EXAMINING THE EFFECT OF ECONOMIC GROWTH ON ENERGY CONSUMPTION DURING HIGH-GROWTH AND LOW-GROWTH PERIODS

AMIT KUMAR UPADHYAY

Contents

1 INTRODUCTION **4**

2 MOTIVATION **5**

3 OBJECTIVE **5**

4 DATA **5**

5 METHODOLOGY **6**

6 RESULTS/ DISCUSSION **10**

7 CONCLUSION **19**

8 REFERENCES **20**

1 INTRODUCTION

In the past numerous studies have been conducted to study the relationship between energy consumption and economic growth. Different studies have been conducted in different time periods to study the relationship. Some researchers have found a causality from economic growth to energy consumption whereas some have found a causality running from energy consumption to economic growth but what exactly do we mean by economic growth and energy consumption.

Energy consumption refers to all the energy used to perform an action, manufacture something. In factory, energy consumption refers to the total energy consumes in a production process. In household, energy consumption includes the use of electricity, gas, water and other energies. For transportation the energy consumption include how much diesel or gasoline vehicles consume to run. In general energy consumption does not always come from a single energy source. The availability of energy has transformed the course of humanity over the last few centuries. Not only new sources of energy has been discovered, but also in the quantity we can produce and consume. There are different measures of energy consumption, for instance joules, extrajoules, million tonnes of oil equivalent, barrel equivalent, British thermal units, terawatt-hours.

To get inferences about economic activity within a boundary,Gross Domestic Product (G.D.P) is considered as the most important metric,GDP is the final monetary value of the goods and services produced within a boundary during a specified time period.There are mainly three Methods used to calculate it, namely output, income, and expenditure method.To track economic growth changes in GDP do a reasonable job of capturing changes in economic wellbeing and national income. To track the progress of a nation's GDP growth rate can be considered a key indicator. GDP growth rate can be thought of as a measure of a nation's economic "pulse.The GDP growth rate is the measurement of the percentage change in the value of goods and services produced within a nation's borders over a specific time period. Generally, countries calculate their annual or quarterly GDP. The GDP growth rate is influenced by a complex interplay of economic, social, and political factors, including innovation, technology,entrepreneurship, and public policy. The GDP growth rate is calculated by comparing the value of a country's gross domestic product (GDP) in a given periodto the value of its GDP in the previous period.GDP used in this calculation is adjusted for inflation to obtain real GDP, which mirrors changes in the volume of goods and services produced instead of changes in their prices. Real GDP is a more accurate measure of economic growth since it takes into account the effects of inflation on the value of goods and services produced andis based on constant 2010 U.S. dollars

The energy-growth nexus is of great interest to economists as well as policymakers because of its importance in policy implications. Some researchers have argued that economic growth is the key factor that determines the use of energy consumption.

Stern and Cleveland (2004) in their study of energy and GDP growth observed that GDP growth causes energy consumption when additional variables such as energy prices and other production inputs were included. This limits the prospectus for the further large reduction in energy intensity.

Cheng (1999) applied the Granger causality method to Indian data (1952-1995) and found that the causality runs from economic growth to energy consumption in both the short run and long run. Similarly, Chan and Lee (1996) used the VECM technique to analyze China's energy behavior, suggesting that energy prices, income and the share of industry output in national income are significant factors affecting the consumption of energy.

Kraft and Kraft (1978) and Absosedra and Baghestani (1989) also found a causality from GNP to energy consumption. In the cutting edge paper Ghosh (2002) on the study between electricity consumption and economic growth in India period 1951-1997 have found by applying vector autoregression and Granger causality test that economic growth has an impact on electricity consumption.

Some researchers on the other hand also found a causality running from energy consumption to economic growth. Hwang and Gum (1991) had evident a causality from energy consumption to economic growth for Taiwan. Similarly, Masih and Masih found the same for Taiwan and Korea. Yu and Choi (1985) using data from five different countries confirmed the absence of causality from economic growth to energy consumption.

2 MOTIVATION

The study of the relationship between energy consumption and GDP growth rate has attracted significant attention among researchers, considering energy as a fundamental pillar of modern economic development. Previous studies have extensively examined this connection, but only a limited number of attempts have been made to investigate this relationship during periods of high and low GDP growth. This paper aims to examine the impact of high and low growth regimes on the energy consumption of selected Asian countries. By conducting this study, we seek to contribute to the existing literature and provide insights into the dynamics of energy consumption in different growth scenarios.The study of high and low GDP growth effects on energy consumption can be crucial for informing policy decisions, aiding economic planning and resource allocation, advancing environmental sustainability goals, and facilitating comparative analysis for identifying best practices.

3 OBJECTIVE

The objective of our study is to investigate the impact of economic growth on energy consumption during both high and low growth periods in some ASIAN countries,We aim to analyze the various factors that influence a country's economic growth, subsequently affecting energy consumption. High growth is defined as GDP growth above the mean growth of the data, while low growth refers to GDP growth below the mean growth.

