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Sector Value Addition in GDP and CO2 Emanation in Sri Lanka

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Abstract

This study investigates the impact of agriculture, industry, and service sector value added in the gross domestic production (GDP) on carbon (CO2) emissions in Sri Lanka from 1965 to 2023. 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 and value added in agriculture have negative significant association while value added in service and carbon emission has positive significant association in both short and long run. The results analysis does not support the EKC hypothesis in Sri Lanka. Furthermore, in this study, The EKC hypothesis contradicts in the sense that Sri Lanka moves from the secondary to the tertiary sector (Services) but CO2 emissions do not decrease but rather increase with rising income that is the new findings of the research. Thus, the implication of the research is that staying service economy is not the only way of reducing CO2 emissions because value added services in GDP are also associated with CO2 emissions. As well as other factors that affect CO2 emissions such as environmental awareness, technique effects, trade openness, and environmental regulations, are welcome to further researchers.

Keywords: *ARDL, CO2 emission, environmental Kuznets curve, Value added in GDP*

1. Introduction

Climate change and global warming are the greatest and most significant environmental issues for the last decades. Scientists claim that the increasing human emission of carbon dioxide (CO2) produces a substantial increase in greenhouse gasses (GHGs), which have severe implications for the environment and are a significant contributor to global climate change. Carbon dioxide emissions, largely by products of energy production and use, account for the largest share of greenhouse gasses, which are associated with global warming. CO2 emissions have increased over the years due to the continuous rise in economic growth and human activity. (Zaidi, 2018). 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) which analysis is an econometric methodology that assumes that environmental quality or pollutant emissions are correlated with economic growth. 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 changes and environmental quality has been called the EKC. The inverted-U relationship derives from Kuznets's (1955) work which postulated a similar relationship between income inequality and economic development. The EKC relationship states that environmental degradation increases when GDP per capita increases up to a certain threshold level and beyond a threshold level (the turning point) pollution decreases and environmental quality improves (Dinda, 2004).

According to the World Resources Institute Climate Analysis Indicators Tool (WRICAIT)

Shows that Sri Lanka's greenhouse gas emissions increased by 43 percent from 1990 to 2011, Sri Lanka communicates its intent to reduce GHG releases total by 7 percent by 2030. To meet this goal, policymakers and individuals in Sri Lanka must understand the relationship between GDP and CO2 emissions.

GDP is the monetary value of all final goods and services produced within a country in a given time period. GDP has been calculated using three economic sectors in Sri Lanka which are Agriculture, Industry, and Services. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. According to the annual report 2023 in Sri Lanka, the average contribution of the agriculture sector is 8.28%, the manufacturing sector is 17.30% and the service sector is 59.92%. It is noticeable that the value addition of the service sector in GDP is higher than the other two sectors. Thus, according to the EKC hypothesis, Sri Lanka's economy has moved from the secondary (manufacturing) to the tertiary sector (Services), and environmental pollution should decrease. To justify the hypothesis, the study wants to investigate the association of CO2 emissions with the value added of agriculture, industry, and services in the GDP from the year 1965 to 2023. Therefore, it is highly important to attain a further understanding of the value addition in GDP that affects CO2 emission.

Given the above-mentioned background, the main objective of the study is to determine the impact of agriculture, manufacturing, industry, and service sector value-added in the GDP on CO2 emissions in Sri Lanka by applying the Autoregressive Distribution Lagged (ARDL) approach.

The remainder of the study is divided into four parts: The “Review of Literature” section provides an overview of the current research, while the “Materials and Methods” section describes the data sources and methods used. The "Results and Discussion" section presents the research results, and the "Conclusions" section provides conclusions and recommendations for future research.

2. Review of Literature

This section is divided into two main parts. The first part addresses the theoretical background, focusing on the EKC theory, which serves as the foundation for the study. The second part presents the empirical background, discussing recent studies and findings that are relevant to the current research.

