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Nexus between Carbon Dioxide (CO_2) Emission and Energy use in Sri Lanka

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Abstract

This study investigates the long-run and short-run relationship between the annual CO_2 emission and energy use per person in Sri Lanka. The study applied the Residual Based Test using data from 1985 to 2020. According to the Augmented Dickey-Fuller Test, all the series appear stationary in the first difference for the logarithm form at a 1 per cent significance level. The residual was significant at its level. The results strongly support the conclusion that co-integration between the two variables exists in the long term. The study found a positive relationship between CO_2 emission and energy use in Sri Lanka. The fitted model was confirmed through the Normality Test, Serial Correlation Test, Heteroskedasticity Test and Recursive estimates. Error Correction Model (ECM) results found a positive relationship among the variable in the short term. Hence, energy usage is the most critical factor in CO_2 emissions. While Sri Lanka has been facing a severe energy crisis in 2022, this study suggests using renewable and alternative energy resources like solar to sustain the environment.

Keywords: Co_2 Emission, Energy usage, cointegration.

1. INTRODUCTION

Energy is an inseparable component of economic development. Among the different energy sources, such as coal, oil, natural gas, electricity, solar, wind and nuclear energy, oil continues to play a vital role in a country's economy since energy is the most critical input for many production and consumption activities. Due to a robust global economy and higher heating and cooling demands in some regions, worldwide energy consumption has surged at double the average growth rate since 2010. However, Global energy demand in 2020 fell by 4% due to covid restrictions in many economic activities. According to the Global Energy Review of 2021, energy demand is expected to rebound due to the post-pandemic recovery. Globally, economic activity and energy demand in 2021 exceed the 2019 levels by 1.3 per cent and 0.4 per cent, respectively. Global Carbon dioxide (CO_2) emissions declined by 5.8% in 2020, collaborating with the decline in the worldwide energy demand. Developing nations and emerging markets are responsible for more than two-thirds of the world's CO_2 emissions (Global Energy review, 2021). The usage of fossil fuels mainly causes CO2 emissions, and burning coal produces carbon dioxide gas, which can harm the environment and people's health.

Sri Lanka emitted 23.7 million tons of CO_2 in 2020, which is 1.13 tons of CO2 emissions per person (Knoema.com). The energy sector was the leading source of emissions, accounting for 40 per cent of total emissions. The garbage sector accounted for 28 per cent of emissions, with land-use change and forestry accounting for 15 per cent, agriculture for 14 per cent, and industrial activities accounting for 3 per cent. Various studies have identified the relationship between CO_2 emission and energy consumption (Climatelinks, 2016). Higher energy usage, for example, has resulted in increased CO_2 emissions and environmental damage (Chontanawat, 2020). In 2017, Sri Lanka consumed 383,419,865,000 BTU (0.38 quadrillion BTU). This amounts to 0.07% of world energy usage. Sri Lanka produced 41,956,002,000 BTU (0.04 quadrillion BTU) of energy to meet 11% of the country's yearly energy needs (Worldmeter, 2018). According to Figure 1 and Figure 2, the annual CO_2 emissions and energy use per person have increased, respectively. The COVID-19 pandemic recently had a detrimental impact on the energy sector since energy demand fell dramatically and CO_2 emissions fluctuated in Sri Lanka.

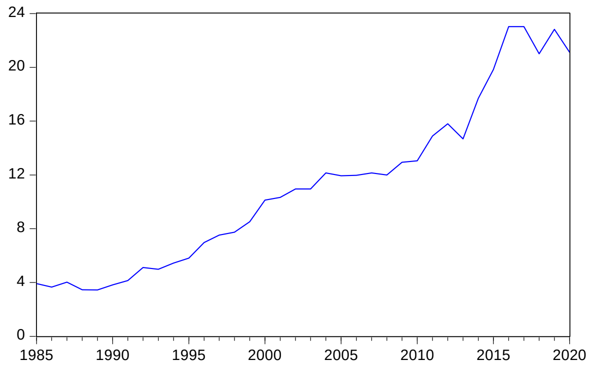

Figure 1 Annual CO_2 emissions (Million Ton)

