Energy Consumption and Economic Growth in

Newly Industrialised Countries of Asia

A Thesis submitted in partial fulfillment for the degree of

DOCTOR OF PHILOSOPHY

In the Goa Business School

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By

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Dedicated to

My Parents

Mr David Fernandes

Mrs Pamela Fernandes

&

My Research Guide

Prof. Y.V. Reddy

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DECLARATION

I, Ms Fernandes Karen Frances, declare that the thesis entitled, **'Energy Consumption and Economic Growth in Newly Industrialised Countries of Asia'** submitted to Goa University for the award of degree of Doctor of Philosophy in Commerce is the outcome of original and independent work undertaken by me under the supervision and guidance of Prof Y.V. Reddy, Senior Professor, Goa Business School, Goa University. This research work has not previously formed the basis for the award of any Degree/ Diploma/ Certificate/ Associateship/ Fellowship or any such similar title to the candidates of this university or any other universities. I have duly acknowledged all the sources used by me in the preparation of this thesis.

Date: **Ms Fernandes Karen Frances**

Place: Goa University, Taleigao, Goa.

CERTIFICATE

This is to certify that the thesis titled **'Energy Consumption and Economic Growth in Newly Industrialised Countries of Asia'** for the award of PH.D Degree in Commerce is the bonafide record of original work done by **Ms. Fernandes Karen Frances** under my guidance and supervision. This thesis has not formed the basis of an award of any Degree/ Diploma/ Certificate/ Associateship/ Fellowship or any such similar title to the candidates of this university or any other universities.

Date: **Prof. Y.V. Reddy**

Place: Goa University, Taleigao, Goa. **(Research Guide)**

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LIST OF ABBREVIATIONS

NIC	Newly Industrialised Countries
GDP	Gross Domestic Product
CO2	Carbon
OLS	Ordinary Least Square
EU	European Union
OECD	Organisation for Economic Cooperation and Development
DOLS	Dynamic Ordinary Least Square
VECM	Vector Error Correction Model
ARDL	Auto Regressive Distributed Lag
GMM	Generalised Method of Moments
ASEAN	Association of South East Asian Nations
FDI	Foreign Direct Investment
FMOLS	Fully Modified Ordinary Least Square
GNP	Gross National Product
ADF	Augmented Dickey Fuller
BRICS	Brazil Russia India China South Africa
MENA	Middle East North Africa
US	United States
USA	United States of America
GCC	Gulf Cooperation Council
SSA	Sub-Saharan Africa
LPG	Liquified Petroleum Gas
CUSUM	Cumulative SUM
CUSUMQ	Cumulative SUM Square
OPEC	Organisation of the Petroleum Exporting Countries
PMG	Pooled mean Group
SDG's	Sustainable Development Goals
USD	US Dollar
COP	Conference of Parties

GW	Giga Watts
CAGR	Compounded Annual Growth Rate
VAR	Vector Auto Regressive
EVA	Economic Value Added
EC	Energy Consumption
REC	Renewable Energy Consumption
TY	Toda Yamamoto
AIC	Akaike Information Criterion
SC	Schwatz Criterion
HQ	Hannin Quinn
KPSS	Kwiatkowski Phillips Schmidt Shin
ADF	Augmented Dickey Fuller
PP	Philip Perron
VA	Value Added