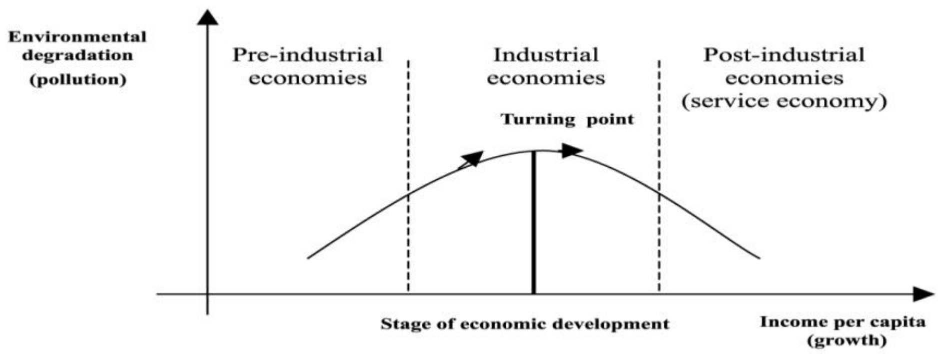
Theoretical Background

This subsection outlines the key theory and concepts pertinent to the study. According to Stern, (2004) the relationship between different environmental indicators and per capita income is suggested by EKC. Early economic growth is characterized by rising pollutant emissions and declining environmental quality. However, this trend reverses and environmental improvement is the result of economic growth over a particular level of per capita income, which varies depending on several factors. This implies that the relationship between per capita income and environmental impact/emissions is an inverted U.

Thus, the EKC has another term “stages of economic growth” as economies pass through a transition from agriculture-based economies to industrial economies results in increasing environmental degradation, and then post-industrial service-based economies consequently begin to demonstrate decreases in pollution and environmental degradation. The transition from agricultural to industrial economies results in increasing environmental degradation due to greater use of natural resources, more emission of pollutants, emphasize to increase in material output. The transition from industrial to service-based economy is assumed to result in leveling off and a steady decline of environmental degradation because of increased environmental awareness, higher environmental expenditures, efficient technologies, and increased demand for environmental quality. As income moves away from the EKC turning point, it is assumed that the transition to improving environmental quality starts (Jayasooriya, (2019) and Alam, (2015)).

According to figure 2.1, The EKC has Stages of economic growth that execute in three phases; Stage 1: Society concentrates resources in the primary sector (For example extraction, and agriculture) to satisfy necessary consumption; Stage 2: As basic needs are satisfied and further consumption is concentrated on consumption goods so resources are switched to the secondary sector (manufacturing) and environmental pollution increases and Stage 3: Society moves from the secondary to the tertiary sector (Services) characterized by much lower levels of pollution.

Figure 1: Stages of Economic Development



Source: Alarm (2015)

Empirical Background

This section examined a few studies on CO2 emission and value-added in GDP concerning EKC. Samargandi, (2017) examines the EKC hypothesis in Saudi Arabia, analyzing production volume, sectoral value addition, and technological innovation from 1970 to 2014 using ARDL methodology. The study refutes the EKC hypothesis, showing that economic growth leads to a linear increase in CO2 emissions. Growth in the industrial and service sectors drives emissions, while agriculture has an insignificant effect. Additionally, technological innovation is found to be insignificant in reducing emissions, indicating the need for substantial technological progress to reduce CO2 without harming economic growth.

Alarm (2015) has investigated the impact of the Agriculture, Industry, and Service Sector value addition in the GDP on CO2 Emissions of Selected South Asian Countries. The study found that the value added of agriculture in the GDP has a negative significant impact on

CO_2 emissions whereas industrial and services value added in the GDP has a positive significant impact on CO_2 emissions.

Shahbazet 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 the 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 is 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 from 1972 to 2011.

3. Materials and Methods

Data

The study includes annual data of CO_2 emission per capita as the dependent variable, and independent variables are agriculture value added (% GDP), industry value added (% GDP) and service sector value added (% GDP) for the period from 1965 to 2023 in Sri Lanka. The study is based on annual data and secondary data from the World Development Indicators, World Bank online database.

Model Construction

This study also developed an empirical model that corresponds to research conducted by Samargandi, (2017) and Alam, (2015) The model can be stated in the following functional form,

$$CO2 = f(\mathrm{AVA}, \mathrm{IVA}, \mathrm{SVA})$$

The empirical model of the study implies that CO_2 emission Per Capita (CO_2) is the function of agriculture value added (AVA), industry value added (IVA) and service sector value added (SVA), in Sri Lanka. 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.

$$\log CO2_t = \alpha + \beta_1 \log(AVA)_t + \beta_2 \log(IVA)_t + \beta_3 \log(SVA)_t + \varepsilon_t$$

Econometric Strategies

Initially, the study analyzed the research data using descriptive statistics and a correlation matrix. After that, the four-step procedure is taken. (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 direction causality between variables by using the Granger causality test.

