010) as cited in Alabdulrazag and Alrajhi (2016) suggest an alternative technique used to support or not the existence of EKC curve in developing economies. The decision compares the magnitude of elasticity of income with respect to CO2 between long run and short run. If the results indicate that the long run effects on income elasticity is lower than the short run effects, this depicts that over a given period of time CO_2 falls as the income rises after turning point which will support the existence of EKC Hypotheses.

3.2 Data Sources

This study employs the set of time series data collected from the World Bank Database (WDI) in 2018. The series of data collection that cover 1974-2014 include; carbon dioxide emission measured in metric tons per capita, Gross Domestic Product per capita as a constant $ in 2010, energy consumption as kg of oil equivalent per capital and population as a percentage of urban population. All variables in this study are transformed into logarithms form namely as $\text{In}CO_2$, InPOP, InY and InENC.

Abbreviation	Variable	Measure	Previous Author on the same variable	Sources	Expected Sign
CO_2	Carbon dioxide	Environmental pollution	J Alam, 2014	WDI	
Y	GDP	Economic growth	Omari, 2013	WDI	(+) short run
Y	GDP	Economic growth	Omari, 2013	WDI	(-)long run
ENC	Per capital energy use	Energy Consumption	Ghos et al, 2014	WDI	(+)
POP	Urban Population	Population	Javid and Zulfiqar, 2017	WDI	(+)

Author Compilation

3.3 Estimation Methodology:

3.3.1 Unit Root Test

Generally, the data collected from the large span of time period, the unit root problem would be possible to exist and without strictly careful, the results will be nonsense. In order to check the unit root problem in the data, the stationarity technique of time series should be applied such as “augmented dickey fuller” (ADF) (1979) and Phillips- Perron (PP) (1989) based on the following regression equation.

$$\Delta y_t = \alpha + \delta_1 + \beta y_{t-1} + \sum_{i=1}^{k} \gamma \Delta y_{t-1} + \mu_t \qquad \textbf{(4)}$$

Where Δ*yt* indicates the first difference of y, ut represents the serial correlation errors and α, δ, β and γ are parameters of the estimated model. If this test shows significant value, “it means that the variable series is stationary and does not has a unit root test, so the null hypothesis will be rejected but alternative hypothesis will be accepted, But if the stationary test is not significant, it means that the variable series is non-stationary and has a unit root test” (Shaari et al, 2012, p.102).

3.3.2 Bound Testing Approach for Co-integration

Bound testing approach for cointegration will be performed once after checking and confirming the stationarity of all variables that are integrated either in I(0) or I(1). This study employed ‘Autoregressive distributed lag model (ARDL) technique’ to check the stability of a long run and equilibrium relationship between CO_2 emission, economic growth, energy consumption and urban population. This technique is most powerful to cointegration since it generates more accurate results particularly for the case of small sample size (Javaid and Zulfiqar, 2017).The Autoregressive Distribute Lag model can be estimated by using a simple linear transformation technique to generate dynamic 'unrestricted error-correction model (UECM)'. This model tends to present the short run dynamism and an equilibrium position in the long run phenomenon. The following UECM is employed for equation 3 and expressed as follow

$$\Delta InCO2_t = \alpha_0 + \alpha_{T^T} + \sum_{i=1}^{p} \varphi_i \Delta InCO2_{t-1} + \sum_{i=0}^{q} \Omega_i lnY_t + \sum_{i=0}^{r} \vartheta_i \Delta InENC_t + \sum_{i=0}^{y} \omega_i \Delta InFDI_t + \lambda_c InCo2_t + \lambda_y LYt_1 + \lambda_E InENC_t + + \lambda_p InPOP_t + \mu_t \quad (5)$$

Where $\varphi, \Omega, \vartheta$ *and* ω show the short run relationship in the given equation respectively and and the long run relationship among the coefficients variable is presenting by λ_C, λ_y, λ_E, λ_F and λ_P. The null hypothesis of no co-integrated among the given variables is stated as $H_0: \lambda_C = \lambda_Y = \lambda_E = \lambda_F = 0$, while alternative hypothesis of co-integrated is given as $H_1: \lambda_C = \lambda_Y = \lambda_E = \lambda_P \neq 0$.