4 DATA

Data for the study on the impact of economic growth on energy consumption during high and low growth periods was collected for the period from 1966 to 2021. GDP growth data was retrieved from macrotrend, while energy consumption data was obtained from ourworldindata.org(world bank). GDP was calculated as the sum of gross value added by resident producers, excluding depreciation of assets and resource depletion. The GDP growth rate was calculated by comparing the GDP of a specific year to the base year (2010 U.S. dollars). Energy consumption data included electricity, transport, and heating, calculated using the "substitution method" accounting for energy waste as heat during combustion. To ensure consistency, energy data was converted to terawatt-hours. This data provides a comprehensive basis for analyzing the relationship between economic growth and energy consumption during different growth phases, contributing to diplomatic and research-oriented discussions on energy and sustainable development.

We have taken 5 developing nations named **INDIA,INDONESIA,THAILAND ,PHILIPPINES,PAKISTAN** and 2 developed Asian nations named **JAPAN** and **SINGAPORE**. The selected countries, including developed nations like Japan and Singapore, and developing nations like India, Pakistan, Thailand, Philippines, and Indonesia, offer a diverse representation of economic, social, and geographical factors in the Asian region. This allows for a comprehensive analysis of how GDP growth affects energy consumption patterns across different stages of economic development, providing valuable insights for policy-making and understanding energy dynamics in varied contexts.

5 METHODOLOGY

In this study, we are examining the impact of GDP growth on energy consumption. The GDP growth rate serves as the explanatory variable, while energy consumption is the dependent variable. Since energy consumption growth is a time series data, it may exhibit its own persistence behavior or component. By analyzing the relationship between these variables, we aim to understand the dynamics of energy consumption growth in relation to changes in GDP growth over time.

$$\mathbf{Y}_t = (\textbf{Persistence Component}) + \mathbf{X}_t + \epsilon_t$$

where

$$\mathbf{Y}_t - \textbf{Energy Consumption Growth}$$

$$\mathbf{X}_t - \textbf{GDP Growth}$$

As we are studying the effect of GDP growth on energy consumption growth during high and low growth periods,we modify the model as

$$\mathbf{Y}_t = ((\textbf{Persistence Component})^l + \mathbf{X}_t^l)I(.)+$$
$$((\textbf{Persistence Component})^h + \mathbf{X}_t^h)(1 - I(.)) + \epsilon_t$$

where

$$I(.) = \begin{cases} 1 & \text{if } X_t \text{ belongs to low growth} \\ 0 & \text{if } X_t \text{ belongs to high growth} \end{cases}$$

I(.) is an indicator variable

(Persistence Component)^l is the persistence component during low growth.

(Persistence component)^h is the persistence component during high growth.

X_t^l is the GDP growth during low periods.

X_t^h is the GDP growth during high periods.

Now, before applying the statistical model to time series data, it is crucial to determine whether the data is stationary. A stationary time series exhibits consistent statistical properties over time, including a constant mean and variance, and a covariance between points that solely depends on the time lag. Ensuring stationarity is essential for accurate statistical tests and analyses.

To assess stationarity, the Augmented Dickey-Fuller (ADF) test is commonly employed. The ADF test, as described by Wooldridge (2013), examines the presence of unit roots in a time series, which indicate non-stationarity. By testing the null hypothesis of the presence of a unit root, the ADF test helps determine if the data is stationary or not.

If the time series data fails the stationarity test, it implies that applying a statistical model would result in an insufficient number of observations relative to the parameters to be estimated. This scenario hinders the statistical analysis and undermines its reliability.

ADF test considers the given time series data is generated through

$$\Delta y_t = \beta_0 + \beta_1 t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \ldots + \delta_{p-1} \Delta y_{y-p+1} + \epsilon_t$$

where β_0 is the constant, β_1 the time trend coefficient and p being the lag order.

The hypothesis of the ADF test is as follows

$$H_0 : \gamma = 0, \text{ (The data is not stationary)}$$

$$H_1 : \gamma \neq 0, \text{ (The data is stationary)}$$

The significancce of the test statistics is then compared to the critical value at the α% level. If the calculated test statistic exceeds the critical value at the α level of significance, we reject the null hypothesis, indicating that the time series data is stationary. Alternatively, if the p-value is less than α, we also reject the null hypothesis based on the p-value criterion.

In cases where the data is found to be non-stationary, we can employ first differencing. This involves subtracting the data at time point t from the data at time point (t-1), thereby generating a new series. The stationarity of this differenced series can then be assessed using the ADF test. If the differenced series remains non-stationary, the differencing process can be repeated until a stationary series is obtained.

By iteratively applying the differencing procedure and checking for stationarity using the ADF test, we can gradually transform the data into a stationary series.

After obtaining stationary data, we examine the presence of persistence in the time series data. By assessing the persistence behavior, we can also determine if significant autocorrelation exists. To investigate significant autocorrelation, we employ the Ljung-Box (1978) test. The Ljung-Box test evaluates whether any autocorrelation values of the time series differ from zero. To perform this test, it calculates the autocorrelation function (ACF) values for corresponding lags.

