The Relationship between Economic Growth and Electricity Consumption in Sri Lanka

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***Abstract*—This paper applies to Sri Lanka an econometric model named as Vector Error Correction Model (VECM) and simple econometric model developed by H.Y. Yang (2000) which can be used for testing the presence of the relationship between economic growth and electricity consumption in Sri Lanka for the period of 1985-2015. The results obtained from the research can be used to justify the investments in electricity sector because of the significant contribution it makes to the economy and the macro economic planning. The research has been separated into four scenarios in order to check the impact to the economic growth from different sectors (Total electricity consumption and total real GDP, Industrial sector electricity consumption and industrial Sector real GDP, Commercial sector electricity consumption and service sector real GDP, [Industrial + Commercial] sector electricity consumption and [Industrial + Service] sector real GDP). The economic output generated from [Industrial + Commercial] sector has a strong relationship with [Industrial + Service] sector electricity consumption. Also, the results obtained suggests that the past and the current electricity consumptions have a significant impact to the economic growth in Sri Lanka.**

***Index Terms*—Economic growth, electricity consumption, simple econometric model, Sri Lanka, vector error correction model.**

I. Introduction

Electrical energy plays a major role in the modern society. It is a crucial factor for both developing and developed countries. Electricity consumption leads to the productivity and industrial growth and it directly affects to the economic growth.

The relationship between economic growth and electricity consumption of a country depends on the condition of the economy of a country and the structure of it. The causal relationship between these two factors can be categorized into three factors: no causality, uni-directional causality and bi-directional causality. Also, it can be categorized as long-term causality and short-term causality.

In the Sri Lankan context, the electric utilities are operated as vertically integrated monopoly system. All utilities from electricity generation to electricity sales are managed by the government. Due to this direct ownership of the government all investments that needs for the electricity sector are done by the government, prices are set by the government and all the revenue goes to the government.

This paper reviews the relationship and the impact of electricity consumption on the economic growth. The results of this research demonstrates that the investments in electricity sector are fully justified. Also, the direction of causality helps the policy makers to get appropriate decisions and results can be used for macroeconomic planning.

II. Review of Literature

Most of the researches in this area address the causality between electricity consumption and economic growth and marginal values to economic output. R. Morimoto and C. Hope studied the impact of electricity supply on economic growth in Sri Lanka from 1960 to 1998 by using the model developed by H.Y Yang (2000) who found the bi-directional causal relationship in Taiwan for the period of 1954 – 1997. Morimoto et al. said that the current and past changes in Electricity supply have a significant impact to the economic growth in Sri Lanka. Also they predicted that for every 1 MWh increase in Electricity supply there is an extra economic output between the ranges of 88000 to 137000 [1].

Another research carried out by Zahid Asghar named as "Energy GDP Relationship: A causal analysis for five countries of South Asia" investigated causal relationship between GDP and Energy Consumption for five South Asian Countries; Pakistan, India, Sri Lanka, Bangladesh and Nepal by using Toda and Yamamoto (1995) approach and Error correction model. He found that Electricity Consumption and GDP are co integrated and there is long run relationship uni-directional causality from GDP to Electricity Consumption. Then he denotes that Sri Lanka has less energy dependent economy energy conservation policies have opposite effects. He said further in his study "As economic growth causes expansion in industrial and commercial activities and electricity is used as a basic input, therefore, energy conservation policies do not harm the economic growth [2]."

In the year of 1998 Sharmin and Mohammed conducted a research for Sri Lanka by applying Johansen's co-integration tests. They found that using trivariate Vector Error Correction Model (VECM) energy consumption to economic growth in Sri Lanka. They used energy consumption, income and price levels and presented that energy consumption is relatively exogenous and it directly influence to the income and prices [3].

The summary of other literature review on Electricity Consumption and Economic growth is presented in the

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Table I and Table II below.

TABLE I: FOR DEVELOPING COUNTRIES

Study	Country (Period)	Method	Findings
Gurgul and Lach (2011) [4]	Poland (2000-2009)	Linear and Nonlinear Causality Tests	Bidirectional Causality between GDP AND Economic Growth
Ghosh (2002) [5]	India (1950-1997)	Granger Causality	Bidirectional causality between Economic growth and Electricity Consumption
Jumbe (2004) [6]	Malawi (1970-1999)	Granger Causality, error correction model	Bidirectional causality between Economic growth and Electricity Consumption
Adom (2011) [7]	Ghana (1971-2008)	Toda and Yamamoto Granger Causality Test	Unidirectional causality from Economic growth to Electricity Consumption
Atif and Siddiqi (2010) [7]	Pakistan (1971-2007)	Granger Causality Test and Modified WALD Test	Unidirectional causality from Electricity Consumption to Economic Growth
Aktas and Yilmaz (2008) [8]	Turkey (1970-2004)	Granger Causality	Unidirectional causality from Economic growth to Electricity Consumption
Mozumder and Marathe (2007) [9]	Bangladesh (1971-1999)	Co-integration, vector error correction model	Unidirectional causality from Economic growth to Electricity Consumption