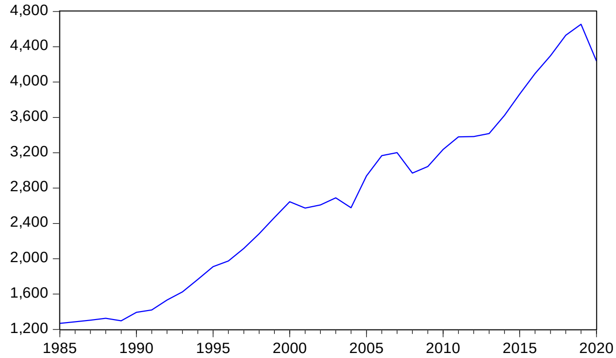

Figure 2 Energy use per person (Kilowatt-hour)

The objective of the study is to investigate the long-run and short-run relationship between CO_2 emissions, and energy consumption. No study has been carried out on the relationship between them in Sri Lanka to the best of the author's knowledge. Therefore, this paper aims to fill this gap. The rest of the article is structured as follows. The next section discusses the theoretical and empirical literature on the relationship between energy consumption and CO_2 emission. Section 3 presents the methodology that has been used in this study. Section 4 deals with the estimation results and interpretation. The final section offers the concluding remarks and policy implications.

2. LITERATURE REVIEW

According to Ngan Thao and Van Chon (2016), energy use benefits the economy but not the ecology. Energy consumption, particularly fossil energy usage, is widely recognized as the primary cause of global warming and climate change. The negative environmental repercussions of such energy use stem not only from energy consumption but also from the extraction process. Meanwhile, renewable energy consumption has a negative connection with CO_2 emissions, implying that increasing renewable energy consumption will reduce CO_2 emissions.

Using data series from 1990 to 2014, Sasana and Eake Putri (2018) conducted a multiple linear regression analysis with an Ordinary Least Square method, which suggested that Indonesians are consuming more energy and emitting more carbon dioxide (CO_2). The findings revealed that in Indonesia, fossil energy use and population increase have a beneficial impact on carbon dioxide emissions. Meanwhile, the renewable energy consumption variable has a negative effect on the amount of carbon dioxide which has been emitted.

Ang (2007) uses cointegration and vector error-correction modelling approaches to investigate the dynamic causal linkages between pollution emissions, energy consumption, and output in France. For the period 1960–2000, the findings support a relatively robust long-run link between these factors. Yang (2000b) investigated the short- and long-run equilibrium between the variables' electricity consumption as a dependent variable, foreign aid as an explanatory variable, and GDP as an explanatory variable in a system of single equation models from 1974 to 2011. Three co-integrating equations indicate that the variables are in long-run equilibrium. The ECM results show that the system is in both short- and long-run equilibrium. The long-run equilibrium is represented by the negative and significant coefficient of the one-period lag residual coefficient. With a value of -0.72, the system corrects its previous period of disequilibrium at 72 per cent per year.

Pao et al. (2011) investigate modelling Russia's CO2 emissions, energy use, and economic growth. They looked at the dynamic correlations between pollutant emissions, energy use, and production in Russia between 1990 and 2007. They used the co-integration technique and the causality test. The empirical findings demonstrate that emissions appear to be energy consumption elastic and output inelastic in the long-run equilibrium. Here elasticity indicates a high energy usage sensitivity to changes in emissions. The causality tests' findings show a substantial bidirectional Granger causality between output, energy use, and emissions.

Asafu-Adjaye (2000) investigate the relationship between energy consumption, energy prices and economic growth: a case study (OPEC countries). The Granger causality runs from income to energy consumption for Iran, Iraq, Qatar, the United Arab Emirates, and Saudi Arabia. However, all OPEC countries have no Granger causation relationship in the long run. Energy, economic growth, and pricing are not mutually causative in the cases of Qatar, Saudi Arabia, and Nigeria.