The null hypothesis of the Ljung-Box test is defined as follows:

$$H_0 : \rho_1 = \rho_2 = \ldots = \rho_k = 0 \text{ (The data is independently distributed)}$$

$$H_1 : \text{at least one } \rho \neq 0 \text{ (The data is not independently distributed)}$$

A significant test statistic value in this test rejects the null hypothesis which means the time series data is not auto-correlated. Under the null hypothesis the test statistic is given by

$$Q = n(n+1)\sum_{k=1}^{h}\frac{\hat{\rho}_k^2}{n-k}$$

Where n is the sample size, ρ_k is the sample auto-correlation at lag k, h is the number of lags being tested. Under null hyothesis the test statistic Q follows a χ^2 distribution with 'h'degrees of freedom. For significance level α, the critical region for rejection of null hypothesis is

$$Q > \chi^2_{1-\alpha,h}$$

Where $\chi^2_{1-\alpha,h}$ is the $(1-\alpha)$ quantile of the chi-squared distribution with h degrees of freedom. If $Q(k) < \chi^2_h$ for all k, then the null hypothesis cannot be rejected, so we can conclude the data are independently distributed.

If $Q(1) > \chi^2_1, Q(2) > \chi^2_2, \ldots, Q(p) > \chi^2_p$ and $Q(k) < \chi^2_k$ $\forall k > p$, then the data follows an MA(p) process.

If the null hypothesis is rejected for all k, i.e., the data are not independently distributed for all k, then the data follows either an AR or ARMA process.

To determine the process it follows, we calculate the PACF (Partial AutoCorrelation Function) values. The PACF provides the partial correlation of a stationary time series with its own lagged value, aiming to identify the extent of lag in an autoregressive model.

The hypothesis of the sample partial correlation test is given by:

$$H_0 : \tau_1 = \tau_2 = \ldots = \tau_k = 0$$

$$H_1 : \text{at least one } \tau \neq 0$$

If the test statistic $n\hat{\phi}$ is such that $\tau_1 \neq 0, \ldots, \tau_q \neq 0$ and $\tau_k = 0$ for all $k > q$, then the data follows an AR(q) process.

If $\tau_1 \neq 0, \ldots, \tau_k \neq 0$ for all k, indicating that the test statistic deviates significantly from the expected values, then the data follows an ARMA process.

A plot of the ACF (AutoCorrelation Function) values with their corresponding lags is called a Correlogram. The Correlogram provides insights into the nature of different models.

The nature of different models on the correlogram is given in the table below:

Model	**ACF**	**PACF**
AR(p)	diminishing	zero after lag p
MA(q)	zero after lag (q+1)	diminishing
ARMA(p, q)	diminishing	diminishing

After examining the persistence behavior of energy consumption growth, we model our data as follows:

$$\mathbf{Y}_t = (\textbf{Persistence Component}) + \mathbf{X}_t + \epsilon_t$$

where

$$\mathbf{Y}_t - \textbf{Energy Consumption Growth}$$

$$\mathbf{X}_t - \textbf{GDP Growth}$$

To investigate the impact of GDP during high and low growth periods, we divide the GDP data into two sub-datas: one for high growth (GDP growth above the mean) and another for low growth (GDP growth below the mean). We modify the model accordingly as

$$\mathbf{Y}_t = ((\textbf{Persistence Component})^l + \beta^l_{gdp}\mathbf{X}^l_t)I(.)+$$

$$((\textbf{Persistence Component})^h + \beta^h_{gdp}\mathbf{X}^h_t)(1 - I(.)) + \epsilon_t$$

where

$$I(.) = \begin{cases} 1 & \text{if } X_t \text{ belongs to low growth} \\ 0 & \text{if } X_t \text{ belongs to high growth} \end{cases}$$

I(.) is an indicator variable

$(\textbf{Persistence Component})^l$ is the persistence component during low growth.

$(\textbf{Persistence component})^h$ is the persistence component during high growth.

X^l_t is the GDP growth during low periods

X^h_t is the GDP growth during high periods

Once we obtain the modified model, we run an Ordinary Least Squares (OLS) regression. OLS regression is a statistical method used to analyze the relationship between a dependent variable and one or more independent variables. It estimates the parameters of a linear regression by minimizing the sum of squared differences between the observed dependent variable values and the predicted values from the linear regression model.

By applying OLS to our modified regression model and obtaining the estimated coefficients, we check the significance of GDP growth during high and low growth periods on energy consumption growth.

Before testing the significance, it is important to check if the errors follow a white noise pattern. To do this, we perform the Ljung-Box test on the error data. If the null hypothesis cannot be rejected, indicating that the errors follow white noise, we proceed with our significance testing. However, if the errors do not follow white noise, we add one more lag to the persistent component, rerun the regression, and repeat the test to ensure that the errors exhibit a white noise pattern. This process can be repeated until the errors follow white noise.

Once we confirm the absence of any remaining patterns in the errors, we proceed to test the significance of GDP growth during high and low periods on energy consumption growth.

