International Journal of Multidisciplinary Research and Development
www.allsubjectjournal.com
Online ISSN: 2349-4182, Print ISSN: 2349-5979, Impact Factor: RJIF 5.72
Received: 11-02-2021, Accepted: 10-03-2021, Published: 20-04-2021
Volume 8, Issue 4, 2021, Page No. 44-50

CO2 emanation, energy consumption and economic growth in Sri Lanka: with reference to environmental kuznets curve

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Abstract
This study investigates the environmental Kuznets curve (EKC) in Sri Lanka from 1965 to 2019. For this purpose, the impact of GDP per capita, Co2 emission per capita, renewable and non-renewable energy consumption per capita is empirically examined within the EKC framework. The study employed the Autoregressive Distribution Lagged (ARDL) bound test to investigate the study variables' long-run relationship. The study results show that carbon emissions, income, and energy consumption of non-renewable and renewable are cointegrated in the long run. The analyses do not support the EKC hypothesis in Sri Lanka and found an "N" shape curve. Therefore, depending on the analyses' results, policies for reducing environmental degradation, raising awareness, and enacting environmental regulations must be explored.

Keywords: renewable and non-renewable energy consumption, environmental kuznets curve, ARDL

Introduction

According to the International Energy Association, the 2018 annual report showed that Global Energy consumption 2018 increased twice the average growth rate since 2010. As a result of higher energy consumption, carbon dioxide (CO2) emission rose by 1.7% and hit a new record. Altogether the Energy sector is responsible for 30% of the global CO2 emission. CO2 emissions have increased over the years due to the continuous rise in global energy demand. They have severe implications for the environment and a significant contributor to global climate change (Zaidi, 2018) [14].

Therefore, individual scholars in different disciplines are trying to contribute to environmental, economic, and social aspects of environmental changes. One of the critical theories in this environment and economics is the Environmental Kuznets Curve (EKC). Ecological pressure increases faster than income in the early development stage and slows down relative to Gross Domestic Production (GDP) growth in higher income levels. This systematic relationship between income change and environmental quality has been called the EKC. The inverted-U relationship derives from Kuznets's (1955) work who postulated a similar relationship between income inequality and economic development (Dinda, 2004) [4].

The World Resources Institute Climate Analysis Indicators Tool (WRI CAIT) Shows that the energy sector dominated Sri Lanka's GHG profile in 2011 by 40 percent. Also, Sri Lanka's GHG emissions increased by 43 percent from 1990 to 2011, with the energy sector accounting for 6 percent of this growth. Sri Lanka communicates its intent to reduce Green Gas (GHG) releases totally by 7% by 2030 compared to a business-as-usual scenario. To meet this goal, policymakers and individuals in Sri Lanka must understand the relationship between renewable and non-renewable energy use, GDP, and CO2 emissions.

Cited Salah Uddin *et al*. (2016) determined the causal relationship between energy consumption, carbon emissions, and Sri Lanka's economic growth. Nevertheless, this study did not estimate the impact of energy consumption on carbon emissions. Furthermore, The researcher did not trace any analysis that considers renewable and non-renewable energy consumption separately as environmental degradation factors along with GDP to test the EKC hypothesis in Sri Lanka. Therefore, to fulfill the research gap, this study focuses on Sri Lanka as the context and the EKC hypothesis to analyze environment degradation with relevant variables that fit the context. The current study examined whether energy consumption (renewable and non-renewable), GDP, and CO2 emission evidence support the EKC hypothesis in Sri Lanka from 1965 to 2019 by applying the Autoregressive Distribution Lagged (ARDL) approach. Furthermore, identify the behavior of the existent EKC curve in Sri Lanka

The paper's remainder is arranged as follows: Section 2 briefly provides an overview of the related literature and presents the study's empirical model. Also, Section 3 presents data, sources, and the methodology of the study. Section 4 includes the interpretation of results and discussion. The last section concludes the study.

Review of Literature

This section examined few studies in CO2 emission, energy consumption, and GDP concerning KEC. Shahbaz*et al*. (2012) investigated the association between energy (renewable and non-renewable) consumption and economic growth using the Cobb–Douglas production function in Pakistan for 1972–2011 using the ARDL bounds testing. The results confirmed cointegration between renewable energy consumption, non-renewable energy consumption, economic growth, capital, and labor in Pakistan. Granger causality analysis of the vector error correction model (VECM) validates the existence of feedback hypotheses between renewable energy consumption and economic growth, non-renewable energy consumption and economic growth, economic growth, and capital. This study consistent with Rahman & Kashem (2017), who examined the empirical cointegration, long and short-run dynamic forces, and causal relationships between carbon emissions, energy consumption, and industrial growth in Bangladesh for 1972-2011. (2017) investigated the relationship between energy consumption, CO2 emission, economic growth, trade openness, and urbanization. The annual data for the period between 1971 and 2013 is employed, and the same results arrived.