TABLE II: DEVELOPED COUNTRIES

Study	Country (Period)	Method	Findings
Shiu and Lam (2004) [10]	China (1971-2000)	Error Correction model	Unidirectional Causality from Electricity Consumption to Economic Growth
Yang (2000) [11]	Taiwan (1954-1997)	Granger Causality	Bidirectional causality between Economic growth and Electricity Consumption
Yoo (2005) [12]	Korea (1970-2002)	Error Correction model	Bidirectional causality between Economic growth and Electricity Consumption
Yoo (2006) [11]	Malaysia, Singapore	Granger Causality, Hsiao's Version of Granger Causality	Bidirectional causality between Economic growth and Electricity Consumption
Cheng (1995) [13]	US (1947-1990)	Cointegration, Granger Causality	No causality

III. METHODOLOGY

The study was conducted using time series analysis for the period of 1985 to 2015. Reliable data for electricity consumption and GDP were obtained from Ceylon Electricity Board (CEB) and Central Bank Sri Lanka (CBSL) respectively. Analysis was carried out for four scenarios to check the significant impact of the electricity consumption on the economic growth in Sri Lanka. Analyzed four scenarios are;

- *Total Electricity consumption and Total real GDP*
- *Industrial Sector Electricity Consumption and Industrial Sector real GDP*
- *Commercial sector electricity consumption and Service sector real GDP*
- *(Industrial + commercial) sector electricity consumption and (Industrial + service) sector real GDP.*

Base year for all the cases has been taken as 2015. Several econometric models have been analyzed for the Sri Lankan context such as Auto Regressive (AR), Moving Average (MA), Auto Regressive Moving Average (ARMA), Auto Regressive Integrated Moving Average (ARIMA), Auto Regressive Distributed Lag (ARDL), Vector Auto Regressive (VAR), and Vector Error Correction Model (VECM). Finally VECM is selected among the other econometric models to perform the time series analysis for the Sri Lankan data. Raw data should not be stationary and all the data should be integrated in same order to use the Vector Error Correction Model (VECM). It can be described as follows:

$$\Delta GDP_t = C_1(GDP_{t-1} + \alpha \times ELECT_{t-1} + \beta) + \sum_{i=1}^{n} a_i \times \Delta GDP_{t-i} + \sum_{j=1}^{n} b_j \times \Delta ELECT_{t-j} + E_t \quad (1)$$

where;

ΔGDP_t = First differenced real GDP at time t

$\Delta ELECT_{t-i}$ = First differenced electricity consumption at time $t-i$

E_t = Error term

C_1, α, β, a_i, and b_j = constants

A. Total Electricity Consumption and Total Real GDP

Augmented Dickey-Fuller (ADF) test was used to check the stationarity of the ΔGDP and ΔELECT. Data collection should be stationary to overcome the occurrence of spurious regression. Both data collections are significant at 5% level and the obtained results are shown in the Table III and Table IV respectively.

TABLE III: STATIONARY TEST RESULTS FOR ΔGDP

		t - Statistic	Probability
Augmented Dicky - Fuller Test Statistic		-5.010881	0.0019
Test Critical Values:	1% Level	-4.309824	
	5% Level	-3.574244	
	10% Level	-3.221728	

TABLE IV: STATIONARY TEST RESULTS FOR ΔELECT

		t - Statistic	Probability
Augmented Dicky - Fuller Test Statistic		-6.937821	0.0000
Test Critical Values:	1% Level	-4.339330	
	5% Level	-3.587527	
	10% Level	-3.229230	

Johanson cointegration test has been performed afterwards. Johanson cointegration test is used to check whether there is long run relationship between real GDP and electricity consumption. It is also significant at 5% level. Results of the Johanson cointegration test for total electricity consumption and total real GDP are illustrated in Table V.

Statistics show that there is a long run relationship between ΔGDP and ΔELECT.