The hypotheses for the significance tests for GDP high and low growth are:

$$H_0 : \beta^l_{gdp} = 0$$

$$H_1 : \beta^l_{gdp} \neq 0$$

and

$$H_0 : \beta^h_{gdp} = 0$$

$$H_1 : \beta^h_{gdp} \neq 0$$

To perform the test, we calculate the test statistic as

$$T = \frac{\hat{\beta}_{gdp}}{SE(\beta_{gdp})}$$

for both high and low growth periods, where SE represents the standard error of β_{gdp}.

The coefficient is considered significant if the test statistic exceeds the critical value at the chosen α level of significance. Alternatively, if the p-value is less than α, then the variable significantly affects energy consumption growth. Same process has been applied for the intercept test for high and low growth.

6 RESULTS/ DISCUSSION

As we are examining the impact of GDP growth on the expansion of energy consumption in seven Asian countries: **Thailand, India, Singapore, Pakistan, Philippines, Japan**, and **Indonesia**. We will outline the process specifically for **Thailand**, remaining countries undergo the same procedure.

Firstly, since the energy consumption data for all the countries is presented in terawatt-hours (TWh). In order to analyze the growth patterns accurately, we have converted the data into growth figures. This conversion entails subtracting the energy consumption at t^{th} time point from that of $(t-1)^{th}$ time point and subsequently dividing the result by the energy consumption at time point $(t-1)$. This calculation enables us to measure the relative growth rate of energy consumption over time.

After obtaining the growth data for energy consumption in the mentioned Asian countries, our next step involves assessing the stationarity of both the energy consumption and GDP growth data. To accomplish this, we employ the Augmented Dickey-Fuller (ADF) test.

For Thailand, ADF test result for the growth data for energy consumption is given below

```
###############################################
# Augmented Dickey-Fuller Test Unit Root Test #
###############################################

Test regression trend


Call:
lm(formula = z.diff ~ z.lag.1 + 1 + tt + z.diff.lag)

Residuals:
     Min       1Q   Median       3Q      Max
-14.4075  -2.3262   0.6389   2.5648   6.8251

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 11.10752    3.18595   3.486 0.001308 **
z.lag.1     -0.62880    0.16349  -3.846 0.000471 ***
tt          -0.20671    0.06957  -2.971 0.005259 **
z.diff.lag  -0.01404    0.16122  -0.087 0.931096
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.222 on 36 degrees of freedom
Multiple R-squared:  0.3626,    Adjusted R-squared:  0.3094
F-statistic: 6.825 on 3 and 36 DF,  p-value: 0.000928


Value of test-statistic is: -3.8462 5.3202 7.9773

Critical values for test statistics:
      1pct  5pct 10pct
tau3 -4.04 -3.45 -3.15
```

From the result, we see that the test statistic -3.8462 greater than the critical value -3.45 at a 5% level of significance. Consequently, we reject the null hypothesis, leading us to conclude that the energy consumption data is stationary.

Similarly, when applying the ADF test to the GDP growth data, the test result obtained is

```
###############################################
# Augmented Dickey-Fuller Test Unit Root Test #
###############################################

Test regression trend


Call:
lm(formula = z.diff ~ z.lag.1 + 1 + tt + z.diff.lag)

Residuals:
    Min      1Q  Median      3Q     Max
-9.5035 -1.3158  0.8843  1.7767  5.9160

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  7.00633    2.61555   2.679  0.01107 *
z.lag.1     -0.63178    0.18389  -3.436  0.00151 **
tt          -0.11406    0.05580  -2.044  0.04830 *
z.diff.lag   0.05627    0.17888   0.315  0.75492
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 3.521 on 36 degrees of freedom
Multiple R-squared:  0.3044,    Adjusted R-squared:  0.2464
F-statistic: 5.251 on 3 and 36 DF,  p-value: 0.004144


Value of test-statistic is: -3.4356 4.0291 5.9856

Critical values for test statistics:
      1pct  5pct 10pct
tau3 -4.04 -3.45 -3.15
```

The test statistic -3.4356 obtained is greater than the critical value -3.15 at a 10% level of significance. Thus, we establish that the GDP growth data is also stationary.

The plot for the stationary energy growth data and GDP growth data is given below