Sadorsky (2009) studies the relationship between renewable energy consumption, income, oil prices, and CO_2 emissions in the Group of Seven (G7) countries between 1980 and 2005 using vector autoregression techniques. The results show that in the long run, increases in real GDP per capita and carbon dioxide emissions per capita contribute to increases in G7 renewable energy consumption per capita. Using annual data from 1980 to 2008, Shahbaz et al. (2011) investigated the association between income and energy use in Romania. The findings indicate a positive relationship between Romania's real output and energy usage. They also discovered a strong positive link between nonrenewable energy consumption and carbon dioxide emissions.

3. RESEARCH METHOD

This research used the annual time series data from 1980 to 2020. It was derived from the website of OurWorldInData. The independent variable of energy use per person was used for energy consumption. Energy use includes electricity and other areas of consumption, including transport, heating and cooking. It was the average energy consumption per person each year and measured in Kilowatt-hour. The dependent variable of the annual CO_2 emissions was measured in a million tones. CO_2 emissions result from the combustion of fossil fuels for energy and cement manufacture. Changes in land usage are not included. E-views – 10 statistical software was used to analyse the data. The Confidence Ellipse is a graphical tool used in this study to determine the relationship between energy consumption and CO_2 emissions in the Sri Lankan context. And also, the Residual Based Test and Error Correction Model were used to investigate the objectives. The estimation was made easier by using the Logarithm Natural Equation model. Thus, the estimated basic model is as follows:

$$lnCO2 = \alpha_0 + \alpha_1 lnENC_t + \mu \text{..............................} (1)$$

Where,

CO2 - Annual CO_2 emissions
ENC - Energy use per person
α_0 - Intercept
α_1 - Value of variable coefficient
ln - Natural log
μ - Error term
t - 1,2,….,41 (time series data of 1985 – 2020)

4. RESULTS AND DISCUSSION

The diagrammatical portrayal of the data in figure 3 is the basis for determining the trend and primary relationship between energy consumption and CO_2 emissions. The preceding graph of Confidence Ellipse and Kernel Fit reveals a strong positive association between ENC and CO_2. There is a strong correlation between series such as ENC and CO2.

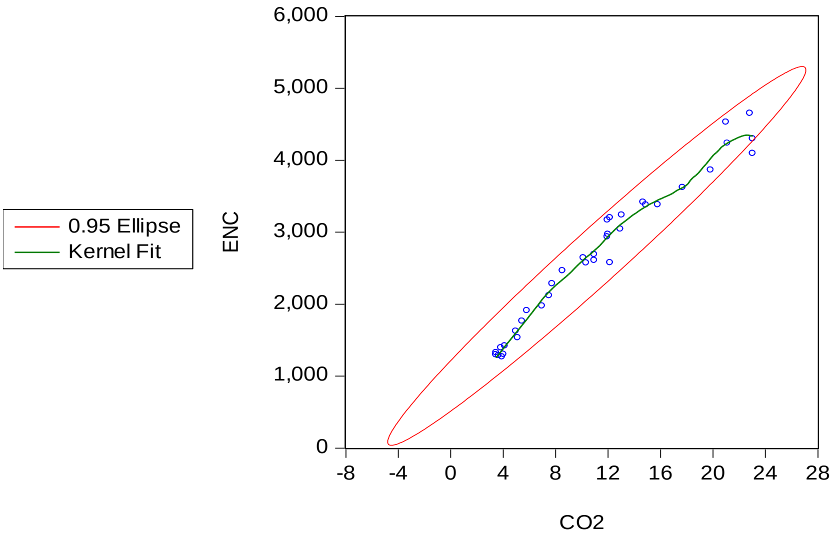

Figure 3 Visual Inspection of the relationship between energy consumption and CO_2 emissions

To analyse the cointegration, the first step is determining whether the variables are stationary or non-stationary. The integration order of each variable was checked using Augmented Dickey-Fuller Stationary unit root tests in this empirical investigation. According to Table 1, all variables are non-stationary at their level form and stationary at their 1st Difference.