3.3.3 Error Correction Model Specification (ECM)

Once after confirming the existence of co-integration among the variables via bound test, the short and long run relation will be established by using VECM. It is possible to calculate the error correction term (ECT) from the long-run equation (Pesaran *et al*, 2001) by replacing the lagged level variables in the ARDL equation with ECT_{t-1} and estimate the model after impose the same optimal lags. The VECM model can be written as follows;

$$\Delta lCO2_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta InCO2_{t-1} + \sum_{i=1}^{q} \alpha_{2i} \Delta InY_{t-1} + \sum_{i=1}^{q} \alpha_{3i} \Delta InENC_{t-1} + \sum_{i=1}^{q} \alpha_{4i} \Delta InPOP_{t-1} + \lambda_1 ECT_{t-1} + \mu_t \ (6)$$

The $InCO_2$ is a function of its lagged values, lagged values of other exogenous variable in the model and the lagged value of ECT. The ECT_{t-1} is the one lagged error correction term indicates the co-integrating vectors and the speed of adjustments to equilibrium points presented by the coefficients of α_s. The presence of ECTs term in the model reveals that any change in the dependent variable as a result of the disequilibrium in the long run relationship and the changes in the independent variables. A negative and significant value of ECTs measures how much the error term is corrected itself each time towards the point of equilibrium in the long run

4.3.4 Granger Causality,

When the results of bound test supports the existence of long run relationship, there is an enough evidence to indicate that the underlying variables in Eq (3) are granger causes at least in one direction. Engle and Granger (1987) proposed that conducting the Granger causality test through Vector Auto Regressive (VAR) approach when long run relationship confirmed may provide inconsistent results in the presence of cointegration, therefore, adding of a new variable such as the Error Correction Term (ECT) to the VAR model would be helpful to explore the long run relationship (Alabdulrazag and Alrajhi, 2016, Shahbaz *et al*., 2012).The direction of causality among the studying variable can be identify by the negative sign of the one lagged coefficient through ECT of the long run relations. The granger causality test through the framework of VECM techniques is expressed in the following equation:

$$(1-L)\begin{bmatrix}\Delta lco_t\\ \Delta ly_t\\ \Delta lENC_t\\ \Delta lPOP_t\end{bmatrix}=\begin{bmatrix}\mu_1\\ \mu_2\\ \mu_3\\ \mu_4\end{bmatrix}+\sum_{t=1}^{P}(1_L)\begin{bmatrix}\pi_{11}&\pi_{12}&\pi_{13}&\pi_{14}\\ \pi_{21}&\pi_{22}&\pi_{23}&\pi_{24}\\ \pi_{31}&\pi_{32}&\pi_{33}&\pi_{34}\\ \pi_{41}&\pi_{42}&\pi_{43}&\pi_{44}\end{bmatrix}+\begin{bmatrix}\varphi\\ \Omega\\ \Phi\\ \omega\end{bmatrix}ECM_{t-1}+\begin{bmatrix}\eta_{1t}\\ \eta_{2t}\\ \eta_{3t}\\ \eta_{4t}\end{bmatrix} \quad (7)$$

Where the (1-L) indicates lag operator, 'ECM_{t-1} is lagged error-correction term'; Therefore, the main benefit of this model is to capture the causal relationship among the co-integrated parameters and to enables us to distinguish between short-run and long-run relations. The significance of the lagged error-correction term based on t-test(s) in the VECM, indicates the "long run" causal relationship, whereas the short run causal relationship is depicted through the significance of F-test of the lagged explanatory variables. After estimation of all equations, the next step is to perform diagnostic tests to validate the adequacy of the model. These diagnostic tests include serial correlation, normality distribution tests and Heteroscedasticity. The stability of the ECM performed using the cumulative sum (SUMUS) and cumulative sum squared (CUMUSQ) techniques to graphically confirm the stability of the variables estimated in the model (Pesaran et al., 2001cited in Alabdulrazag and Alrajhi, 2016).