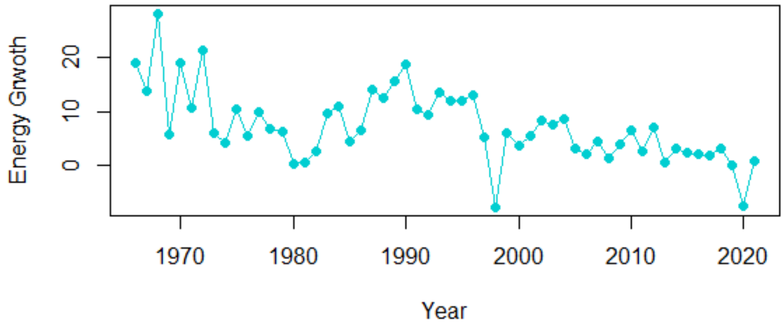

Fig: Stationary plot of energy growth data for **Thailand**

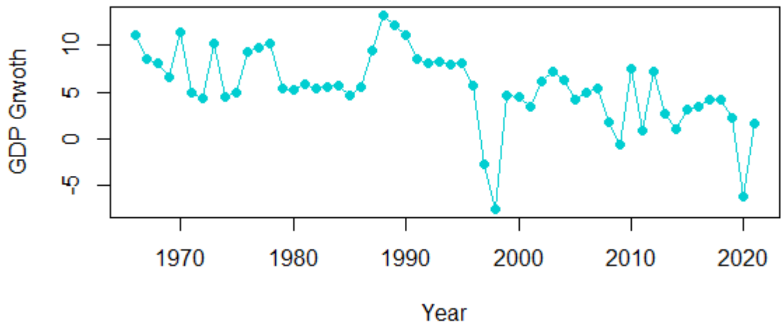

Fig: Stationary plot of GDP growth data for **Thailand**

Next, we examine the persistence behavior of energy consumption growth, as energy consumption as the dependent variable. To accomplish this, we utilize the Ljung-Box test to assess the significance of autocorrelations for various lag values. The obtained p-values for lags up to 20 are presented below:

	k	acf	Q_statistics	p_value
1	1	1.00000000	11.88452	5.660231e-04
2	2	0.44860511	25.48595	2.922779e-06
3	3	0.47553351	29.08417	2.150054e-06
4	4	0.24231139	34.56128	5.716168e-07
5	5	0.29612104	36.97201	6.067353e-07
6	6	0.19455920	39.06795	6.941394e-07
7	7	0.17962483	40.14042	1.183241e-06
8	8	0.12719848	40.35770	2.747759e-06
9	9	-0.05666591	40.43291	6.341895e-06
10	10	-0.03298925	41.08305	1.090847e-05
11	11	-0.09595676	41.18408	2.240424e-05
12	12	-0.03741376	41.25130	4.448137e-05
13	13	-0.03017574	41.45508	8.036635e-05
14	14	-0.05194037	42.63147	9.810283e-05
15	15	-0.12333661	42.63974	1.790544e-04
16	16	-0.01021703	42.74187	3.055793e-04
17	17	0.03546606	43.36630	4.244199e-04
18	18	0.08658936	44.29231	5.239184e-04
19	19	0.10408599	45.24210	6.338736e-04
20	20	0.10401724	46.43633	7.019738e-04

From the analysis of the p-values, we observe that the null hypothesis is rejected for all lag values. This rejection implies that the data is likely to follow either an autoregressive (AR) or autoregressive moving average (ARMA) process. We can also see this from the correlogram

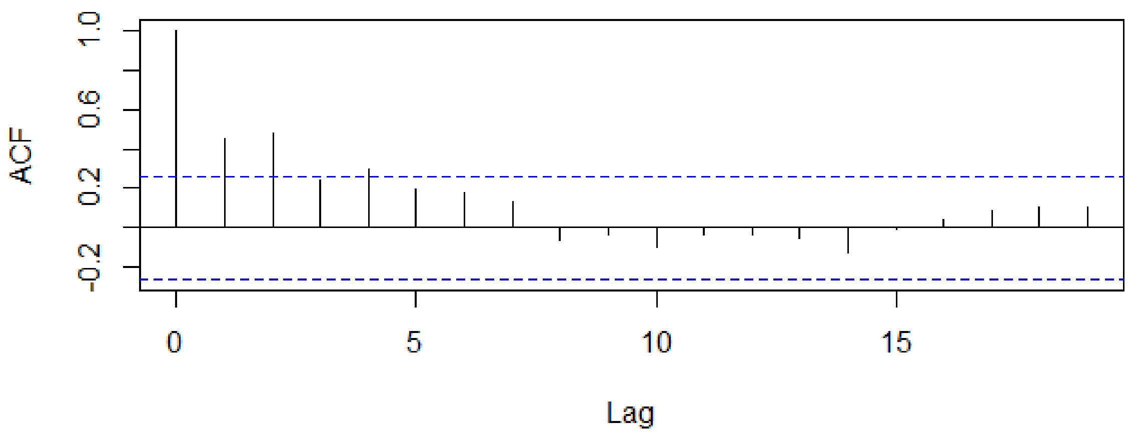

Fig: Correlogram of ACF values

Furthermore, to delve deeper into the relationship, we calculate the partial autocorrelation function (PACF) values and conduct the associated test. The resulting p-values are presented below:

	k	pacf	Q_statisctics	normal
1	1	0.448605112	3.35705326	1.96
2	2	0.343393775	2.56972371	1.96
3	3	-0.073532589	-0.55026751	1.96
4	4	0.111337048	0.83317018	1.96
5	5	0.030022964	0.22467129	1.96
6	6	-0.019522034	-0.14608952	1.96
7	7	0.008467080	0.06336183	1.96
8	8	-0.241706057	-1.80876251	1.96
9	9	-0.014703067	-0.11002768	1.96
10	10	0.003957399	0.02961446	1.96
11	11	0.008010360	0.05994405	1.96
12	12	0.091239767	0.68277590	1.96
13	13	-0.048000789	-0.35920501	1.96
14	14	-0.105334202	-0.78824899	1.96
15	15	0.179477759	1.34308857	1.96
16	16	0.081483055	0.60976335	1.96
17	17	0.021329097	0.15961235	1.96
18	18	0.046814718	0.35032927	1.96
19	19	-0.022336060	-0.16714776	1.96
20	20	0.061946748	0.46356701	1.96