The study is developed by analyzing concerning data from 1965 to 2023 by applying the ARDL approach. The ARDL representation for the current study can be formulated as in the following equation.

$$\Delta \log CO2_t = \alpha_0 + \sum_{i=1}^{p} \beta_1 \log \Delta (CO2)_{t-r} + \sum_{i=1}^{p} \beta_2 \log \Delta (AVA_{t-i}) + \sum_{i=1}^{p} \beta_3 \log \Delta (IVA_{t-1}) + \sum_{i=1}^{p} \beta_4 \log \Delta (SVA)_{t-i}$$
$$+\lambda_1 \log (CO2_{t-1}) + \lambda_2 \log (AVA_{t-1}) + \lambda_3 \log (IVA_{t-1})$$
$$+\lambda_4 \log (SVA_{t-1}) + \varepsilon_t$$

Testing for Stationary

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 were conducted to check the stationary and random walk of the variables. ADF and PP tests can be specified with intercept, and also intercept with trend. Hence study is used for these two specifications.

The null hypothesis which is the series has a unit root is rejected if the probability value is less than 0.05 for the test statistic computed. The series has no unit roots implies a stationary time series. Once the data of time series unit root properties have been identified, the researcher employs ARDL to determine the time series cointegration

In-Sample Model Comparison Criteria/Lag Length Criteria

The study has applied three information criteria namely Akaike information criteria (AIC), Schwarz information criteria (SC), and Hannan-Quinn information criteria (HQC) for model comparison. The model which gives the lowest value of these criteria was selected. As well as lag length is usually determined using the above three main methods, which are considered to be the classical procedures for determining the lag length. The lag is a lap of time (Epaphra, 2017).

Diagnostic tests of the model

To ensure the robustness and reliability of the ARDL model, a series of diagnostic tests were conducted, addressing key assumptions of the model, including serial correlation, heteroscedasticity, normality, and stability of parameter estimates. To detect the presence of serial correlation in the residuals, this study employs the Breusch-Godfrey Serial Correlation LM test. The study applies the Breusch-Pagan-Godfrey test to check for heteroscedasticity, which tests if the variance of the residuals is constant across observations.

The Jarque-Bera (JB) test was employed to assess the normality of the residuals. To ensure the stability of the model 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.

Granger Causality test

The long-run relationship between variables implies that there must be a causal relationship between the variables either bi-directional or at least uni-directional. (W. Ali et al., 2017). The present study follows a twostep procedure to identify short and long run relationships. Short run causality is determined by the significance of F statistics with reference to the Wald test and long run causality corresponding to the error correction term is determined by the significance of t statistics. The long run equation is as follows.

$$\Delta \log CO2_t = \alpha_0 + \sum_{i=1}^{p} \beta_1 \log\Delta(CO2)_{t-r} + \sum_{i=1}^{p} \beta_2 \log\Delta(AVA)_{t-i}) + \sum_{i=1}^{p} \beta_3 \log\Delta(IVA)_{t-1} + \sum_{i=1}^{p} \beta_4 \log\Delta(SVA)_{t-i} + \lambda ECT_{t-1} + \eta_t$$

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, and λ indicates the speed of adjustment coefficients.

4. Results and Discussion

The summary statistics are reported in table 1. This is necessary to ascertain the basic measure of central tendency and dispersion of the variables and how they fare over the investigated period (1965–2023).

Table 1 shows that carbon dioxide emission (per capita) has a minimum value of -1.1389 from the start-up years with a maximum of 0.0781 over the period under consideration while agricultural value added has the highest (maximum) of over the period 3.5124 and a minimum of 1.9818. Industrial Value added varies between 2.0771 (minimum) and 3.080 (maximum). Service Value Added varies between 3.6908 (minimum) and 4.0931 (maximum). The current study is conducted for a sample size of 59 observations with the JB statistic confirming that only CO2 and agriculture value added followed normal distribution.