4. Result Analysis and Discussion

4.1 Results of Unit Root Test

The bounds test framework is applicable for the variables that are either integrated in I (0) or I (1) (Pesaran et al, 2001). Therefore, the unit root tests are performed to determine the order of integration among the variables and to avoid any spurious results. The "Augmented Dickey-Fuller (1979) (ADF)" and "Phillips-Peron (1988) (PP)" unit root tests were performed to test the null hypotheses of unit root against the alternative hypotheses of stationarity. The results show all variables become stationary at I(0) or I(1) and not I(2). These results verify the adoption of ARDL model. The results of these tests are consistent with Ali et al (2015), Malibey M (2015) and Shaari (2017).

Table 02 below presents the results of Unit Root Tests:

	Augmented Dickey-Fuller (ADF)		**Phillips Perron (PP)**	
	Level			
Variable	**Constant Without Trend**	**Constant With Trend**	**Constant Without Trend**	**Constant With Trend**
InCO2	-2.8173	-1.3443	-2.7931	-2.6275
InY	-.6251	-1.4312	-.3241	-1.6125
InENC	-2.4900	-3.5476*	-3.5475	-3.3981
InPOP	-2.1149	-1.1755	-9.2480**	-2.6797
	First Difference I(1)			
∆InCO2	-4.9363**	-5.3291**	-7.3386**	-6.6963**
∆InY	-4.7898**	-4.7709**	-4.0141**	-4.1245**
∆InENC	-5.8319**	*******	-12.5931**	-8.1187**
∆InPOP	-3.1090*	-3.7755*	******	-3.7755*
Note: ** and * denotes significant at 1%, and 5% significance level, respectively.				

4.2 Bounds test approach to Co-integration

The results of unit root test among the underlying variables indicate the application of the ARDL model to cointegration will give efficient and realistic estimates. The ARDL bounds test to cointegration investigate the possible existent of long run and short-run relationships among the underlying variables using the bound F-statistics in equation (5). Table (3) demonstrates the outcomes of 'ARDL bounds test to cointegration'. The results of this test confirm the existence of co integrated equation among the underlying variables, where the value of F-test is greater than the upper boundary of critical value at 5 percent. Therefore, we reject the null hypothesis of no co-integrated among the studying variables when InCO$_2$ is dependent variables. Based on the results of cointegration using bound test, supports the estimation of VECM model of InCO2 equation to determine the long and short run relation.

Table 03 Results of bounds testing to cointegration

Dep. Var.	Function	F-Statistics	C.V	Coint.	
InCO$_2$	F_{InCO2}(InCO$_2$/ InY, InENC, InPOP)	5.0914	5%	Yes	ECM
InY	F_{InY}(InY/ InCO$_2$, InENC, InPOP)	1.7912	5%	No	ARDL
InENC	F_{InENC}(InENC/InCO$_2$, InY, InPOP)	3.1687	5%	No	ARDL
InPOP	F_{InPOP}(InPOP/InCO$_2$/ InY, InENC,)	2.4405	5%	No	ARDL
	Significant Value	**Critical Values**			
		Lower Bound I(0)		Upper Bound I(1)	
	1%	2.72		3.77	
	5%	3.23		4.35	
	10%	4.29		5.61	

4.3 Long-run estimation results

The coefficient of economic growth is negative and statistical significant at 5 percent level as shown in table 04 below. The 1 percent increases in the economic growth in the long run is predicted the CO$_2$ emission to decreases by 5.33 percent. . This result is consistent with the findings of (Ahmed and Long, 2013) for Pakistan. The results also indicate one percent increases in the energy consumption holding other variables fixed the pollutants of CO$_2$ emission will increases by 1.531 per cent in the long run. The coefficient of population growth also has significant impact to reduce CO2 emission to more than 6 percent in the long run.

Table 04: Long-run estimation results

Long Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
INEC	1.531756	.602970	2.540350*	.02
INPOP	-6.416853	2.321043	-2.764643**	.01
INY	-5.337163	2.063439	-2.586537*	.02
C	74.570173	27.958662	2.667158*	.02
Diagnostic test			Test-stats	*p*-value
Serial correlation			1.686965	.23

Normality			1.305386	.52
Heteroscedasticity			1.141277	.40

Note: ** and * denotes significant at 1%, and 5% significance level, respectively.