By analyzing the obtained p-values, we conclude that the growth data of energy consumption follows an $AR(2)$ process. The correlogram for the same is given below

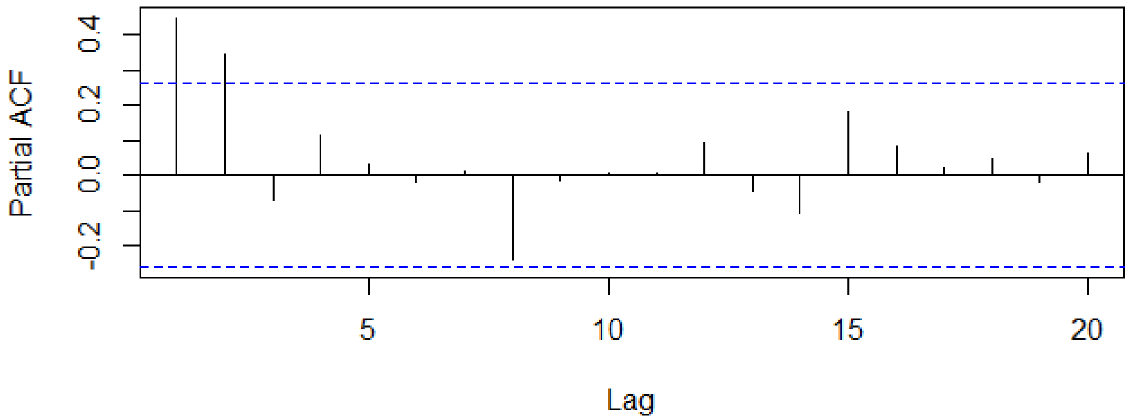

Fig: Correlogram of PACF values

The model obtained for different countries is given in the table below:

Country	Persistence Component
Thailand	AR(2)
India	No persistence component
Indonesia	No persistence component
Philippines	No persistence component
Pakistan	No persistence component
Japan	AR(1)
Singapore	No persistence component

As the persistence component obtained for **Thailand** is $AR(2)$, the autoregressive model can be written as

$$\mathbf{Y}_t = \alpha_0 + \alpha_1 \mathbf{Y}_{t-1} + \alpha_2 \mathbf{Y}_{t-2} + \beta_{gdp} \mathbf{X}_t + \epsilon_t$$

In order to investigate the impact of high and low GDP growth on energy consumption growth, we divide the GDP growth data into two periods: high growth and low growth. To achieve this division, we calculate the mean of the GDP growth data. The data points that are above the mean value are categorized as high growth data, while the data points below the mean are categorized as low growth data.

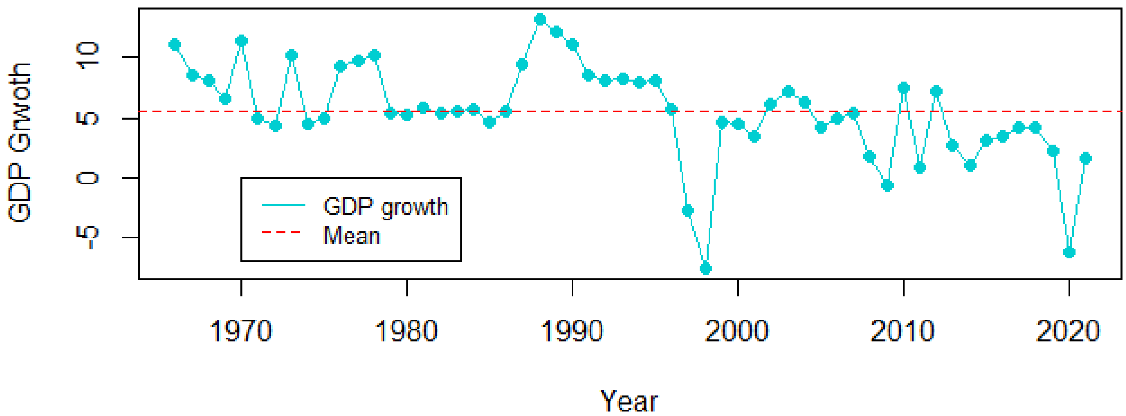

Fig: GDP growth data with mean line

Thus the modified model for Thailand is given below:

$$\mathbf{Y}_t = (\alpha_0^l + \alpha_1^l \mathbf{Y}_{t-1}^l + \alpha_2^l \mathbf{Y}_{t-2}^l + \beta_{gdp}^l \mathbf{X}_t^l) I(.) + (\alpha_0^h + \alpha_1^h \mathbf{Y}_{t-1}^h + \alpha_2^h \mathbf{Y}_{t-2}^h + \beta_{gdp}^h \mathbf{X}_t^h)(1 - I(.)) + \epsilon_t$$

where

$$I(.) = \begin{cases} 1 & \text{if } X_t \text{ belongs to low growth} \\ 0 & \text{if } X_t \text{ belongs to high growth} \end{cases}$$

