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ELECTRICITY CONSUMPTION AND ECONOMIC GROWTH IN THE PRESENCE OF STRUCTURAL BREAKS: EVIDENCE FROM SRI LANKA

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Abstract: *Many studies that investigates growth and energy consumption relation uses cross country pooled data and ends with contradictory results which is still debatable and inconclusive. Such outcome is obvious due to country wide heterogeneous nature in the energy sector, its complementarities with the rest of the economy and measurement issues in energy variables. Motivating by this fact this study examines energy and growth relation using electricity consumption as a proxy for energy, in the presence of structural breaks. The country in focus is Sri Lanka, a middle income, small South Asian economy that entirely imports petroleum and coal resources. Multivariate Johansen cointegration results indicate that there is cointegration between growth and electricity consumption. The direction of the causality was tested using Toda Yamamota test, a test superior to conventional Granger causality test which indicate that the causality runs from growth to electricity consumption. Electricity demand is likely to be generated by rapid urbanization, industrial and service sector growth, since Sri Lanka has achieved 100% electrification of households. This paper contributes to this literature emphasizing country specific analysis in the energy and growth relation which could be hidden in a pooled analysis.*

1. Introduction:

The relationship between electricity consumption and income growth has been of keen interest to energy economist as well as policy makers because of the hypothesis that asserts that our existence is closely linked to availability of energy just as the existence of any heliotropes depends on energy (Beaudreau, 2010). This link which appears to have a generic effect which indeed varies across countries and the literature provides evidence on this variation (see,Apergis, 2016; Ozturk & Bilgili, 2015; Shahbaz et al., 2014). Country specific research is particularly important since the related decisions must consider country specific multidimensional aspects. i.e. catering to the growing energy demand, energy security, price stability, environmental issues, long term shift into green and renewable energy sources etc. A single study is unable disentangle all these aspects. One such issue which is not addressed in the literature is how structural breaks affects links between key energy related variables and non energy variables in Sri Lanka. A study of key related energy variables is more important for Sri Lanka because the country is in a region with abundance of hydroelectricity but with a history of relying upon imported fossil fuels for energy usage. Such a high import of fossil fuels creates a serious concern on trade deficit in the country which may have important implications for the country's economic growth prospect.

In the last decade Sri Lanka has witnessed changes in the economy not only in the size of the economy but also its structure in many important dimensions. Sri Lanka has achieved middle income status in 2014. In the energy sector Sri Lanka achieved 100% household electrification in 2016. In terms of energy efficiency Sri Lanka uses 0.47TJ (Tera Jul) to produce LKR one million worth GDP which is considered as lower intensity of energy to produce one unit of GDP[1]. On the supply side Sri Lanka depends more than 50% of total energy on fossil fuel resources (petroleum 43% and 11% coal[2]) which is entirely imported. The energy policy in Sri Lanka plans to cutdown this dependency on fossil fuel resources by 50% of its current use by 2030. Therefore it is important to investigate the effect of shocks in the energy sector on growth.

[1] See Sri Lanka Energy Policy 2019.
[2] Sri Lanka Energy Sector Assessment, Strategy and Road Map, December, 2019.

The literature has shown the importance of changes in the economy and the relation between energy and growth. Altinay and Karagol (2005) have argued that the influence of changing economic structure can result in the change of causality between energy variable and growth. Using electricity consumption as a close proxy for energy use in Sri Lanka we empirically investigate the relationship between electricity consumption and economic growth of Sri Lanka by incorporating structural breaks into the model along with recent advances in cointegration and causality testing. These test together are useful in assessing the dynamic inter-relationship as well as degree of dependence of electricity demand on economic growth. Such analysis could add a different dimension to this debate. Lack of understanding in the context of country specific effects could result in misguiding long run investment decisions and planning in electricity sector. Such misguidance could lead to power shortages which are common in many developing countries (Athukorala & Wilson, 2010).

Besides hiding country specific issues there is contradictory results between different studies related to the role of energy in economic growth when all countries are pooled. For instance in a panel study consisting of 102 countries, Le et al. (2020) find that the utilization of renewable and non-renewable energy plays a prominent role in improving income across countries. On the other hand, Huang et al. (2008) argued that expanding energy usage cannot bring about any significant effect on output growth because energy was found not to drive economic growth. Such contradictory results are not surprising when one considers cross country variation in terms of the structure of the economy, whether a country is a net energy importer or not, main sources of electricity generation, energy resource availability etc,. Besides that there could be many measurement issues related to energy related measurements between countries which could affect results.