4.4 Short-run estimation

The results of the short-run relationship between carbon dioxide (CO_2), economic growth (GDP), energy consumption (ENC) and population (POP) in Brunei are depicted in table (5). The lagged value of the Error Correction model has a negative and statistical significant at 5 percent level. The coefficient of economic growth is negative and statistical significant. This indicates that, economic growth in Brunei tends to improve the environmental quality in the short run. This implies that a 1 percent increases in economic growth will leads to reduce the level of CO_2 emission by 4.84 percent. The energy consumption has the positive effects on the amount of carbon dioxide emissions. This depicts that a 1% increases in consumption of energy will increases CO_2 emission by 0.89 percent. The results of population found to be negative and significant at 5 percent level. This indicates that a percent rises in urban population is predicted to reduce emitted of CO_2 gases by 52.38 percent in Brunei when short run taken into consideration (Javaid and Zulfiqar, 2017). To examine the Inverted U-shaped curve of Environmental Kuznets theory in Brunei, We compare the magnitude of CO2 with respect to economic growth between long run and short run. The estimation of long-run and short-run as indicated in table 5 show that the negative elasticity of economic growth on CO_2 emission in the short-run fail to support the existence of EKC whiles the negative elasticity change in the long run tends to support the EKC hypotheses in Brunei. This result supported with the study findings of [Ahmed and Long, 2013].

Table 05: Short estimation results (InCO_2)

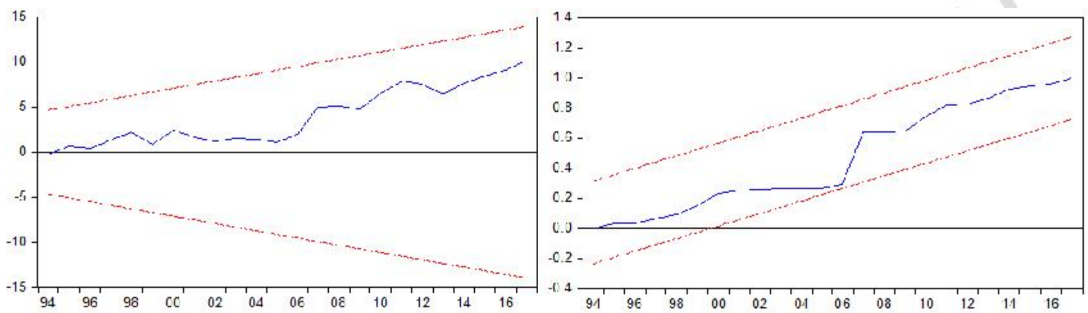
Co-integrating Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(INEC)	.888452	.263483	3.371953	.005
D(INEC(-1))	.168295	.297546	.565611	.58
D(INEC(-2))	-.399902	.295666	-1.352546	.20
D(INEC(-3))	-.363335	.249568	-1.455857	.17
D(INPOP)	-52.382543	299.7550	-.174751	.86
D(INY)	-4.843530	1.490686	-3.249194	.007
D(INY(-1))	-1.428382	2.900069	-.492534	.63
D(INY(-2))	4.050801	1.864779	2.172268	.05
CointEq(-1)	-1.143057	.309676	-3.691138	.003
Cointeq = INCO2 - (1.5318*INEC -6.4169*INPOP -5.3372*INY + 74.5702)				

Note: ARDL (2, 3, 1, 4) selected on the basis of AIC. ** and *** Represent 5% and 1% level of significance, respectively. Dependent variable is InCO_2.

4.5 Stability Test and Sensitivity Analysis

The structural changes of macroeconomic policies in developing countries may likely to causes the multiple structural breaks among the macroeconomic series. Therefore, it is vital to verify the stability of long run and short run coefficients through ‘the cumulative Sum (CUSUM)’and ‘Cumulative Sum of Squares (CUSUMSQ)’ techniques which proposed by Brown et al, 1975 as cited in Javaid and Zulfiqar, 2017. These tests do not require the specification of dates where the structural breaks occurs, it only suggest that the parameters will be stable if the line passes within the bounds at 5 percent critical bounds. If the plot of these techniques passes outside the critical bound of 5 percent level of significance, reject the null hypothesis of not stable the regression coefficient and this implied that the coefficient in the ECM are not stable (Bekhet and Mater, 2013). The findings in the figure 1 below, indicate that the lines within the plots of 'CUSUM' and 'CUSUMSQ' test statistics passes within the critical bound of 5 percent for the studying period, and therefore, the coefficients are stable and do not suffer the structural change over the given time in the study.