Table 1: Descriptive Statistics for the Variables

Variable	Ln CO2	Ln AVA	Ln IVA	Ln SVA
Mean	-0.8876	2.8998	2.7031	3.9151
Median	-1.1389	3.1789	2.7151	3.9155
Maximum	0.0781	3.5124	3.080	4.0931
Minimum	-1.6108	1.9818	2.0771	3.6908
Std. Dev.	0.5642	0.5307	0.2080	0.1060
Skewness	0.2836	-.0.6080	-0.1606	-0.1446
Kurtosis	1.5452	1.6927	2.9545	2.0219
Jarque-Bera	5.9935	7.8365	0.2589	2.5572
Probability	0.0499	0.0198	0.8785	0.2784
Observations	59	59	59	59

Source: Authors Calculations

Stationary Test

The ADF test and PP test results are displayed in table 2. it can be inferred from the estimates that both tests attain all variables are stationary after taking both intercept and trend at either I (0) or I (1), it ensures that no variable is found to be stationary at 2nd difference or beyond that order of integration. Thus, the unit root test confirmed that the study can implement the ARDL bound test.

Table 2: Result of ADF and PP unit root tests

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)
Ln CO2	-1.467 (0.13)	-7.954 (0.00)*	-0.647 (0.85)	-8.157 (0.00)*	-2.078 (0.54)	-8.089 (0.00)*	-1.495 (0.12)	-7.954 (0.00)*	-0.598 (0.86)	-8.156 (0.00)*	-2.052 (0.56)	-8.088 (0.00)*
Ln AVA	-1.860 (0.06)**	-	-0.001 (0.95)	-7.689 (0.00)*	-2.137 (0.51)	-7.722 (0.00)*	-1.882 (0.05)**	-	-0.001 (0.95)	-7.689 (0.00)*	-2.130 (0.51)	-7.722 (0.00)*
Ln IVA	0.736 (0.87)	-8.159 (0.00)*	-3.247 (0.02)*	-	-3.321 (0.07)**	-	0.801 (0.88)	-8.262 (0.00)*	-3.276 (0.02)*	-	-3.400 (0.06)**	-
Ln SVA	0.866 (0.89)	-3.525 (0.00)*	-0.771 (0.81)	-3.603 (0.00)*	-2.493 (0.33)	-3.644 (0.03)*	0.737 (0.87)	-7.698 (0.00)*	-0.648 (0.85)	-7.682 (0.00)*	-2.485 (0.33)	-7.585 (0.00)*

Source: Authors Calculations
**and ** denotes statistically significant at 5% and 10% respectively*
p vales are presented in parenthesis

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 implies 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 greater than the upper critical bound at 1%, 5%, and 10% level of significance. Value added in agriculture, industry, and service are treated as predicted variables. This implies that there is cointegration between the series which confirms that value added in agriculture, industry, and service and CO2 are cointegrated for a long-run relationship for 1965–2021 in the case of Sri Lanka.

Table 3: The results of the ARDL bound Test

Test Statistic	Value	Significant.	I (0)	I (1)
			Asymptotic: n=1000	
F-statistic	5.80428	10%	2.72	3.77
K	3	5%	3.23	4.35
		2.5%	3.69	4.89
		1%	4.29	5.61

Source: Authors Calculations

According to the three information criteria (AIC, HQC, SC) used in the study selected ARDL model is ARDL (1,0,1,0). The short-run and long-run equilibrium relationship among the variables was estimated using the ARDL (1,0,1,0). approach is given in the table as follows.

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 (−0.2444)]. As required, ECT has a negative sign and it is very significant even at a 1% level. This represents that there exists a long-term relationship between the dependent variable and the regressor.

The results show that and second lag coefficients of Co2 and industrial value added are statistically significant in the short run. Also, the short-run results indicate that similar to the long-run, the coefficient of service value added has a positive significant impact whereas the coefficient of industrial value added has a positive and significant influence on CO2 emissions. Furthermore, the coefficient of agricultural value added significantly and negatively affects the CO2 emissions level. This result is consistent with Alarm (2015).

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

ARDL Model Regression				
Variable	Coefficient	Std. Error	t-Statistic	Prob.*
Ln CO2 (-1)	0.6784	0.1003	6.7637	0.00*
Ln AVA	-0.2444	0.0959	-2.5474	0.01*
Ln IVA	0.0325	0.1776	0.1830	0.85
Ln IVA (-1)	-0.0973	0.1550	-0.6281	0.53
Ln SVA	0.6065	0.2768	2.1908	0.03*
C	-1.7611	1.1383	-1.5471	0.12
Error Correction Model Regression				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(Ln AVA)	-0.7602	0.1619	-4.6935	0.00*
D(Ln IVA)	-0.2018	0.3599	-0.5607	0.57
D(Ln SVA)	1.8866	0.8689	2.1712	0.03*
CointEq (-1)	-0.3215	0.1003	-3.2050	0.00*
R-squared	0.9620	Mean dependent variable		-0.8782
Adjusted R-squared	0.9584	S.D. dependent variable		0.5645
S.E. of regression	0.1151	Akaike info criterion		-1.3881
Sum squared residuals	0.6890	Schwarz criterion		-1.1749
Log likelihood	46.2556	Hannan-Quinn criterion		-1.3051
Durbin-Watson stat	1.8472			