In this study, our aim is to investigate the presumed relationship between electricity consumption and GDP growth with an emphasis on the deviations between the two variables in the presence of structural shock. This is a novel approach as our contribution is in two fold. Firstly, we depart from looking at pooling data across countries because pooling hides country effects and results in over parameterization of the model. Secondly, the existence of the relationship is analyzed considering structural breaks. This is an area we believe there has been limited research.

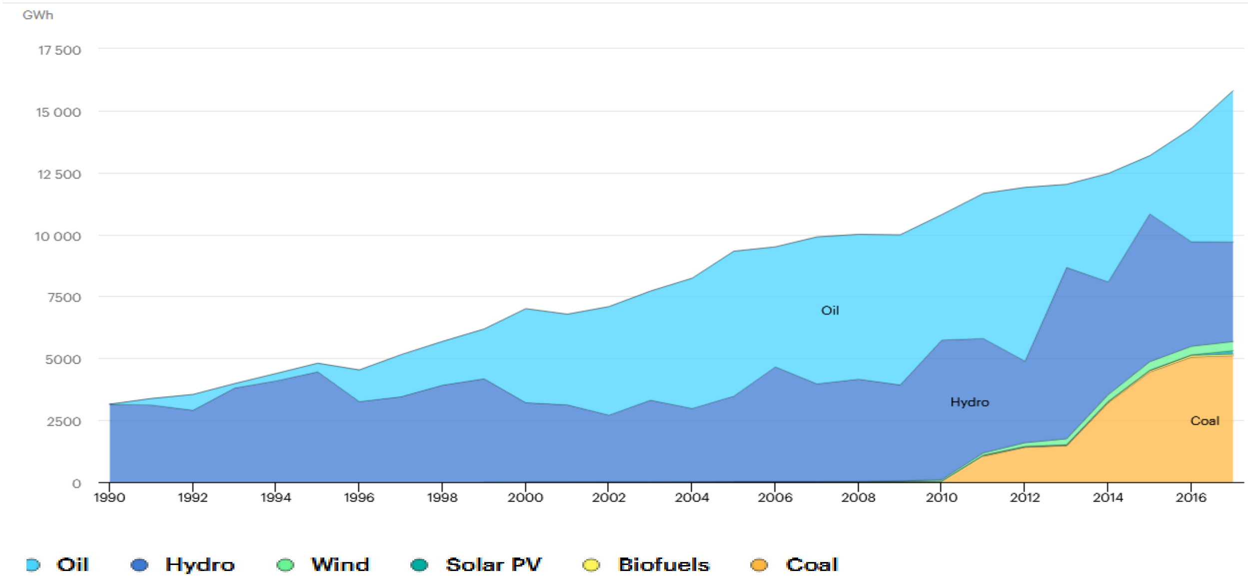
The outline of the paper is as follows: Section 2 presents an overview of the trend in electricity sector of Sri Lanka. Section 3 briefly reviews the relevant literature. Section 4 shows model construction and data collection, as well as econometric methodology adopted, section 5 presents results interpretations and section 6 concludes and points out the implications of the findings.

2. Electricity in Sri Lanka: An Overview

Sri Lanka is a Middle income country that has prematurely transitioned to a more urbanized economy driven by services and manufacturing with a GDP per capita of USD 3,853 (WDI 2019). For the past few years, Sri Lanka's electricity demand has been increasing, owing to rapid growth performance of the services sector which accounts for almost 60% of the GDP. At the same time Sri Lankan electricity sector has experienced series of reforms over the last three decades. A good detail of the institutional background regarding the Sri Lankan Electricity Supply industry can be found in (World Bank and International Finance Corporation, 2019). The electricity sector in Sri Lanka is dominated by the state owned entity, Ceylon Electricity Board, (hereafter CEB) while private sector participation is limited to power generation. The CEB is the sole vertically integrated player in Sri Lanka's power market. It is engaged in power generation, transmission and distribution. As at 2019, CEB, accounted for 71.1 percent of the total installed capacity while the independent power producers had approximately 29 percent of the total installed capacity.