CHAPTER 1

INTRODUCTION

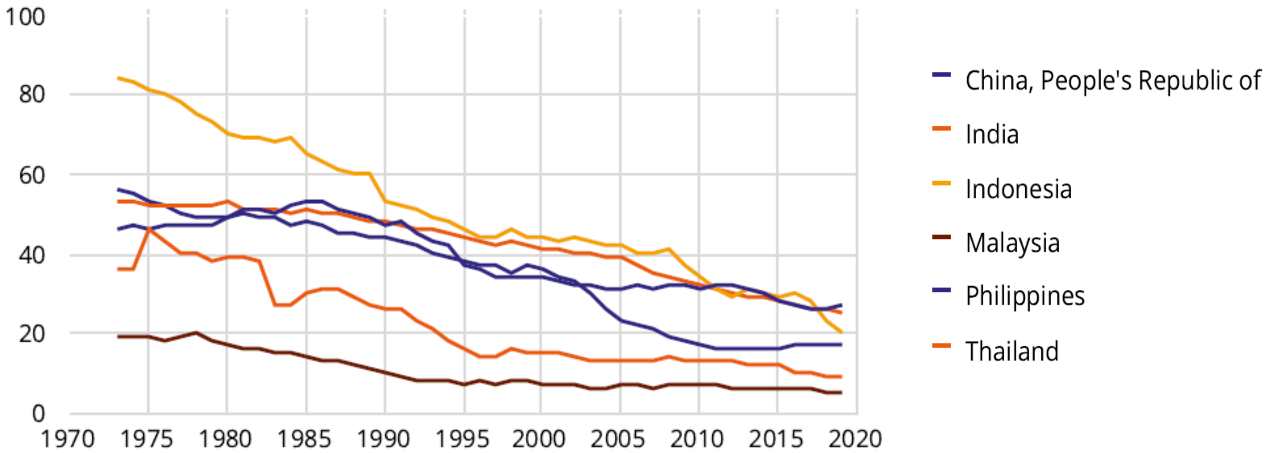
1.1 Energy Consumption and Economic growth

Sustainable growth and development of a country depends upon the availability of continuous supply of energy at a reasonable cost. Energy use leads to economic growth of an economy and economic growth further necessitates the need to consume energy. Energy consumption and economic growth have been analysed in depth by researchers since the oil crises of 1973. Energy plays a crucial role towards global development. It has the potential to improve the standard of living, improve productivity, healthcare and education or even technology in general.

The link between energy consumption and economic growth has been a topic of wide discussion. A number of studies have attempted to derive the causal relationship between energy consumption and economic growth, however no clear consensus has emerged.

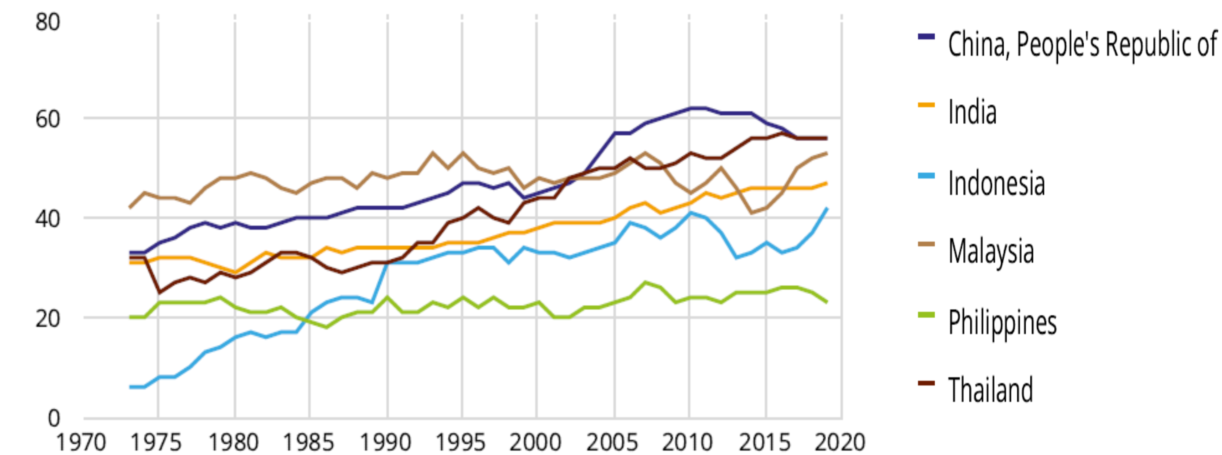
According to **Bozyk (2006) MANKIW (2010) Vithayasrichareon et al. (2012) International Monetary Fund (2016) Speier et al. (2018)** the Newly Industrialised Countries of Asia are China, India, Philippines, Malaysia, Indonesia and Thailand as the economic development of such countries falls between the classifications of First World and developing. The countries known as Newly Industrialised Countries are identified by increasing exports, economic growth and migrations from rural to urban areas. Although great cultural, geographical and economic differences exist among the NIC's, environmental impacts of modern civilisation like air pollution, water pollution or improper waste management are being observed equally. **(Speier et al., 2018)**

Figure 1 : Share of residential energy consumption in total final energy consumption



Source: energyatlas.iea.org

Figure 2: Share of industrial energy consumption in total final energy consumption



Source: energyatlas.iea.org

The share of industrial energy consumption as a percentage of total final energy consumption is increasing while residential energy consumption is showing a decreasing trend for all six countries viz. China, India, Indonesia, Malaysia, Philippines and Thailand. This indicates that the industrial sector of Newly Industrialised Countries is consuming energy at an increasing rate since 1971 in contrast to the energy consumption by the household sector.