Figure 01: Stability Test



4.6 VECM Granger Causality Analysis

The short-run co-integrated relations between CO_2, economic growth, energy consumption and population have shown the existence of causal relationship among the underlying variables. The short run causality has shown there is unidirectional significant causal relationship which runs from CO_2 to population. Similarly, there is also a unidirectional causal relationship which runs from economic growth (InY) to carbon dioxide emission (CO_2) in the short run. The t-statistic of the ECT in the same table when carbon dioxide emission as a dependent variable reveals the existence of long run causal relationship which run from energy consumption, economic growth and population to CO_2 emission, Since the value of CO_2 emission is negative and statistical significance. There is no evidence of long run-relationships for DInENC; DInY and InPOP, since, the soon after has a positive but insignificant Error correction term, while the two later have failed to pass the bounds of cointegration equation. The t-statistics of the ECT in the same table reveals the existence of long-run causal relationship among the mentioned variables. It is obvious to say that there is a bidirectional long-run causal relationship (equilibrium is corrected) between CO_2, InY, INPOP and InENC.

Table 06: The results of Granger-Causality (Wald F-statistic test)

	Short-run (Weak) Causality				**Joint/Long-run (Strong) Causality**				**Long-nun**
	DICO2	**DLY**	**DLENC**	**DLPOP**	**DICO$_2$**	**DLY**	**DLENC**	**DLPOP**	
DICO$_2$	----	1.97	1.77	7.65*	----	5.53*	3.24#	4.47*	**-.480***
DLY	3.62*	----	.08	0.14	**----**	----	----	----	**-.017#**
DLENC	2.92	3.32	----	1.12	----	----	----	---	**.452***
DLPOP	2.05	.08	.09	----	----	---	----	----	**-.001#**

Notes: the null hypothesis is that there is no Granger causality between variables, *, **, # denote significant level at 1% and 5% and insignificant respectively.

4. CONCLUSION

This study examines the short run and long run dynamic relationships between CO2, energy consumption, urban population and economic growth in Brunei. It is one among the crucial topic that deserves a special attention, since in most cases the economic growth in developing economy associated with the environmental degradation. This happed due to heavy consumption of pollutant substances as sources of energy in the industries and means of transportation. The empirical results indicate the existence of long-run relationship among the Co2, energy consumption, urban population and economic growth. The results of EKC found to be Inverted U-shaped curve indicates an evidence to support the EKC hypothesis in Brunei. Therefore, the government of Brunei Darussalam should continue to target the sustainable means of production which has environmental friendly and consumes less energy to maintain the high rate of economic growth and improve the environmental quality.

AC

COMPETING INTERESTS

“Authors have declared that no competing interests exist.”

REFERENCES

1. Abdouli & Hammami (2017),”The Impact of FDI Inflows and Environmental Quality on Economic Growth: an Empirical Study for the MENA Countries”, Springerlink.com, DOI 10.1007/s13132-015-0323-y

2. Akinsola And Odhiambo (2018), *“*Carbon Emission And Economic Growth Nexus: Empirical Evidence From The Five Largest Carbon Emitters”,*Unisa Economic Research Working Paper Series.*

3. Alabdulrazag & Alrajhi (2016), “The validity of Environmental Kuznets Curve Hypothesis in the Kingom of Saudi Arabia: ARDL Bounds testing Approcah to Cointegration”, International Review of Management and Business Research, Vol.5 Issue.4. www.irmbrjournal.com

4. Alam and Janifar (2014), “the Relationship between Economic Growth and CO2 Emissions: The Bangladesh Experience” *IOSR Journal of Economics and Finance* (IOSR-JEF)e-ISSN: 2321-5933, p-ISSN: 2321-5925 www.iosrjournals.org

5. Asia Pacific Energy Research Centre (2017), “APEC energy overview”, *The institute of energy Economics,* Japan, Chuo_Ku, Tokyo 104,0054, Japan

6. Aye and Edoja (2017),”Effect of economic growth on CO2 emission in developing countries: Evidence from a dynamic panel threshold model”Cogent OA, part of Taylor &Francis Group,https://doi.org/10.1080/23322039.2017.1379239

7. Balıbey M (2015), “Relationships among CO2 Emissions, Economic Growth and Foreign Direct Investment and the Environmental Kuznets Curve Hypothesis in Turkey” *International Journal of Energy Economics and Policy*, 1042-1049.