Although almost 40% of Sri Lanka's electricity came from hydropower in 2017, a Significant share of this generation is based on imported liquid fuels. Particularly, expensive oil-based generation is often used to supplement for low hydropower generation during drought periods. If there is to be a significant change in this trend, more investment would be needed in renewables based generation, else this would have detrimental effect on health and environment.

Sri Lanka's coal's shares in power generation has been increasing since 2010, as can be seen in Figure 1 below.



Source: IEA Electricity Information (2020)

As can be seen from Figure 1 above, which highlights the generation mix in the country from 1990-2016, the main forms of electricity generation are hydro, fuel oil, coal and non-conventional renewable energy sources which are not immune to global shocks. The relative price and availability of the various fuel types are the major determinants in choosing between fuels, since fuels can be substituted more easily in this sector than others.

3. Literature Review

A large number of developing countries have concerns about electricity shortages due to scarce resources and infrastructures (Shahbaz et al., 2011). The availability of electricity as a factor input in economic activity has been a major contributor to the technological and scientific advancement that has improved the levels of living across countries (Apergis & Payne, 2011). There is a large literature that has centered on the role of electricity as an important energy input in production process. The exact nature and direction of causality is not clear. For instance, the question in the literature has centered on whether electricity consumption, brings about changes in the growth rate of GDP or is it the other way round? This is an old question in the literature that a consensus has largely not being reached. Similar to the causality literature, the existence of long-run relationship has remained elusive. Recently numerous studies have attempted to highlight the importance of electricity in the production process and they have tried to incorporate electricity as an additional factor of production in addition to labor and capital (Morimoto & Hope, 2004; Narayan & Smyth, 2005; Soytas & Sari, 2007; Yang, 2000) Apergis and Payne 2013 Aslan (2014), Asumadu-Sarkodie and Owusu (2017),(Bildirici & Kayikçi, 2016). An understanding of this issue would make us understand better the claim that as income increases we should expect an energy mix towards higher quality cleaner and more flexible energy carriers. It is expected that electricity demand will continue to grow at high rates as a natural consequence of industraliztion. Therefore, substantial new investments are required in order to expand the power generation capacity of Sri Lanka. We look at the case of Sri Lanka where research is extremely limited when it comes to electricity demand and growth. An early attempt was by Morimoto and Hope (2004), the study estimated the causal relationship between electricity supply and GDP using Granger causality analysis. They concluded that the change in electricity supply has a significant impact on the change in real GDP in Sri Lanka and therefore every MWh increase in electricity supply will contribute to an extra output of around US$1120-1740. But this studied missed an important issue regarding the effect of structural break. It therefore suffices to ask, what is the effect energy demand shock on the growth path of Sri Lanka, because the perceived linear relationship between growth and energy consumption cannot go on forever.

In a related study using annual data for the period 1971-2001, (Amarawickrama & Hunt, 2008) estimated an electricity demand function using the Engle and Granger two –step methodology and found the estimated long-run income elasticity to be 1.1 and the estimated long-run price elasticity to be -0.003. This was used as the basis for an indicative forecast for electricity demand underpinning their analysis of proposed electricity industry reforms for Sri Lanka. The study failed to model the persistence in the energy variables

Similarly Athukorala and Wilson (2010), using annual data for the period 1960-2007 investigated the short-run dynamics and long-run equilibrium between residential electricity demand and factors influencing demand. The study employed the unit root, cointegration and error-correction models. The long-run demand elasticities of income, own price and price of kerosene oil were estimated to be 078 - 0.62 and 0.14 respectively. The short-run elasticities for the same variables were estimated to be 0.32, -0.16 and 0.10 respectively. The results of the study suggest among others that increasing the price of electricity is not the most effective tool to reduce electricity consumption, the long-run income elasticity of demand shows that any future increase in household incomes is likely to significantly increase the demand for electricity. More importantly the study suggest that any power generation plans which consider only current per capita consumption and population growth should be revised taking into account the potential future income increases in order to avoid power shortages in the country. Contrary to the finding of Athukorala and Wilson (2010) for Sri Lanka, Shiu and Lam (2004) find that despite the remarkable growth in the electric power industry of China, the speed did not keep up to pace with the country's economic growth. The authors suggest that there appears to have been a decoupling of electricity consumption and economic growth in China, which implies that the rate of growth of electricity consumption is no longer a direct one-to one correlation with the growth in GDP. In a related study of China, (Shiu & Lam, 2004) investigate electricity consumption and growth in china for the period 1971-2000. The study applied the error-correction model to examine the causal relationship between electricity consumption and real GDP. The results indicate that real GDP and electricity consumption for China are cointegrated and there is unidirectional Granger causality running from electricity consumption to real GDP but not vice versa. The study conclude that for sustained electricity consumption, the Chinese economy has to speed up the nation-wide interconnection of power networks, to upgrade urban and rural distributions grids, to accelerate rural electrification.