Jebli (2015) used the ARDL bounds testing approach for cointegration with structural breaks and the VECM Granger causality approach to examine associations among per capita CO2 emissions, GDP, renewable and non-renewable energy consumption, and international trade (exports or imports) for Tunisia in the period 1980–2009. The inverted U-shaped EKC hypothesis is not supported graphically and analytically in the long-run. Moreover, Özokcu & Özdemir (2017) investigated a smiler study using the panel data estimation techniques to apply Driscoll-Kraay Standard Errors. The results showed that N-shape and an inverted N-shape relationship for cubic functional form are observed. Thus, the results do not provision the EKC hypothesis, implying that environmental degradation cannot be solved automatically by economic growth. This result in line with Gasimli*et al*. (2019), who examined the nexus between energy, trade, urbanization, and environmental degradation in Sri Lanka.

(2017) examined the interrelationship between energy consumption, economic growth, and CO2 emissions under the six alternative and plausible hypotheses, including EKC in low and middle-income countries high-income countries and the aggregated panel, for 1975–2015. The results supported the EKC hypothesis.

W. Ali*et al*. (2017) used an empirical analysis on real GDP per capita, financial growth, trade openness, foreign direct investments, and energy use on CO2 emissions to find the existence of EKC in the background of Malaysia from 1971 to 2012. The results of Granger causality test show that energy consumption and CO2 emissions are bidirectional, while other variables cause CO2 emissions unidirectionally. In the short run, there is no bidirectional causality between variables. On the other hand, unidirectional causalities run from trade openness and foreign direct investment to economic growth, financial development, and CO2 emissions. The evidence for the EKC hypothesis is supported by unidirectional causality from other variables to CO2 emissions, which occurs in countries where the EKC is validated.

Wang (2017) analyzed the importance of renewable and non-renewable energy use in Pakistan to test the EKC hypothesis at the individual country level. From 1970 to 2012, several econometric techniques were employed. In the case of Pakistan, the results strongly support the existence of the EKC. It has also been discovered that renewable energy consumption and CO2 emissions and non-renewable energy consumption, and CO2 emissions have bi-directional causality.

In Pakistan, Zaidi (2018) [14] looked at renewable and non-renewable energy use in CO2 emissions. The empirical evidence is based on a 1970-2016 ARDL model of data. The disaggregated study shows that renewable energy consumption has a marginal effect on CO2 emissions in Pakistan and that natural gas and coal are the critical contributors to the country's pollution levels in the non-renewable energy model. Economic growth tends to minimize CO2 emissions in the renewable energy model but not in the non-renewable energy model.

The Model and Data

1. *An Empirical Model Of The Study*

This study also developed an empirical model closely following research performed by Dinda (2004) [4], Rahman & Kashem (2017), Zaman & Moemen (2017), Özokcu & Özdemir (2017), Gamage & Kuruppuge (2017), S. Ali*et al*., (2017), Gasimli*et al*., (2019) and Jayasooriya, (2019). The functional form of the model as follows.

$$CO2_t = f(GDP, GDP^2, GDP^3, REC, NREC)$$

The empirical model of the study implies that carbon emission per capita (CO_2), the function of gross domestic production per capita (GDP), gross domestic production squares per capita (GDP^2), gross domestic production cubic per capita (GDP^3), renewable energy consumption per capita (REC) and non-renewable energy consumption per capita (REC), in Sri Lanka.