$I(.) -$ indicator variable

$Y_t -$ energy growth data at t^{th}time point

$Y_i^l -$ energy growth data at i^{th}time point for low GDP growth

$Y_i^h -$ energy growth data at i^{th}time point for high GDP growth

$X_t^l -$ GDP growth data at low periods

$X_t^h -$ GDP growth data at high periods

Now we will run OLS regression to check the significance of GDP low growth and GDP high growth on the growth of energy consumption, the summary for OLS regression is given below:

```
Call:
lm(formula = Y ~ (. - 1), data = X_final_thailand)

Residuals:
     Min       1Q   Median       3Q      Max 
-14.6489  -2.6768   0.0641   3.2951  12.0419 

Coefficients:
               Estimate Std. Error t value Pr(>|t|)  
intercept_low   2.70418    1.62204   1.667   0.1023  
`y(t-1) low`    0.25718    0.19842   1.296   0.2014  
`y(t-2) low`    0.10380    0.24566   0.423   0.6746  
`gdp low`      -0.02228    0.40263  -0.055   0.9561  
intercept_high -5.29389    4.09522  -1.293   0.2026  
`y(t-1) high`   0.14011    0.17838   0.785   0.4362  
`y(t-2) high`   0.40381    0.20234   1.996   0.0519 .
`gdp high`      1.06624    0.53124   2.007   0.0506 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 5.275 on 46 degrees of freedom
Multiple R-squared:  0.7352,    Adjusted R-squared:  0.6891 
F-statistic: 15.96 on 8 and 46 DF,  p-value: 5.773e-11
```

Before interpreting the results of the OLS regression, it is essential to verify if thers is any patterns or residual correlations exist in the data. To accomplish this, we perform the Ljung-Box test,on the residual data. The null hypothesis of the Ljung-Box test suggests no autocorrelation between the data. The p-values obtained from the residual diagnostic are as follows:

	k	Q_statistics	p_value
1	1	0.8671441	0.3517472
2	2	1.1728344	0.5563169
3	3	1.7877631	0.6176014
4	4	2.6327324	0.6210358
5	5	2.6349635	0.7560461
6	6	5.1376856	0.5262792
7	7	5.9822400	0.5418246
8	8	7.9708015	0.4363275
9	9	8.7671777	0.4590375
10	10	10.0574883	0.4354642
11	11	10.0989845	0.5215060
12	12	10.2279331	0.5959718
13	13	10.3907015	0.6617156
14	14	11.8976708	0.6145204
15	15	11.9443677	0.6832350

Since the p-values of the residual diagnostic is greater than 0.05 for all k , we can conclude that there is no auto-correlation left in the data, and our model is adequate.

Thus the estimated model for Thailand is

$$\mathbf{Y}_t = (2.704(1.622) + 0.257(0.198)\mathbf{Y}^l_{t-1} + 0.103(0.246)\mathbf{Y}^l_{t-2} - 0.0222(0.403)\mathbf{X}^l_t)I(.)$$

$$+(-5.294(4.095) + 0.140(0.178)\mathbf{Y}^h_{t-1} + 0.404(0.202)\mathbf{Y}^h_{t-2} + 1.066(0.531)\mathbf{X}^h_t)(1 - I(.))$$

Upon analyzing the results, we observe that the p-value obtained for growth GDP during high period is 0.0516 which less than 0.1 at 10% level of significance, leading us to reject the null hypothesis. This signifies that high growth GDP has a significant impact on the growth of energy consumption.

Additionally, the p-value for growth GDP during low period is 0.9561 which is greater than 0.1 at 10% level of significance, leading us to not reject the null hypothesis. This signifies that low growth GDP does not have significant impact on the growth of energy consumption.

The same procedure has been applied to other countries in our study. The estimates coefficients of intercept and GDP growth for high and low periods for other countries are presented in the table below:

Country	α_0^l	α_0^h	β_{gdp}^l	β_{gdp}^h
Thailand	-1.514 (1.397)	2.001 (3.419)	0.931**** (0.251)	0.612 (0.424)
India	3.034**** (0.722)	6.201 (2.895)	0.2600** (0.1929)	-0.0185 (0.3987)
Indonesia	2.099 (1.494)	-0.193 (5.849)	0.491 (0.303)	1.181 (0.821)
Philippines	0.202 (1.175)	2.009 (4.412)	0.763** (0.286)	0.710 (0.745)
Pakistan	-2.344 (1.669)	6.585* (3.356)	1.749**** (0.488)	-0.002 (0.492)
Japan	-6.38e-16**** (1.28e-16)	2.176e-15**** (3.457e-16)	1.00**** (6.57e-17)	1.00**** (6.785e-17)
Singapore	3.719* (2.137)	0.025 (6.356)	-0.397 (0.482)	0.826 (0.608)

*,**,***,**** indicates significance at 10%, 5%, 1% and 0.1% level of significance and the numbers inside parenthesis indicate standard error.