Source: Authors Calculations
** denotes statistically significant at 5%.*

The regression of CO2 emission's per capita function seems to fit the data quite well because the model can approximately explain 96% of the reason for the carbon emissions per capita and the rest by the error term. (Adj. R squared=0.95). The DW statistics is 1.84, which confirms that the model is not spurious regarding the fixed effects model result

Diagnostic tests of the model

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

Table 5: Model diagnostic tests results

Test	F-Statistics	Probability
Breusch-Godfrey Serial Correlation LM test	0.3155	0.7308N/S
Breusch-Pagan-Godfrey Heteroscedasticity test	0.7535	0.5873N/S
Jarque-Bera test	0.2591	0.8784N/S

Source: Authors Calculations
N/S denotes statistically not significant at 5%.

Stability of the model

To ensure the robustness of the results, researchers employ structural stability tests on the parameters of the long-run results based on the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of recursive residuals of squares (CUSUMSQ) test. A graphical representation of CUSUM and CUSUMSQ statistics is provided in Figs. 2 and 3 as follows. If the plots of the CUSUM and CUSUMSQ remain within the 5 percent critical bound, it would 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.

Figure 2: Plot of CUSUM test

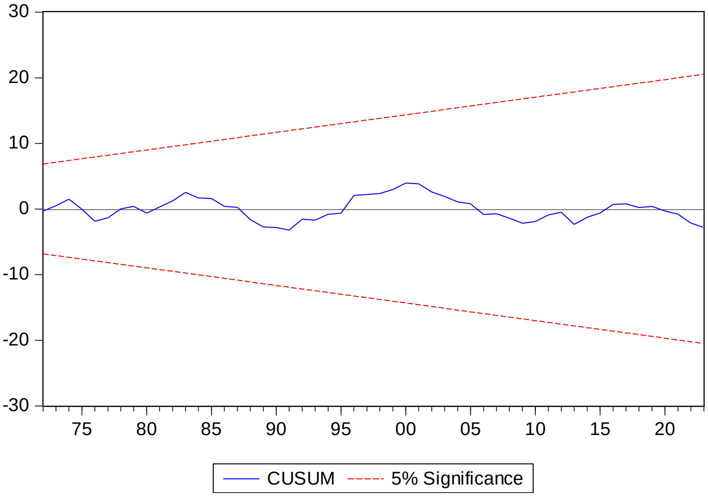
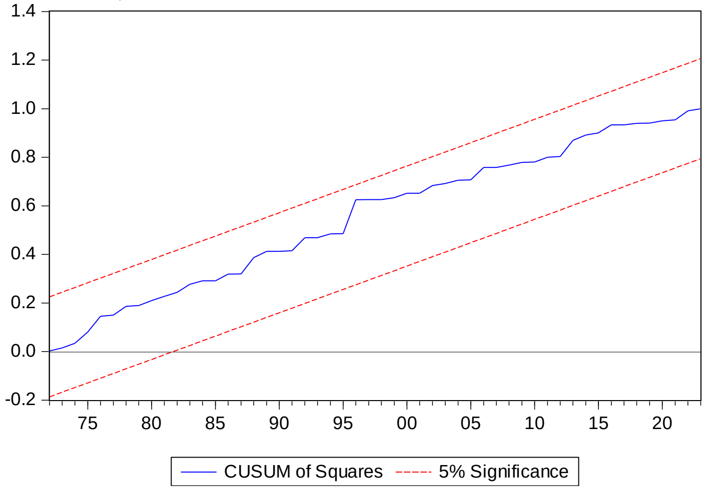


Figure 3: Plot of CUSUM of squares test



Granger causality test

After examining the long-run relationship between the variables, the study used the Engle and Granger techniques to determine the causality between the variables. Short and long-run Granger causality tests for the model are reported in Table 6.