The study inspects the effect of energy consumption and GDP on CO2 emissions and EKC's existence. Concerning Dinda (2004) [4] and (2017), the cubic model equation to test the EKC hypothesis is a present study used revealed as follows.

$$CO2_t = \alpha + \beta_1 GDP_t + \beta_2 GDP_t^2 + \beta_3 GDP_t^3 + \beta_4 REC_t + \beta_5 NREC_t + \varepsilon_t$$

The variables are the same as described above, α is the intercept and β_1-β_5 are coefficients of descriptive variables, and ε is the error term. As (2004), the signs of the coefficients of GDP, GDP2, and GDP3 determine the EKC curve's shape. Therefore, the presence of the EKC hypothesis can be verified as follows;

- $\beta_1 > 0$, $\beta_2=\beta_3=0$ then there is a monotonically increasing relationship between GDP and CO_2 emission.
- $\beta_1 < 0$, $\beta_2=\beta_3=0$ then there is a monotonically decreasing relationship between GDP and CO_2 emission.
- $\beta_1 > 0$, $\beta_2 < 0$, and$\beta_3=0$ then there is an inverted U-shape relationship between GDP and CO_2 emission. In other words, the EKC hypothesis is valid.
- $\beta_1 < 0$, $\beta_2 > 0$, and $\beta_3=0$ then there is a U-shape relationship between GDP and CO_2 emission.
- $\beta_1 > 0$, $\beta_2 < 0$, and $\beta_3 > 0$ then there is an N-shape relationship between GDP and CO_2 emission.
- $\beta_1 < 0$, $\beta_2 > 0$, and $\beta_3 < 0$ then there is an inverted N-shape relationship between GDP and CO_2 emission.

For the data series to have a constant variance, the study applies a logarithmic transformation. Thus, the model can be rewritten in log-form as follows.

$$\log CO2_t = \alpha + \beta_1 \log(GDP)_t + \beta_2 \log(GDP)_t^2 + \beta_3 \log(GDP)_t^3 + \beta_4 \log(REC)_t + \beta_5 \log(NREC)_t + \varepsilon_t$$

2. *data*

This study includes annual data of CO2 emissions per capita, per capita real GDP, or output in constant 2010 US dollars. Simultaneously, the researcher adjusted renewable and non-renewable energy consumption in kilowatt-hours per capita using the following formula.

$$NREC/REC\_percapita = \frac{NREC/REC(in\_kwh)}{populatoion}$$

Data on GDP variable was collected from World Development Indicators, World Bank online database. Data on CO_2, REC, and NREC variables are collected from Our World in Data based on Global Carbon Project, BP; Maddison; UNWPP, and BP Statistical Review of Global Energy. This study uses time-series data from 1965 to 2019 and gets a log transformation for estimation purposes. Since this is time-series data, the study variables have to be tested for the unit root. The researcher applied conventional unit root tests such as the Augmented Dickey-Fuller (ADF) unit root test and Phillips-Perron (PP) test. Once the time series data's unit root properties have been identified, the researcher employs ARDL to determine the time series's cointegration. The ARDL representation for the current study can be formulated as in the following equation.

$$\Delta \log CO2_t = \alpha_0 + \sum_{i=1}^{p} \beta_1 \log \Delta(CO2)_{t-r} + \sum_{i=1}^{p} \beta_2 \log \Delta(GDP_{t-i}) + \sum_{i=1}^{p} \beta_3 \log \Delta(GDP)^2{}_{t-1} + \sum_{i=1}^{p} \beta_4 \log \Delta(GDP)^3{}_{t-i}$$
$$+ \sum_{i=1}^{p} \beta_5 \log \Delta(REC)_{t-1} + \sum_{i=1}^{p} \beta_5 \log \Delta(NREC)_{t-1} + \lambda_1 l\,og(CO2)_{t-1} + \lambda_2 l\,og(GDP)_{t-1} + \lambda_3 l\,og(GDP)^2{}_{t-1}$$
$$+ \lambda_4 l\,og(GDP)^3{}_{t-1} + \lambda_5 l\,og(REC)_{t-1} + \lambda_1 l\,og(NREC)_{t-1} + \varepsilon_t$$

Analyses and Result

In this study, the following four-step procedure is engaged. Those are (i) examines the stationary proprieties of each variable using traditional unit root tests, (ii) tests the existence of long-run relationship among variables using the ARDL bounds testing approach, (iii) estimates the short and long-run parameters and tests the stability of the model, and (iv) establishes the direct causality between variables by using the Granger causality test.

The summary statistics are reported in the table - 01which is necessary to ascertain the primary measure of central tendency and dispersion of the variables and how they fare over the investigated period (1965–2019). Table 01 shows that carbon dioxide emission (per capita) has a minimum value of 0.1997 from the start-up years with a maximum of 1.165 over the period under consideration, while real income has the highest (maximum) of over $4011.6819 and a minimum of $604.6381. Non-renewable energy consumption per capita varies from 493.3959 kWh (minimum) to 3926.939 kWh (maximum) and renewable energy consumption per capita varies from 32.8509 kWh (minimum) to 349.9925 kWh (maximum). The current study is conducted for a sample size of 55 observations with all series normally distributed given the failure to discard the null hypothesis of normality at a 5% significance level.