TABLE V: RESULTS OF JOHANSON COINTEGRATION TEST

Hypothesized No. of CE(s)	Eigen value	Trace Statistic	0.05 Critical Value	Probability **
None *	0.548329	32.52327	15.49471	0.0001
At most *	0.336193	11.06362	3.841466	0.0009
Trace test indicates 2 cointegrating eqn(s) at the 0.05 level				
*denotes rejection of the hypothesis at the 0.05 level				
**Mackinnon-Haug-Michelis (1999) p – values				

After performing the ADF test and Johanson cointegration test, optimum time lag for the econometric model was obtained using Akaike information criterion (AIC). Obtained value is illustrated in Table VI and it is 27.66. According to the results, optimum time lag for total electricity consumption and total GDP became 5 years.

TABLE VI: ECONOMETRIC MODEL FOR THE 1ST SCENARIO

D(GDP) = C(1)*(GDP(-1)-738.17482962*ELEC(-1)-628583.194996)+C(2)*D(GDP(-1))+C(3)*D(GDP(-2))+C(4)*D(GDP(-3))+C(5)*D(GDP(-4))+C(6)*D(GDP(-5))+C(7)*D(ELEC(-1))+C(8)*D(ELEC(-2))+C(9)*D(ELEC(-3))+C(10)*D(ELEC(-4))+C(11)*D(ELEC(-5))+C(12)

	Coefficient	Standard Error	t-Statistic	Probability
C(1)	-1.246192	0.393461	-3.167257	0.0074
C(2)	0.755413	0.353174	2.138925	0.0520
C(3)	1.616068	0.362233	4.461408	0.0006
C(4)	1.847763	0.538342	3.432322	0.0045
C(5)	1.411433	0.628181	2.246857	0.0427
C(6)	0.900467	0.563594	1.597722	0.1341
C(7)	-1230.988	463.8372	-2.653923	0.0199
C(8)	-1930.714	486.5903	-3.967844	0.0016
C(9)	-1773.602	623.9508	-2.842535	0.0139
C(10)	-733.5864	629.4578	-1.165426	0.2648
C(11)	-210.8841	494.8982	-0.426116	0.6770
C(12)	355255.2	166143.6	2.138241	0.0521
R-squared 0.768404	Mean dependant var 346849.9			
Adjusted R-squared 0.572439	S.D dependant var 322271.4			
S.E of Regression 210727.4	Akaike info criterion 27.66059			
Sum squared residual 5.77E+11	Schwarz criterion 28.24565			
Log likelihood -333.7574	Hanan-Quinn criterion 27.82286			
F-statistic 3.921118	Durbin Watson statistics 1.844484			

Obtained Econometric model for the GDP and Electricity consumption of the 1st scenario are as follows.

$$\boldsymbol{\Delta GDP_t = -1.25(GDP_{t-1} - 738.17 \times ELECT_{t-1} - 628585.93) + \sum_{i=1}^{5} a_i \times \Delta GDP_{t-i} + \sum_{j=1}^{5} b_j \times \Delta ELECT_{t-j} + E_t} \quad (2)$$

After obtaining a mathematical equation from VECM, stability of the model should be checked. Four specific statistical tests should perform in order to check the stability of the model. Performed statistical tests and a brief description of those statistical tests are given below.

- Wald test
- Heteroscedasticity test
- Normality test
- Serial correlation LM(Lagrange Multiplier) test

Table VII illustrates the Wald test results between total electricity consumption and total real GDP. Chi-square value for the above case corresponds to 0.0001 probability. Hence the null hypothesis can be rejected at 5% interval.

TABLE VII: RESULTS OF WALD TEST

Wald Test			
Test Statistic	Value	df	Probability
F-Statistic	5.043221	(5,13)	0.0087
Chi-Square	25.21611	5	0.0001
Null Hypothesis : C(7) = C(8) = C(9) = C(10) = C(11) = 0			

TABLE VIII: RESULTS OF HETEROSCEDASTICITY TEST

Heteroskedasticity Test Breusch-Pagan-Godfrey			
F-Statistic	1.616133	Prob.F(12,12)	0.2088
Obs*R-squared	15.44391	Prob.Chi-Square(12)	0.2181

Table VIII shows the hetheroskedasticity test that was performed for the above model. Heteroscedasticity test is used to check whether the variance of the model is a time function. Probability of Chi-square value shows more than 5% significance and this reveals that the model has homoscedasticity which is good.