8. Balıbey M. (2015), “Relationships among CO2 Emissions, Economic Growth and Foreign Direct Investment and the Environmental Kuznets Curve Hypothesis in Turkey ”.*International Journal of Energy Economics and Policy*, 5(4): 1042-1049.

9. Bekhet, H. A., & Matar, A. (2013). Co-integration and Causality Analysis betweenStock Prices and Their Determinants in Jordan. Economic Modeling, 35, 508–514

10. Bildiric M (2017),”CO_2 emission, oil consumption and production, economic growth in MENAP countries: ARDL and ANOVA methods*”,International Journal of Oil, Gas and Coal Technology,*

11. DavoudM., Behrouz S. A., Farshid P. & Somayeh J., (2013), "Oil products Consumption, Electricity Consumption -Economic growth Nexus in the Economy of Iran: A Bounds Testing Co-integration Approach". *International Journal of Academic Research in Business and Social Sciences*, 3(1):

12. Jardón et al (2017) “Economic growth and carbon dioxide emissions: An analysis of Latin America and the Caribbean” Universidad Nacional Autónoma de México, Centro de Ciencias de la Atmósfera. This is an open access article under the CC BY-NC-ND License (http://creativecommons.org/licenses/by-nc-nd/4.0/).

13. Javaid, W., & Zulfiqar, H. (2017). Environmental Kuznets Curve: A Times Series Evidence from Pakistan Journal of Quantitative Methods 1(1), 79-98 DOI: 10.29145/2017/jqm/010105 https://journals.umt.edu.pk/sbe/jqm/volume1issue1.aspx

14. Kebede, Shemelis (2017): *Modeling Energy Consumption, CO2 Emissions and Economic Growth Nexus in Ethiopia: Evidence from ARDL Approach to Cointegration and Causality Analysis.* MPRA Paper, https://mpra.ub.uni-muenchen.de/id/eprint/83000

15. Khalid Ahmed, Wei Long, (2013) "An empirical analysis of CO2 emission in Pakistan using EKC hypothesis", Journal of International Trade Law and Policy, Vol. 12 Issue: 2, pp.188-200, https://doi.org/10.1108/JITLP-10-2012-0015

16. Kuznets, S., 1955. Economic growth and income inequality. American Economic Review 45, 1–28.http://links.jstor.org/sici?sici=0002-8282%28195503%2945%3A1%3C1%3AEGAII%3E2.0.CO%3B2-Y

17. Lacheheb et al (2015),”“Economic Growth and Carbon Dioxide Emissions: Investigating the Environmental Kuznets Curve Hypothesis in Algeria” *International Journal of Energy Economics and Policy,* 2015, 5(4), 1125-1132, http: www.econjournals.com

18. M. Hashem Pesaran & Yongcheol Shin & Richard J. Smith, 2001. "Bounds testing approaches to the analysis of level relationships," Journal of Applied Econometrics, John Wiley & Sons, Ltd., vol. 16(3), pages 289-326.

19. Manuel A. Zambrano-Monserrate, Christopher Carvajal-Lara & Roberto Urgiles-Sanchez (2018) Is there an inverted *U*-shaped curve? Empirical analysis of the Environmental Kuznets Curve in Singapore, Asia-Pacific Journal of Accounting & Economics, 25:1-2, 145-162, DOI: 10.1080/16081625.2016.1245625

20. Marsiglio, S., Ansuategi, A. & Gallastegui, M. Carmen. (2016). The environmental Kuznets curve and the structural change hypothesis. Environmental and Resource Economics, 63 (2), 265-288

21. Muftau O et al (2014), "An Empirical Analysis of the Relationship between CO2 Emission and Economic Growth in West Africa" *American Journal of Economics* 2014, 4(1): 1-17 DOI: 10.5923/j.economics.20140401.01.