Table 1: Descriptive Statistics for the variables

	LOG_CO2	LOG_GDP	LOG_GDP2	LOG_GDP3	LOG_NREC	LOG_REC
Mean	-0.961031	7.254767	52.96400	389.1254	7.189353	4.901608
Median	-1.202577	7.146011	51.06547	364.9144	6.983518	5.098330
Maximum	0.152721	8.296966	68.83964	571.1602	8.275616	5.857912
Minimum	-1.610806	6.404630	41.01929	262.7134	6.201312	3.491978
Std. Dev.	0.540134	0.581821	8.554710	94.79853	0.611075	0.611928
Skewness	0.575270	0.320847	0.412577	0.503410	0.133175	-0.746547
Kurtosis	1.992920	1.883122	1.949611	2.031188	1.788818	2.656018
Jarque-Bera	5.357808	3.802308	4.088782	4.473983	3.524360	5.380034
Probability	0.068638	0.149396	0.129459	0.106779	0.171670	0.067880
Observations	55	55	55	55	55	55

Stationary Test

The ADF and the PP unit root testing results are displayed in the following table (Table 02). It can be inferred from the above estimates that under ADF test and PP test attains all variables are stationary stationarity after taking both intercept and trend at levels. Therefore, it can be either I(0) or I(1). However, it ensures that no variable is stationary at 2nd difference or beyond that order of integration.

The ARDL bounds testing assumes that the variables should be integrated at I(0) or I(1) or I(0)/I(1), and no series is stationary at I(2). If any variable is integrated at I (2), then the ARDL F-statistic computation becomes invalid. Thus, the unit root test confirmed this assumption. The study implemented the ARDL bound test.

Table 2: Result of ADF and PP unit root test

Variable	ADF						PP					
	None		Intercept		Intercept and trend		None		Intercept		Intercept and trend	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
LOG_CO2	0.12	0.00*	0.98	0.00*	0.79	0.00*	0.12	0.00*	0.98	0.00*	0.82	0.00*
LOG_GDP	1.00	0.11	0.99	0.00*	0.74	0.00*	1.00	0.03*	0.99	0.00*	0.82	0.00*
LOG_GDP2	1.00	0.13	0.99	0.00*	0.74	0.00*	1.00	0.04*	0.99	0.00*	0.82	0.00*
LOG_GDP3	1.00	0.14	0.99	0.00*	0.74	0.00*	1.00	0.05**	0.99	0.00*	0.82	0.00*
LOG_REC	0.98	0.00*	0.23	0.00*	0.04*	-	0.98	0.00*	0.17	0.00*	0.07**	0.00*
LOG_NREC	0.99	0.00*	0.87	0.00*	0.25	0.00*	0.99	0.00*	0.89	0.00*	0.25	0.00*

- * and ** denotes statistically significant at 5% and 10%, respectively.

ARDL bounds test

Since the model passed all the diagnostics tests, the bounds test for cointegration was tested. The associated F-test result of ARDL Bounds Testing is implying that cointegration among the variables exists. The empirical results of the ARDL bounds testing are shown in Table 3. The results indicate that computed F-statistics are more significant than the upper critical bound at 1%, 5%, and 10% level of significance once non-renewable energy consumption, renewable energy consumption, and economic growth are treated as predicted variables. It implies that there is cointegration between the series. Also, it confirms that renewable energy consumption, GDP, non-renewable energy consumption, and CO_2 are cointegrated for a long-run relationship for 1965–2019 in Sri Lanka.

Table 3: The results of the ARDL bound Test

Test Statistic	Value	Significant.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	7.987377	10%	1.81	2.93
K	5	5%	2.14	3.34
		2.5%	2.44	3.71
		1%	2.82	4.21

The Akaike Information Criterion (AIC) has been used to determine the model's optimum lag length, and the selected Model is ARDL (3, 1, 1, 0, 3, 0). The short-run and long-run equilibrium relationship among the variables estimated using the ARDL (3, 1, 1, 0, 3, 0) approach is given in the table as follows. The results show that the coefficients are significant for all the variables besides non-renewable-energy consumption.