H_0: The series has a unit root (Non – Stationary)

H_1: The series has no unit root (Stationary)

Table 1. Results of Augmented Dickey-Fuller (ADF)

Variable	P value		Accept hypothesis	Remarks
	Level	**1st Difference**		
LnCO2	0.8606	0.0000	H_1	I(1)*
LnENC	0.7319	0.0021	H_1	I(1)*

(*) - significant at 1% respectively

The unit root was tested in the residual series of the estimated equilibrium relationship by employing the Dickey-Fuller test. Therefore, the null and alternative hypotheses are:

H_0: The residual series has a unit root (No cointegration)

H_1: The residual series has no unit root (Cointegrated)

Table 2 shows the results of the residual unit root test. It can be deduced that the residual series is either non-stationary or have a unit root. At a 5% significance level, the p-value is less than the alpha value (0.05). Therefore, the residual series has no unit root. As a result, Carbon dioxide emission and energy consumption are co-integrated, indicating that long-run equilibrium exists.

Table 2. Results of Augmented Dickey-Fuller (ADF) - Residual

Form		P-value	Accept hypothesis	stationary
Level		0.0015	H_1	I(0)*

(*) - significance at 1% respectively

In the long run, we had checked this hypothesis here.
H_0 – The energy consumption doesn't Statistically determine carbon dioxide emission.
H_1 – The energy consumption does Statistically determine carbon dioxide emission.

According to Table 3, The regression output below shows that energy consumption has a statistically significant impact on carbon dioxide emission because their p-value (0.0000) is less than the alpha value (0.05). Therefore, it can be said that a one per cent increase in energy consumption is associated with a 1.477849 per cent change in carbon dioxide emission.

Table 3. Results of Regression

Variable	Coefficient	P-Value
LNENC	1.477549	0.0000*
C	-9.300987	0.0000*
R Squared – 0.984099 Adjusted R-squared – 0.983632		

(*) - significance at 1% respectively

In the short run, we had checked this hypothesis here.
H_0 – The energy consumption doesn't Statistically determine carbon dioxide emission.
H_1 – The energy consumption does Statistically determine carbon dioxide emission.

According to the Error Correction Model (Table 4), there is a short-run relationship between CO_2 emission and energy use per person. Below, the output shows that the energy consumption is statistically significant on the carbon dioxide emission in the short run because their p-value (0.0025) is less than the alpha value (0.05). R-squared of 98% reveals that the regression model explains 98% of the variability observed in the target variable.

Table 4. Results of ECM

Variable	Coefficient	P-Value
D(LNENC)	0.887993	0.0025*
C	0.017333	0.2586
RESID01(-1)	-0.593628	0.0008*
R-squared – 0.369527 Durbin-Watson stat – 1.884188		

(*) - significance at 1% respectively

The speed of adjustment of the error correction coefficient (-0.593628) term is statistically significant, based on the error correction model's results. Furthermore, the calculated coefficient's value is negative. This negative sign indicates that CO_2 is moving in the direction of equilibrium. It means that CO_2 is being adjusted downwards toward the equilibrium rate of 59.3628% each year. In this Error Correction Model, the Durbin-Watson Statistic is larger (1.884188) than the R squared (0.369527). This nature demonstrates that this simple regression model has no spuriousness issues.

According to the result based on the regression model given in Table 5, the residual is normally distributed, not a serially correlated error, model is homoscedastic. Also, the model specification is accurate.

Table 5. Residual Diagnostic Test

Test	Probability Value	Conclusion
Normality Test - Jarque-Bera	0.570915	Accept The Null Hypothesis
Serial Correlation LM Test	0.1128	Accept The Null Hypothesis
Heteroskedasticity Test Breusch – Pagan Godfrey	0.6661	Accept The Null Hypothesis