4. Data and Methods.

This study used the annual time series data of the Sri Lankan economy from 1971-2018. The data was obtained from World Bank Development Indicators and IEA. All variables are converted to natural logs prior to analysis. The multivariate framework includes real GDP in billions of constant 2010 US dollars, real gross fixed capital formation (K) in billions of constant 2010 U.S dollars, real Foreign Direct investment, total labour force (L) in millions and electric power consumption (ELC) defined in kilowatt hours (per annum). Gross capital formation is seen as a proxy for capital on the basis that changes in the capital stock reflect changes in investment (Odhiambo, 2009). The use of Gross Capital Formation as a proxy for capital stock is standard in the energy literature and follows Tang et al. (2016).

4.1. Production Function

To examine the relationship between electricity consumption and economic growth we use an augmented production function in which output is expressed as a function of capital, labour and electricity consumption. We further add a fourth variable, Foreign direct investment to the model. This is standard in the energy literature (see e.g. Hamdi et al., 2014; Sbia et al., 2014) where in addition to capital, labour and energy, the fourth variable is added to the model. This is to capture the relationship between external financing and economic growth. We feel this is necessary because the country spends a great proportion of its foreign reserves on importation of fossil fuels. In addition Todaro and Smith (2012) points out that, as a result of factor accumulation we would expect higher investment rates in developing countries, either through domestic sources or through attracting foreign investment. Therefore, with higher investment rates, output would grow more quickly in developing countries.

Considering the following Augmented Cobb-Douglas production function:

$$Y_t = f(K_t, L_t, E_t FDI_t) \qquad 1$$

Where Y is output, K is the stock of capital, L is labour force used in production and E is electric energy used in producing output while FDI represents Foreign direct investment.

Econometrically, the generic form of empirical model that can be used to analyze the long-run relationship between economic growth and its determinants is written below**:**

$$\ln GDP = \beta_0 + \beta_1 T_t + \beta_2 \ln EC_t + \beta_3 \ln K_t + \beta_4 \ln FDI_t + \beta_5 \ln L_t + \varepsilon_t ----------- \mathbf{2}$$

In our analysis, we apply the Granger Causality approach developed by Toda and Yamamoto (1995) to ascertain the direction of causality between electricity consumption and economic growth. The estimation procedure begins with testing the time series properties of the data. The paper then tests for presence of cointegration using the Johansen multivariate approach.

4.2. Unit root test.

For most of the cointegration approaches, the time series properties of the individual variables need to be investigated prior to any estimation technique(Amarawickrama & Hunt, 2008). In particular, it needs to be determined whether the variables in the model are stationary in levels and therefore integrated of order zero I(0), or are non-stationary and consequently have a unit root, requiring differencing to achieve stationarity; therefore being interpreted of order d, *I(d)* where *d* is the number of times the variable in the model needs differencing to achieve stationarity. This is required since modelling with non-stationary variables can result in spurious relationships.