There are short-run dynamics in conjunction with the long-run relationships as shown by the value and sign of lagged error correction term (ECT), coefficient α [Coint Eq (−0.29)]. As required, ECT has a negative signal, and it is very significant even at a 1% level. It shows that there exists a long-term relationship between the dependent variable and the regressor.

Also, the short-run results indicate that the GDP has a positive and significant influence on CO2 emissions, similar to the long-run. The results disclose an increase of 1% in the overall income in Sri Lanka the CO2 emissions will rise by 29.33% in the short run. All variables significantly influence CO2 emission in each lagged value except NREC in lags 2 and 3. Lag periods of CO2, NREC, and GDP have a positive and significant impact (though the extent of the effect is not significant) on CO2 emissions in the short-run. The sign confirms and statistical significance of the coefficients of its current, first, second, and third lagged values in current both GDP and NREC. However, the first lagged value of GDP significantly and negatively affects the carbon emissions level. Similarly, NREC and current REC's three-period lags positively impact carbon emissions level at a 1% level of significance.

Table 4: Estimated short-run and long-run coefficients using the ARDL approach.

ARDL Model Regression				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.***
LOG_CO2(-1)	0.275529	0.145788	1.889927	0.0662**
LOG_CO2(-2)	0.071799	0.151749	0.473146	0.6387
LOG_CO2(-3)	0.359199	0.153824	2.335126	0.0248*
LOG_GDP	29.33647	8.200119	3.577567	0.0009*
LOG_GDP(-1)	-30.86856	8.277786	-3.729085	0.0006*
LOG_GDP2	-1.593564	0.544298	-2.927739	0.0057*
LOG_GDP2(-1)	2.039276	0.555090	3.673777	0.0007*
LOG_GDP3	-0.025408	0.009115	-2.787509	0.0082*
LOG_NREC	0.303158	0.113304	2.675610	0.0108*
LOG_NREC(-1)	-0.110879	0.125428	-0.884005	0.3821
LOG_NREC(-2)	-0.015158	0.125334	-0.120943	0.9044
LOG_NREC(-3)	-0.363786	0.111938	-3.249878	0.0024*
LOG_REC	-0.321716	0.066771	-4.818180	0.0000*
Error Correction Model Regression				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LOG_CO2(-1))	-0.430999	0.115318	-3.737484	0.0006*
D(LOG_CO2(-2))	-0.359199	0.116118	-3.093397	0.0036*
D(LOG_GDP)	29.33647	5.342515	5.491136	0.0000*
D(LOG_GDP2)	-1.593564	0.327595	-4.864426	0.0000*
D(LOG_NREC)	0.303158	0.084263	3.597745	0.0009*
D(LOG_NREC(-1))	0.378945	0.107461	3.526348	0.0011*
D(LOG_NREC(-2))	0.363786	0.090548	4.017613	0.0003*
CointEq(-1)*	-0.293473	0.039911	-7.353122	0.0000*
R-squared	0.985334	Mean dependent variable		-0.934539
Adjusted R-squared	0.980822	S.D. dependent variable		0.543805
S.E. of regression	0.075309	Akaike info criterion		-2.122121
Sum squared residuals	0.221185	Schwarz criterion		-1.634310
Log-likelihood	68.17515	Hannan-Quinn criterion		-1.935106
Durbin-Watson stat	2.017501			

- and ** denotes statistically significant at 5% and 10%, respectively.

Regression of CO2 emissions per capita function seems to fit the data reasonably well because the model can approximately explain 98% of the carbon emissions per capita and the rest by the error term. (Adj. R squared=.980).

The DW statistics is 2.0175, which confirms that the model is not spurious regarding the fixed effects model result; all variables are statistically significant at 1% level except NREC. Moreover, According to the Wald chi-square statistic, the model is jointly substantial (Wald chi-square (4) =44.29). An N-shaped curve is observed; hence, the EKC hypothesis is not valid for the model. The study further reveals that EKC does not hold in the short-run as the squared term of GDP bears a negative sign, and this finding is different from the study of (Shahbaz*et al*., 2012) for Pakistan for (W. Ali*et al*., 2017) Malaysia.

Diagnostic tests of the model

This model is a good fit, and it passes all the diagnostic tests. As illustrated in the following table (Table 5), the model gives the test regarding serial correlation (Breusch-Godfrey Serial Correlation LM tests), Normality (Jarque-Bera test), and Heteroscedasticity ('Breusch-Pagan-Godfrey' test).