For **Japan** the summary showed that there is a perfect fit, so summary may be unreliable.

7 CONCLUSION

From our natural instinct, we can say that there is a general positive relationship between GDP growth and energy consumption. As GDP growth increases, energy consumption tends to increase as well. So, from the table above, we can conclude the following:

Thailand: In Thailand, high periods of GDP growth have a significant impact on the growth of energy consumption. This suggests that economic expansion in Thailand leads to an increased demand for energy resources.

India: In India, both the intercept value at low growth and GDP value at low growth significantly impact energy consumption. This indicates that even during periods of low GDP growth, certain factors contribute to increased energy consumption in the country.

Indonesia: The results suggest that none of the factors examined in the study significantly affect energy consumption in Indonesia.

Philippines: Only GDP at low growth has an impact on the growth of energy consumption in the Philippines. This indicates that economic fluctuations during low-growth periods play a role in shaping energy demand in the country.

Pakistan: In Pakistan, GDP at low periods and the intercept at high periods have a significant impact on energy consumption. This suggests that both economic conditions and certain fixed factors contribute to energy demand in the country.

Developed Countries(**Japan** and **Singapore**): For developed countries like Japan and Singapore, the intercept at low growth has an impact on energy consumption. Additionally, GDP growth during high periods, low periods is also influential, particularly for Japan. This implies that both fixed factors and economic growth patterns affect energy consumption in developed economies.

8 REFERENCES

1. Examining the Linkage between Energy Consumption and Economic Growth in India by Hrushikesh Mallick The Journal of Developing Areas, Vol. 43, No. 1 (Fall, 2009), pp. 249-280.

2. On the Relationship Between Energy and GNP by John Kraft and Arthur Kraft The Journal of Energy and Development Published By: International Research Center for Energy and Economic Development (ICEED).

3. New Evidence on the Causal Relationship between United States Energy Consumption and GNP by Abosedra, S. and Baghestani, H. (1989) Journal of Energy and Development, 14, 285-292.

4. Electricity Consumption and economic growth in India by Sajal Ghosh ScienceDirect, Energy Policy, Volume 30, Issue 2, January 2002, Pages 125-129.

5. The casual relationsjip between energy and GNP: An international Comparison by Eden S. H. Yu and Jai-Young Choi.

6. The Journal of Energy and Development,Published By: International Research Center for Energy and Economic Development (ICEED).

7. Economic Growth and Energy by David I. Stern Energy and Economic Growth. Rensselaer Working Paper in Economics No.0410. Rensselaer Polytechnic Institute, Troy, NY.

8. Causality Between Energy Consumption and Economic Growth in India: An Application of Cointegration and Error-Correction Modeling by Benjamin S. Cheng Indian Economic Review, Vol. 34,(January-June 1999), Published By: Department of Economics, Delhi School of Economics.

9. Forecasting the Demand for Energy in China by Chan and Lee The Energy Journal Vol. 17, Published By: International Association for Energy Economics.

10. Electricity consumption-economic growth Nexus: An aggregated and disaggregated causality analysis in India and Pakistan by Faisal Abbas, Nirmalya Choudhury ScienceDirect, Journal of Policy Modeling 35 (2013) 538–553.

11. Electricity consumption and economic growth: Evidence from Turkey by Galip Altinay, Erdal Karagol ScienceDirect, Energy Economics, Volume 27, Issue 6, November 2005, Pages 849-856.

12. Examining the linkages between electricity consumption and economic growth in African economies by Adedoyin, Ilhan, Ifedolapo, Abiola ScienceDirect, Energy Volume 208, 1 October 2020, 118363.

13. A structural VAR analysis of electricity consumption and real GDP: Evidence from the G7 countries by Paresh Kumar Narayan, Seema Narayan, Arti Prasad ScienceDirect,Energy Policy,Volume 36, Issue 7, July 2008, Pages 2765-2769.

14. Causal Relationships between Energy Consumption and Economic Growth by Zhang Zhixin, Ren Xin ScienceDirect, Energy Procedia, Volume 5, 2011, Pages 2065-2071.

15. GDP and energy consumption: A panel analysis of the US by Brinda Mahalinga and Wafa Hakim Orman ScienceDirect, Applied Energy, Volume 213, 1 March 2018, Pages 208-218.

16. Inspecting non-linear behavior of aggregated and disaggregated renewable and non-renewable energy consumption on GDP per capita in Pakistan by Junxian Wang a, Muhammad Shahid Hassan b, Majed Alharthi c, Noman Arshed b, Imran Hanif d, Muhammad Ibrahim Saeed e ScienceDirect, Energy Strategy Reviews Volume 39, January 2022, 100772.

17. Bridging the gap between the energy-to-GDP ratio and composite energy intensity index by B.W. Ang, Tian Goh ScienceDirect, Energy Policy, Volume 119, August 2018, Pages 105-112.

18. Energy consumption and GDP revisited: A new panel data approach with wavelet decomposition by Mauricio Saldivia, WernerKrist, Josephine ScienceDirect, Applied Energy Volume 272, 15 August 2020, 115207.