To test for a unit root in each of the series we employ the Lagrange multiplier unit root test with one structural break proposed by Lee and Strazicich (2013). The LM unit root test with one break in the intercept (Model A), is known as a "crash" model, and allows for a one-time change in intercept under the alternative hypothesis.

$$y_t = \delta Z_t + X_t,\; X_t = \beta X_{t-1} + \varepsilon_t \qquad \text{(3) model (A)}$$

Where Z_t contains exogenous variables. The unit root null hypothesis is described by $\beta = 1$. Testing for structural breaks is important because if there are structural breaks, then testing procedure is no longer valid, since the relationship is no longer linear in parameter. One advantage of employing the LM family of tests is that the one-break test is free of bias and spurious rejections under the null and alternative hypotheses and identify the break more accurately than the alternative linear unit root test (see, Barros et al., 2011; Bélaïd & Abderrahmani, 2013; Lean & Smyth, 2014).

4.3 Multivariate Johansen Cointegration Approach:

We utilize the Johansen Multivariate procedure which is a powerful way of analyzing data. it allows a complex interaction of causality and structure which allows us to understand systems in a much deeper way**.** The Johansen approach estimates cointegrating relationships between non-stationary variables using a maximum likelihood approach(Amarawickrama & Hunt, 2008).The Johansen procedure is based on the following specifications:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + ... + A_p y_{t-p} + Bx_t + \varepsilon_t ------4$$

Where y_t is a k -vector of non-stationary 1(1) variables (i.e electricity consumption, real GDP, real foreign direct investment, and labour force); x_t is a d-vector of innovations or disturbance.

Given the unit-root test suggests that the variables are *I(1)* they entered as endogenous variables in the unrestricted VAR in equation (4) with a lag length of 2 years, using the updated version of gretl 2020d as at the time of writing this paper. This produces both the Trace and Maximum Eigen statistics to test for the number of cointegrating vectors. Once this has been determined, we then impose the restriction based on economic theory to full identify the system. This is referred to as the Philips normalization.

4.4 Causality Test.

Causality can be investigated using a Modified Wald Test as suggested by Toda and Yamamoto (1995). This approach is superior to the traditional Granger Causality test because the Modified Wald test does not require prior knowledge of the order of integration of the variables and also it does not depend on the fact whether the variables in the system are cointgerated . The approach suggested by Toda and Yamamoto (1995) uses a VAR model in the levels and augments the appropriate VAR order *k* by the maximum order of integration *d (Soytas et al., 2007)*. Therefore, we employ the TYDL causality approach to verify the direction of causality among electricity consumption and economic growth. The optimal lag structure of the VAR system in levels is selected by the Akaike information criteria (AIC) due to its superiority over the Schwartz Bayesian criterion (SBC). Having identified d as 1 and the optimal lag using the AIC as 2, we thus estimate a VAR(3) system as shown below:

$$V_t = \alpha_v + \beta_1 V_{t-1} + \beta_2 V_{t-2} + \varepsilon_{vt} ----------5$$

Where $V_t = (Y_t, K_t, L_t, E_t, FDI_t)'$ α_v is a (5x 1) vector of constants, β_1 and β_2 are (5x 5) coefficients matrices, and ε_{vt} denotes white noise residuals.

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5. Results and Discussion

The first section of results presents a descriptive statistics of the variables, while the next section discusses the stationarity of the variables. The third section presents multivariate Johansen test results. The final section presents results of Toda-Yamamoto causality model.

5.1 Descriptive Statistics

Table 1: Descriptive Statistics

Variable	Mean	Std. Dev.	Ex. kurtosis	IQ range
lnGDP	24.454	0.44538	-1.2326	0.80569
lnL	15.892	0.06964	-0.97538	0.12439
lnFDI	20.010	0.68105	0.03620	0.87285
lnENG	8.928	0.20204	-1.0370	0.31880
lnK	22.952	0.57251	-1.3453	1.1215

5.2. Stationarity testing.

We used the LM unit root test with one break. The results are presented in table 2. Interestingly there are two variables (FDI, L) for which the unit root null is rejected and the break in the intercept is significant at 10 percent level or better. Failing to incorporate endogenous structural breaks can result in situations where researchers may incorrectly conclude that a time series is stationary with break, or "trend-break stationary," when in fact the series is nonstationary with break (Lee and Strazicich ,2013)

5.3 Multivariate Johansen test results.

To determine the presence of long-run equilibrium relationship between economic growth and its determinants we applied the multivariate Johnasen (1998) cointegration test[3]. The results of Johansen cointegration tests are presented in table 3. The Trace statistics rejects the null of $r \leq 0$ but cannot reject $r \geq 1$ and also, the Lmax statistics rejects the null of r=0 but fails to reject r=1