Table 5: Model diagnostic tests results

Test	F-Statistics	Probability
Breusch-Godfrey Serial Correlation LM test	0.0978	0.9070N/S
Breusch-Pagan-Godfrey Heteroscedasticity test	1.6459	0.1071N/S
Jarque-Bera test	0.9012	0.6372N/S

- N/S denotes statistically not significant at 5%.

Stability of the Model

To ensure the results' robustness, the researcher employs structural stability tests on the long-run effects parameters based on the cumulative sum of recursive residuals (CUSUM) and cumulative sum of recursive residuals squares (CUSUMSQ) test. A graphical representation of CUSUM and CUSUMSQ statistics is provided in Figs. 01 and 02 as follows. If the designs of the CUSUM and CUSUMSQ remain within the 5 percent critical bound, it will signify the parameter constancy and the model stability. Therefore these statistics confirm the model stability and that there is no systematic change identified in the coefficients at a 5% significance level over the study period.

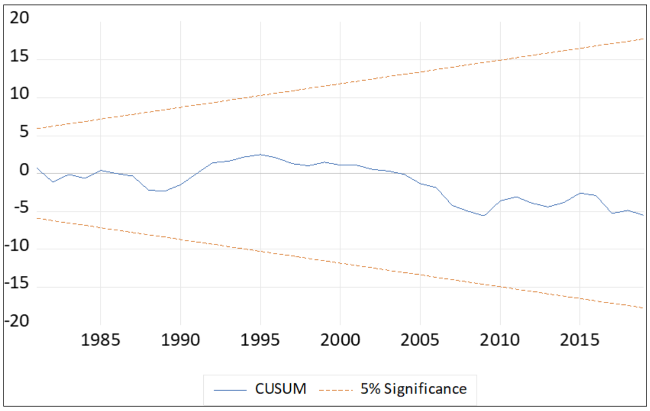

Fig 1: Plot of CUSUM test

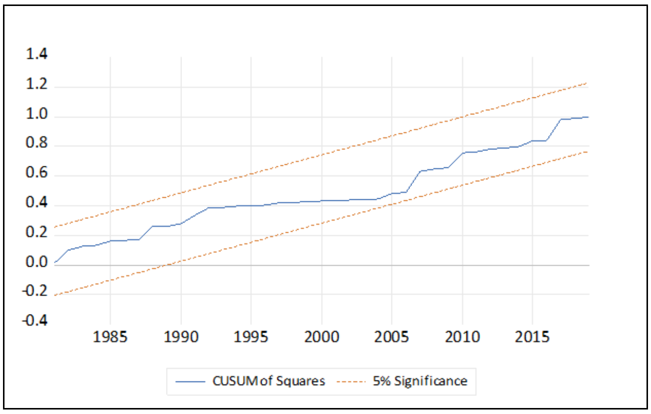

Fig 2: Plot of CUSUM of squares test

Granger causality test

After investigative the long-run relationship between the variables, the study used the Engle and Granger techniques to determine the variables' causality. The long-run relationship between variables implies that there must be a causal relationship between the variables, either bi-directional or at least unidirectional. (W. Ali*et al*., 2017). The present study follows a two-step procedure to identify the short and long-run relationship. Short-run causality is strongminded by the significance of F statistics concerning the Wald test and long-run causality corresponding to error correction term, which is determined by the significance of t statistics. The long-run equation as follows.

$$\Delta \log CO2_t = \alpha_0 + \sum_{i=1}^{p} \beta_1 \log \Delta(CO2)_{t-r} + \sum_{i=1}^{p} \beta_2 \log \Delta(GDP_{t-i}) + \sum_{i=1}^{p} \beta_3 \log \Delta(GDP)^2{}_{t-1} + \sum_{i=1}^{p} \beta_4 \log \Delta(GDP)^3{}_{t-i}$$

$$+ \sum_{i=1}^{p} \beta_5 \log \Delta(REC)_{t-1} + \sum_{i=1}^{p} \beta_5 \log \Delta(NREC)_{t-1} + \lambda ECT_{t-1} + \eta_t$$

Where Δ indicates the first difference, ηt denotes the standard error term, ECT_{t-1} is the lagged error correction term generated from the ARDL model, p indicates the VAR lag length, which is set to 1 λ suggests the speed of adjustment coefficients. Short and long-run Granger causality tests for the model are reported in Table 6. Long-run dynamics results reveal that the ECT coefficients of emissions, renewable, and non-renewable energy consumption are comprised between 0 and 1 and are statistically significant with a moderate speed of adjustment from short to long-run equilibrium.