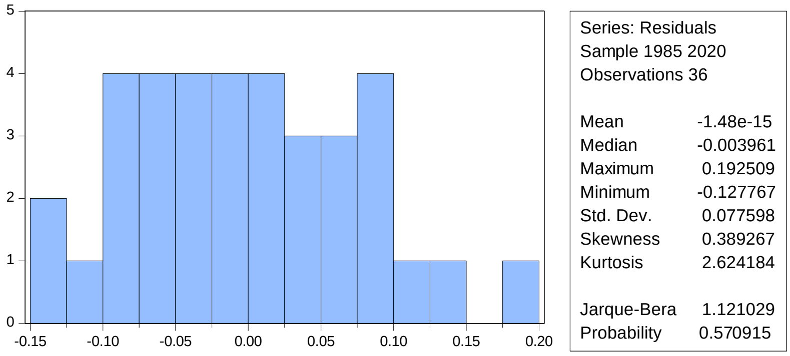

Figure 4 Residual Diagnostic Test - Histogram Normality Test

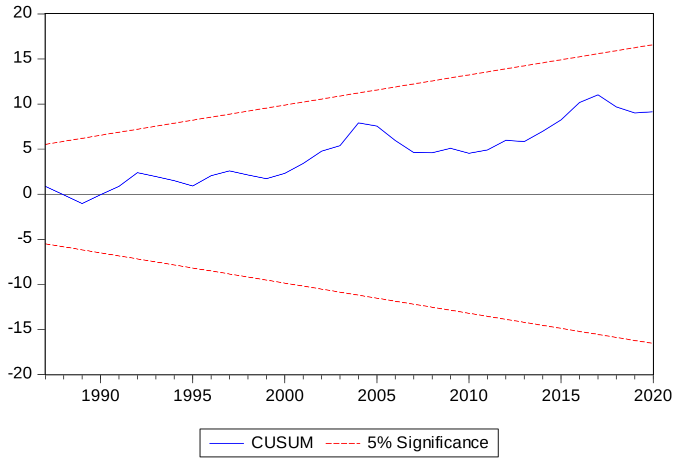

Figure 5 Stability Diagnostic recursive estimate – CUSUM TEST

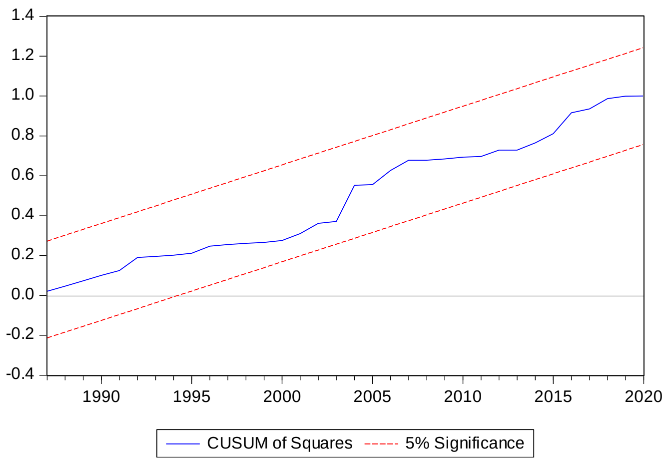

Figure 6 Stability Diagnostic recursive estimate – CUSUM of Squares

The CUSUM and CUSUM of squares tests have been used in the above statistics to check the stability of the long-run parameters generated in the model using the residuals from the regression model.

5. CONCLUSION

This study analyses the relationship between CO_2 emissions and per capita energy consumption by employing annual data between 1980 and 2020 for Sri Lanka. The co-integration techniques have been applied to examine the long-run relationship. The short-run relationship has been analysed using the Error Correction Model. The empirical analysis reveals specific characteristics of Sri Lanka's energy consumption and CO_2 emission. This study has found a positive coexistence between carbon dioxide emissions and energy usage in the short run and long run. Statistically, it was found through this study by using available recent data. These findings contribute to identifying the real situation and taking necessary action for government and policymakers to reduce the co2 emission.

Increased emissions and global warming have posed substantial problems to governments worldwide, attempting to address the issue in various ways. Energy usage is essential to improve any economy. Then, CO_2 emission is inevitable. So, renewable resources should be used for sustainable development. The government must impart concern on environmental pollution while developing macroeconomic policies. Future studies can find more variables related to these relationships. Sri Lanka needs to change its energy consumption pattern. Therefore, must give awareness and real facts about the energy crisis. People need to use environmentally friendly energy sources, like renewal energy. Researchers would do further related studies to find valuable findings.

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