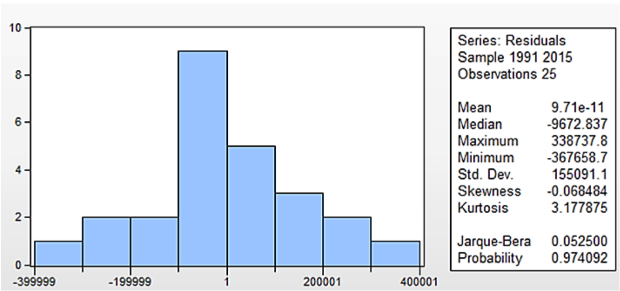

Fig. 1. Results of normality test.

Fig. 1 shows the normality test that was performed for the total Electricity consumption and total GDP. The bell shape graph can be seen in the residual series. The probability value of 0.974 reveals that it is an acceptable model.

TABLE IX: RESULTS OF SERIAL CORRELATION LM TEST

Breush-Godfrey Serial Correlation LM Test			
F-statistic	1.837894	Prob.F(5,8)	0.2117
Obs*R-squared	13.36497	Prob.Chi-Square(5)	0.0202

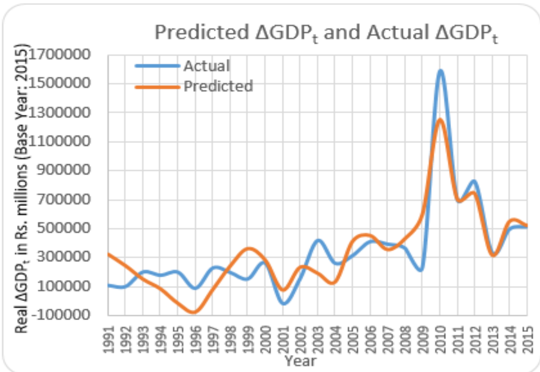

Fig. 2. Results for first scenario (R^2 = 0.77).

Serial correlation LM test (Table IX) is used to find the auto correlation of errors in the regression model. The test statistic was derived from use of residuals considering regression analysis. Chi-square value for the above case corresponds to 0.0202 probability. Hence the null hypothesis can be rejected at 5% interval.

Durbin-Watson test statistic also suggests the less auto-correlation of the residuals (Table VI). For satisfy the Durbin-Watson test, the test statistic should be in the range of 1.5 to 2.5. Obtained Durbin-Watson value for 1st scenario is 1.84. Obtained graph for first scenario is shown in Fig. 2.

Models were developed and tested for other three scenarios as well. Results of the model outputs (Fig. 3 to Fig. 5) are shown here.

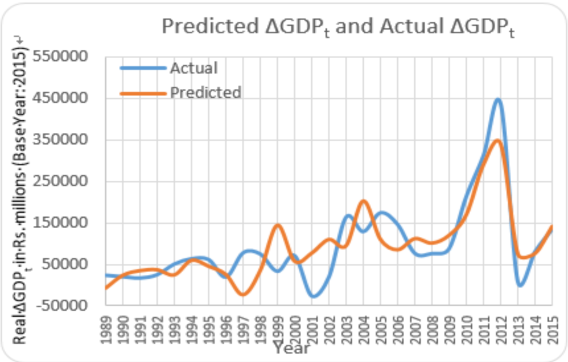

Fig. 3. Results for second scenario (R^2 = 0.68).

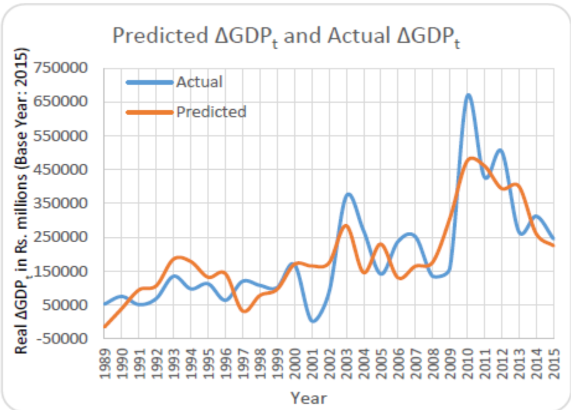

Fig. 4. Results for third scenario (R^2 = 0.66).

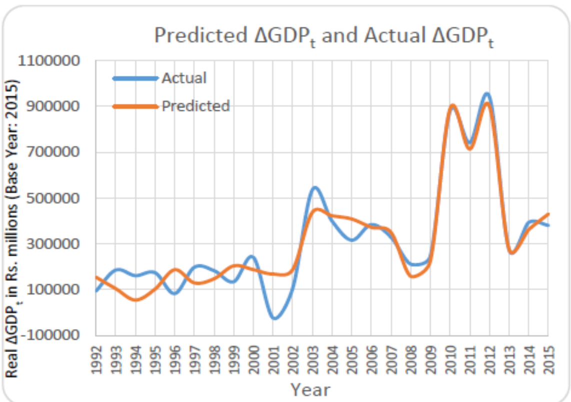

Fig. 5. Results for forth scenario (R^2 = 0.91).