[3] The VECM test has been carried out using the StuctBreak package for the free econometric program Gretl http://gretl.sourceforge.net/)

at 5% level of significance. Results of both trace and maximum Eigenvalue test suggest the existence of at least two cointegrating relationship among the variables n, (i.e electricity consumption per capita, real GDP, real foreign direct investment, Gross fixed capital and Labour force; at 5% level of significance. In addition both the trace and L max test accept the null hypothesis that the smallest eigenvalue in both model is 0, so we may conclude that the series are in fact non stationary. However some linear combination may be I(0), since the L max test rejects the hypothesis that the rank of II is 0.

5.4 Causality Results.

Even though we find that electricity consumption and economic growth in Sri Lanka are cointegrated, it does not confirm the direction of causality. For this reason, we implemented the TYDL causality test proposed by Toda and Yamamoto and Dolado-Lutkepohl (1995) approach to verify the direction of causality. The results of the TYDL causality test are presented in table 4. The results suggest that electricity consumption does not granger cause GDP growth but GDP growth granger cause electricity consumption. This finding does not imply that electricity is not important for economic growth in Sri Lanka but rather that electricity consumption plays a minial role in economic growth. The results further suggest that Sri Lankan economy is not energy dependent. Implying that limited energy resources will not impose serious constraints on growth potentials. As such conservation hypothesis would not be counterproductive.

Table 2. Results of LM test with one break (Model A)

Series	TB	K	S_{t-1}	Bt
Elc	1999	7	-0.1327 (-2.5723)	-16.5799 (-1.5116)
Gdp	1999	4	-0.0319 (-1.7323)	-162.0239 (-5.7022)
Fdi	1991	7	-2.3996 (-5.0463)	-1.0191 (2.8114)
Di	1999	7	0.3857 (-3.1796)	-7.7607(-4.8505)
L	2003	6	-0.0546 (-4.7734)	-0.3321 (-2.0291)

Table 3 Johansen Cointegration test Results

Null	Optimal lag used in VAR	Eigenvalues	Trace test		Max Eigenvalue test	
			λ -trace	p-value	λ-max	p-value
Null	2	0.81139	125.99	[0.0000]***	56.715	[0.0000]***
$r \leq 0$		0.58695	47.285	[0.0121]***	30.062	[0.0101]***
$r \leq 1$		0.33410	16.487	[0.3411]	13.825	[0.2756]
$r \leq 0$		0.11939	6.0656	[0.6970]	4.3228	[0.6988]

Table 4: Granger Causality test Using VAR (1) using GDP, and ELC as dependent variables

	Dependent variable GDP		Dependent variable Elc	
	F statistics	P value	F statistics	P value
All lags of l_Elc	0.0007	[0.9781]	19.156	**[0.0001]**
All lags of l_gdp	877.16	**[0.0000]**	10.057	**[0.0028]**

Table 4, suggest that causality runs from electricity consumption to economic growth in Sri Lanka. Given that Sri Lanka has achieved 100% electrification this result could be explained considering rapid urbanization and the growth in the industrial and the service sectors. Put it differently the energy demand drives by the development in the country in Sri Lanka.

6. Conclusions and Policy Implications

Sri Lanka has recently achieved a near 100 percent electrification rate, as such it is important to investigate the relationship among the key determinants of energy so as to improve our understanding as to whether electricity consumption spurs economic growth or whether it is growth that drivers electricity consumption. This study explores the long-run relationship between electricity consumption, economic growth and Foreign direct investment. For this purpose, recent developments in unit root tests considering structural breaks have been applied. Taking a different approach this paper was able to highlight that due to country wide variation in factors such as energy demand, energy security, price stability, environmental issues, energy source mix the relation between electricity consumption and growth changes will be hidden in a pooled data analysis as such the study focused on a specific country. The results of the causality relationship suggest that Sri Lanka is not an energy dependent country because electricity consumption was found not to be a driver of economic growth, rather it was growth that was found to be an important driver of electricity consumption. The implication of this finding is that policies that focus on cutting back on our electricity consumption would not retard growth prospects. Some policies like energy conservation would not have adverse effects on growth.

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