The Newly Industrialized Countries of Asia being emerging countries are looking to accelerate economic growth which will in turn depend upon the availability of energy to sustain economic activities.

The consumption of energy is a result of certain factors which directly or indirectly have an impact of energy consumption of a country. It is necessary to identify and study those factors that have an impact on energy use for a country to formulate appropriate energy policies and to control such factors accordingly.

The factors identified as those that affect energy consumption based on literature review are Economic growth (GDP), Industrialisation, Exchange rate, Financial development and Trade openness.

Economic growth measured by Gross Domestic Production (GDP) refers to the total output of an economy. An increase in GDP indicates that the economic growth of a country is robust. High economic growth implies more energy requirements to sustain economic activities. When a country is an emerging economy, it moves from an agricultural based economy towards industry and service. The rapid spread of industries will lead to an increase in demand for various forms of energy to support output. Similarly, the expansion of the service sector leads to increased energy requirements. Exchange rate refers to the rate at which domestic currency can be exchanged for foreign currency. An increase in exchange rate would discourage import of energy thereby reducing energy consumption or increase the cost of energy consumption since emerging countries are not self -sufficient in energy resources. Financial development refers to the availability of finance especially with reference to the private sector. Increase in financial development will encourage energy demand as an economy will be able to afford energy requirements. Trade openness is the ratio of trade to GDP of a country. Higher the trade openness of a country, higher energy consumption of a country to meet export demand.

This study makes a multivariate attempt to identify which variables have a significant impact on energy consumption for China, India, Indonesia, Malaysia, Philippines and Thailand. This will assist individual countries to monitor identified variables in order to achieved desired policy outcomes with respect to energy consumption and related environmental issues.

Since the oil crises of the 1970's energy consumption and its relationship with economic growth has awakened the curious minds of numerous researchers. A study undertaken by **Kraft & Kraft (1978)** which resulted in the formulation of four hypothesis to explain how energy consumption and economic growth interact has encouraged research towards the area of energy economics over the last 40 years.

There can be four forms of relationship between energy consumption and economic growth as advocated by **Kraft & Kraft (1978)** through four hypothesis viz. Growth Hypothesis, Conservative Hypothesis, Feedback Hypothesis, Neutrality Hypothesis.

Unidirectional causality from energy consumption to economic growth (growth hypothesis) signals the economy is energy dependent in which case energy conservation policies may have a negative impact on economic growth. On the other hand, unidirectional causality from economic growth to energy consumption (conservation hypothesis) indicates that energy conservation policies may not have an impact on economic growth.

Bidirectional causality between energy consumption and economic growth (feedback hypothesis) reflect the interdependence association of energy consumption and economic growth. Absence of causality between energy consumption and economic growth supports the neutrality hypothesis. Literature in the domain of energy economics has gained momentum after this remarkable study.

The overall growth of an economy is dependent upon the growth and development of various sectors. Energy is an essential resource necessary for sectoral growth and development of a country.

This study attempted to understand the relationship between energy consumption and GDP at the sectoral level for the six Newly Industrialised Countries (NIC's) countries. The economic growth of each sector is measured in terms of value added which refers to the contribution of each sector towards the overall GDP of the country. The sectors identified include agriculture, industry, service and residential. This will help one to understand in which sector of the economy growth dependent on energy and vice versa.

In view of the important role energy plays towards the growth and development of an economy, research must be directed towards understanding the fact that renewable energy consumption is the engine towards a promising future. This is because of the alarming increase in environmental degradation, climate change and over-dependence on fossil fuels that non- conventional energy is essential. This study aims to understand the linkage between renewable energy consumption and GDP for the six Newly Industrialised Countries. Since these economies are growing and developing at a fast pace, the energy requirements are increasing, and sustainability in growth and development is the need of the hour. Therefore, it is vital that countries understand the need to identify and employ renewable energy which does not have an adverse impact on the environment i.e. does not cause environmental degradation as compared to conventional sources of energy. In addition, CO_2 emissions is a variable used in this study to measure the quality of the environment of a country and its relationship with renewable energy use and economic growth. Countries are making efforts to tackle environmental issues. Thus, this study attempts to understand the relationship between renewable energy use, GDP and CO_2 emissions.