Table 6: Results of the Granger Causality Test

Dependent variable	Short-run						Long run
	CO2	GDP	GDP2	GDP3	NREC	REC	ECT
CO2	-	60.2050 (0.00)*	-3.6328 (0.00)*	-0.025 (0.00)*	0.3031 (0.01)*	-0.3217 (0.00)*	-0.2935(0.00)*
GDP	-0.0001 (0.21)	-	0.2535 (0.00)*	-0.01538 (0.00)*	-0.0003 (0.01)*	-0.0002 (0.00)*	0.0035(0.00)*
GDP2	-0.0012 (0.00)*	7.3855 (0.00)*	-	0.0449 (0.00)*	0.002 (0.01)*	0.0017 (0.00)*	0.0068(0.00)*
GDP3	0.0257 (0.27)	-164.0034 (0.00)*	22.2237 (0.00)*	-	-0.0481 (0.01)*	-0.0404 (0.00)*	0.0103(0.00)*
NREC	0.2763 (0.07)**	-17.9625 (0.02)*	1.0986 (0.04)*	0.0098 (0.37)	-	0.2027 (0.13)	-0.6528(0.00)*
REC	-0.8406 (0.00)*	-735.2420 (0.00)*	102.5238 (0.00)*	-4.7339 (0.00)*	0.0048 (0.97)	-	-0.8871(0.00)*

- * and ** denotes statistically significant at 5% and 10%, respectively.
- P values are presented in parenthesis

Fig. 03 sums up short-run Granger causalities between variables. The test results found unidirectional causality running from GDP, GDP2, GDP3, and REC to CO2 emissions, GDP, GDP2, GDP3, and CO2 to NREC. The obtained results favor the findings of the studies mentioned above of W. Ali*et al*. (2017), (Wang, 2017), and (Bekun*et al*., 2019). Therefore, it can be concluded that the GDP and renewable energy consumption are caused for the carbon emissions growth in Sri Lanka.

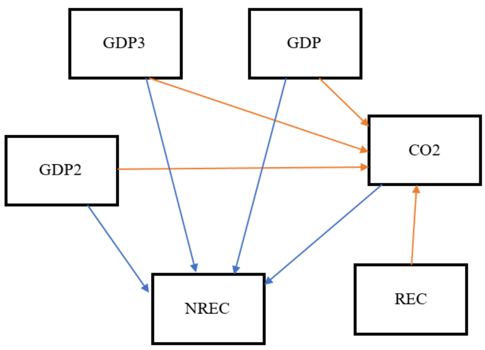

Fig 3: Result of Pairwise Granger Causality test

1. Conclusion and discussion

In the last decades, studies about CO2 emissions have been increasing due to global climate change concerns. CO2 emissions, which of enormous amounts result from fossil fuel combustion, have been accelerating drastically after the industrial revolution and damage the environment.

Most of the literature studies empirically detect the relationship between economic growth and environmental degradation in the EKC context. In this study, the relationship between per capita income, per capita renewable and non-renewable energy consumption, and per capita CO2 emissions is examined under the ARDL approach.

The outcomes of the analysis show that the N-shaped curve, which does not hold the EKC. N-shaped curve signifies that environmental degradation starts rising again after a reduction to a specific level. As (2017) cited from Choi, Heshmati, and Cho (2010) specify, environmental quality improvements with an environment-friendly development path cannot continue; it would worsen again. However, the current analysis results do not confirm that CO2 emissions increase and the increase in income until the turning point and decline due to higher income levels. This finding in line with Özokcu & Özdemir, (2017) and Gasimli*et al*., (2019). Moreover, the N-shaped curve is an indication of the insufficiency of environmentally-friendly improvements. Therefore, depending on the analyses' results, policies for reducing environmental degradation, raising awareness, and enacting environmental regulations must be explored.

There are contradictory results about EKC in the literature. More specifically, the findings depend on many criteria, such as the pollutants taken into account, and the econometric technique is used to change these studies' results. Thus, the analyses' results should be perceived as empirical analyses, although they disprove the EKC's validity. Other factors are affecting CO2 emissions such as environmental awareness, scale, composition, technique effects, trade openness, environmental regulations, and institutional capacity are welcome to further researchers.

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