B. Industrial Sector Electricity Consumption and Industrial Sector GDP

$$\Delta GDP_t = 0.05(GDP_{t-1} + 1744.81 \times ELECT_{t-1} - 5310230.37) + \sum_{i=1}^{3} a_i \times \Delta GDP_{t-i} + \sum_{j=1}^{3} b_j \times \Delta ELECT_{t-j} + E_t \quad (3)$$

C. 3rd Scenario: Commercial Sector Electricity Consumption and Service Sector Real GDP

$$\Delta GDP_t = -0.84(GDP_{t-1} - 2037.86 \times ELECT_{t-1} + 99937.98) + \sum_{i=1}^{3} a_i \times \Delta GDP_{t-i} + \sum_{j=1}^{3} b_j \, \Delta ELECT_{t-j} + E_t \quad (4)$$

D. (Industrial + Commercial) Sector Electricity Consumption and (Industrial + Service) Sector GDP

$$\Delta GDP_t = -1.2(GDP_{t-1} - 686.68 \times ELECT_{t-1} - 1844863.37) + \sum_{i=1}^{6} a_i \times \Delta GDP_{t-i} + \sum_{j=1}^{6} b_j \times \Delta ELECT_{t-j} + E_t \quad (5)$$

There was a difficulty to find a match for service sector GDP in electricity sector. But commercial sector electricity consumption falling under electricity sector can be considered as the most significant variable for regression analysis [14].

IV. Results and Conclusion

This paper examined the relationship between economic growth and electricity consumption in Sri Lanka for the period of 1985-2015. At first, four econometric models were developed and then the feasibility of these models were tested using statistical tests. The methodology that we have used here is Vector Error Correction Model (VECM) which falls under multiple time series models. The findings reflects that (Industrial + Commercial) sector electricity consumption and (Industrial + Service) sector GDP have a significant relationship.

According to the Johanson cointegration test performed, Sri Lanka has a Long run relationship between Electricity Consumption and Real GDP for all four cases considered.

We compared our results with another model (Simple Econometric Model) developed by H.Y. Yang (2000) [1]. Predicted ranges are approximately the same for both models.

These findings can be used to estimate the parameter EO (economic output) which indicates that the increase in economic output per increase of unit electricity consumption in Sri Lanka. Calculated extra economic outputs for every 1 GWh increase of electricity consumption for Sri Lanka are shown in Table X.

TABLE X: FINDINGS

	Results of from Simple Econometric Model (Rs. Mn/GWh)	Results from VECM model (Rs. Mn/GWh)
Total GDP and Electricity	559.77 to 1156.35	484.61 to 1354.92
Industrial GDP and Electricity	21.35 to 484.18	47.284 to 125.8
(Industrial + Service) GDP and (Industrial + Service) Electricity	687.98 to 1376.63	578.64 to 1068.02

Some interpretations can be made on the variations of the obtained graphs. There is a huge economic growth can be seen in 2009-2010 period. This may have happened due to end of the Sri Lankan civil war from 1983 to 2009. Civil war adversely effected to the Sri Lankan economy throughout this period.

Decline of economy in 2008-2009 period may have happened due to some undesirable situations in oil exporting countries. Sri Lankan power system was governed by oil based power plants at that time.

From 2000 to 2001, a huge decline on economic development can be seen due to energy crisis. There were some power cuts throughout the country for least 1 or 2 hours daily. Also agriculture and tourism sectors were declined in this period too.

In 1996, Sri Lanka faced a severe drought season and economy declined 3.8% from 5.5%. Decrement of paddy and food crop production was happened due to this drought condition. Power cuts were also occurred because Sri Lankan power system was governed by hydro power at that time [1].

This paper confirms the significant contribution of electricity consumption to the economic development of Sri Lanka. Hence, to maintain a good economic growth, power sector should always be in a healthy condition. So that, we can say, investments in electricity sector in Sri Lanka can be fully justified, because of the significant contribution it makes to the economy.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

All the authors conducted the research. K.K.C.S. Kiriella and W.L.T. Peiris developed the methodology and worked on literature review. K.T.A.B. Samarasinghe and W.H.A. Samarakoon analyzed the statistical data and worked on the results and conclusions. W.D.A.S Wijayapala and M.P Dias supervised the research. All authors had approved the final version.

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