22. Naminse and Zhuang(2017) Economic Growth, Energy Intensity, and Carbon Dioxide Emissions in China, Pol. J. Environ. Stud. Vol. 27, No. 5 (2018), 2193-2201. DOI: 10.15244/pjoes/78619

23. Narayan, P.K., Singh, B. (2007), "The electricity consumption and GDP nexus for Fiji Islands". *Energy Economics,* 29.

24. OECD/Economic Research Institute for ASEAN and East Asia (2018), "Brunei Darussalam", in SME Policy Index: ASEAN 2018: Boosting Competitiveness and Inclusive Growth, OECD Publishing, Paris/Economic Research Institute for ASEAN and East Asia, Jakarta. DOI: https://doi.org/10.1787/9789264305328-16-en page 205 to 229.

25. Osabuohien E.S, Efobi U.R and Gitau C.M (2014). Beyond the environmental Kuznets Curve in Africa: evidence from panel cointegration. *Journal of Environmental Policy and Planning*, http://www.tandfonline.com/loi/cjoe20

26. Palamalai S et al (2015) "Relationship between energy consumption, CO2 emissions, economic growth and trade in India" Journal of Economic & Financial Studies, 03(02), 1-17. DOI: http://dx.doi.org/10.18533/jefs.v3i02.93

27. Pandey and Mishra (2016)," "CO2 Emissions and Economic Growth of SAARC Countries: Evidence from a Panel VAR Analysis" World Journal of Applied Economics (2015) 1(2): 23-33 doi:10.22440/EconWorld.J.2015.1.2.SP.0009

28. Perg and Chen (2017), "Application of the bootstrap panel method an empirical study of the granger causality between carbon dioxide emissions and economic growth in emerging countries" Department of Environmental Engineering Dayeh University 168 University Rd. Dacun Changhua 51591 Taiwan.

29. Saboori et al (2012),"Economic growthandCO2 emissions in Malaysia: A cointegration analysis of the Environmental Kuznets Curve", journal of energy policy,elsevierhttp://dx.doi.org/10.1016/j.enpol.2012.08.065

30. Salahuddin M et al (2015), "Is the long-run relationship between economic growth, electricity consumption, carbon dioxide emissions and financial development in Gulf Cooperation Council Countries robust?" DOI: http://dx.doi.org/10.1016/j.rser.2015.06.005

31. Shaari et al (2012) "Foreign Direct Investment and Economic growth: evidence from Malaysia, *International business research*, Vol 5, No. 10, 2012, Malaysia.

32. Shaari et al (2017), "The Effects of Electricity Consumption and Economic Growth on Carbon Dioxide Emission",*International Journal of Energy Economics and Policy*, 017, 7(4), 287-290

33. Shahbaz et al. (2014)," Causality between Trade Openness and Energy Consumption: What Causes What in High, Middle and Low Income Countries" *The Pakistan Development Review* 53:4 Part II (Winter 2014) pp. 423–459

34. UNFCCC (2017), Brunei Darussalam's Second National Communication, Under the United Nations Framework Convention on Climate Change Energy and Industry Department, The Prime Minister's Office, Jalan Perdana Menteri Bandar Seri Begawan BB3913 Negara Brunei Darussalam

35. Usama Al-Mulali; Sakiru A. S.; and Ilhan O. (2016), "Investigating the Presence of the Environmental Kuznets Curve (EKC) Hypothesis in Kenya: An Autoregressive Distributed Lag (ARDL) Approach" *Nat Hazards,* 80:1729 –1747.

36. Xiongling T (2016),"The Relationship between Carbon Dioxide Emission Intensity and Economic Growth in China: Cointegration, Linear and Nonlinear Granger Causality. *Journal of Resources and Ecology*. 7(2):122–129.J. Resour. Ecol. 2016 7(2) 122-129 DOI: 10.5814/j.issn.1674-764x.2016.02.007

37. Zahidul Islam et al (2017), "CO2 Emission, Energy Consumption and Economic Development: A Case of Bangladesh" *The journal of Asian Finance, Economics and business* Vol.4 No.4 pp.61-66 DOI: http://dx.doi.org/10.13106/jafeb.2017.vol4.no4.61