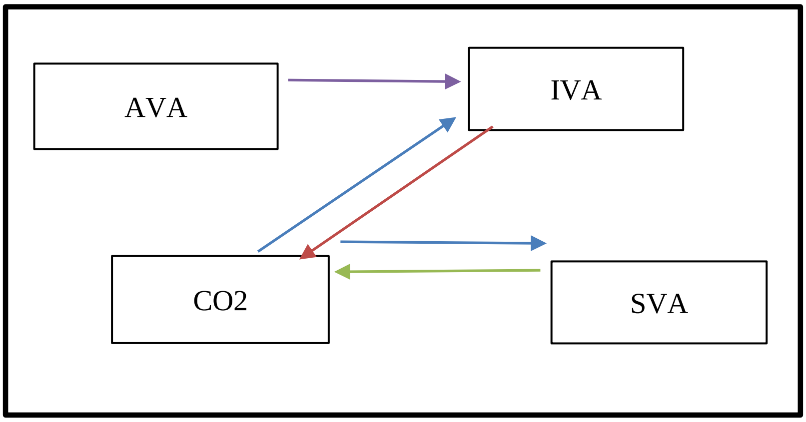
Table 6: Results of the Granger Causality Test

Dependent variable	Short-run				Long run
	CO2	AVA	IVA	SVA	ECT
CO2	-	2.1647 (0.12)	0.2507 (0.00) *	1.249 (0.00) *	-0.2935 (0.00) *
AVA	1.003 (0.37)	-	0.4757 (0.06)**	0.4428 (0.62)	-1.3542 (0.00)*
IVA	3.4798 (0.03) *	0.1937 (0.82)	-	1.061 (0.35)	0.0129 (0.81)
SVA	0.5321 (0.06) **	1.2145 (0.30)	0.3317 (0.71) *	-	0.5911 (0.00) *

Source: Authors Calculations
**and ** denotes statistically significant at 5% and 10% respectively.*
p vales are presented in parenthesis

Fig. 4 sums up short-run Granger causalities between variables. The test results found the existence of a uni-directional causality running from AVA to IVA, and there is bi-directional causality running from IVA and SVA to Co2 emission. Therefore, it can be concluded that the IVA and SVA are caused for the carbon emissions growth in Sri Lanka.

Figure.4: Result of Pairwise Granger Causality test



MANOVA made strong statistical evidence to prove that political literacy, political expertise, political knowledge, political awareness, political interest, and political participation significantly differed based on academic year, family income level, frequency of making political discussions in the family, colleagues' interest in politics, participation of societies and social works in the university, medium of study, and nature of the living area, achieving the core objective of the study. The Bonferroni post-hoc analysis detected that the exact levels of factors considered differed in the five aspects of political literacy. In addition, the statistical analysis provided evidence to detect no significant difference in political interest due to the academic year. There was no significant difference in political expertise and political awareness due to the family income level, even though there was a substantial difference in other aspects measured in political literacy due to the family income level. Further, there was no statistical evidence proving a significant difference in proper political knowledge and awareness due to family discussions on politics. It may impact a lack of an appropriate source of information related to political phenomena in families. Hence, there was a variation in the political literacy of the undergraduates according to their social factors. It is suggested that a proper mechanism be implemented to enhance political literacy among the young generation, considering the social aspects of relevant authorities. The future research implications may be compared among the faculties and universities to detect the variation due to relevant factors such as involvement with political parties and psychological and cultural factors that may impact political literacy.

5. Conclusions

In the last decades, studies about CO_2 emissions have been increasing due to concerns with global climate change. CO_2 emissions, which are enormous amounts resulting from the combustion of fossil fuels, have been accelerating drastically after the Industrial Revolution and they damage the environment. Most of the studies in the literature are empirically detecting the relationship between economic growth and environmental degradation in the context of the EKC. In this study, the relationship between value added agriculture, industry, service, and per capita CO_2 emissions is examined under the ARDL approach in Sri Lanka using annual data from 1965 to 2023.

The results of the analysis found service value added has a significant positive effect on carbon emission in the short term. However, the results of the current analysis do not confirm the EKC hypothesis which is economy moves from the secondary to the tertiary sector and environmental pollution should decrease not valid for the Model. Thus, the implication of the research is that staying service economy is not the only way of reducing CO2 emissions because value added services in GDP are also associated with CO2 emissions.

Further, other factors affecting CO2 emissions such as environmental awareness, scale, composition, and technique effects, trade openness, environmental regulations, and institutional capacity are welcome for further researchers.

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