1.2 REVIEW OF LITERATURE

1.2.1 Determinants of Energy Consumption

Researchers have identified and examined the various possible factors that lead to energy use in a context of time series and panel studies for countries.

Sadorsky (2010) examined the impact of financial development on energy consumption for twenty- two emerging economies by employing generalized method of moments estimation techniques for a period from 1990 to 2006. Results indicated that there exists a positive and significant relationship between energy consumption and financial development when measured using stock market variables. Therefore, emerging countries whose stock markets are developing due to economic growth will observe increase in energy consumption.

Sadorsky (2011) aimed to study the interaction between trade, income and energy consumption by applying panel cointegration techniques for a sample of eight middle eastern countries for a period from 1980 to 2007. In the short run exports prove to cause energy consumption according to Granger causality test while a bidirectional causal relationship is found between imports and energy consumption. Fully Modified OLS was applied to measure long run elasticities and results revealed that a percent increase in per capita exports increases energy consumption by 0.11% while a percent increase in exports increases energy consumption by 0.04%.

Sadorsky (2012) attempted to study the relationship between energy consumption, output and trade for a sample of seven countries belonging to South America for a period ranging from 1980 to 2007. Panel cointegration and regression techniques were applied where panel cointegration tests indicated a long run relationship between output, capital, labour, energy and exports as well as between output, capital, labour, energy and imports. Besides, in the short run there exists a feedback relationship between energy consumption and exports, output and exports and output and imports. There also exists a unidirectional relationship running from energy consumption to imports. However, in the long run there exists a causal relationship between trade and energy consumption. Therefore, if energy consumption is mitigated to preserve the environment; trade will reduce thus environmental policies should be framed keeping in mind the need to maintain trade of these countries.

Shahbaz & Lean (2012) assessed the relationship among energy consumption, financial development, economic growth, industrialisation and urbanisation in Tunisia by employing Autoregressive Distributed Lag Bounds testing approach to cointegration and Granger causality test for a period from 1971 to 2008. Results of analysis indicated that long run bidirectional causalities between financial development and energy consumption, financial development and industrialisation, Industrialisation and energy consumption exists which suggests that policy makers should recognise the role of financial development, urbanisation and industrialisation when formulating energy policies.

Çoban & Topcu (2013) investigated into the relationship between financial development and energy consumption for countries belonging to the European Union (EU) for a period from 1990-2011. At an aggregate level no significant relationship is found between financial development and energy consumption. When countries were segregated into old and new members, evidence of the impact of financial development on energy consumption is found in the old member countries irrespective of the source of financial development. However, the impact of financial development on energy consumption of new member countries is sensitive to how financial development is measured.

Dedeoğlu & Kaya (2013) attempted an investigation into the relationship between energy use, GDP, imports and exports for OECD countries at an aggregate level. Panel cointegration and causality tests are applied to examine the long run relationship and causal links between the variables. Results of Canning and Pedroni causality tests reveal the bidirectional causal links between variables exists. Panel DOLS was also applied to identify long run elasticities and results indicate that a percent increase in GDP, exports and imports result in an increase in energy consumption by 0.32%, 0.21% and 0.16% resp.

Islam et al. (2013) explored the causal relationship between energy consumption, aggregate production, financial development and population in Malysia by using Vector Error Correction Model (VECM) from 1971 to 2009. It was concluded that economic growth and financial development of the country influences energy consumption in the long run and short run. However, there is a relationship between population and energy consumption in the long run where population has a positive impact on energy consumption.

Mahalik & Mallick (2014) using ARDL approach to cointegration investigated into the relationship between energy consumption, economic growth and financial development in India from 1971 to 2009. ARDL approach to cointegration was applied to conclude that Energy consumption is positively and significantly impacted by urban population however negatively and significantly impacted by financial development, economic growth and proportion of industrial output.

Nasreen & Anwar (2014) studied 15 Asian countries and tried to explore the relationship between economic growth, trade openness and energy consumption from 1980 to 2011 by applying panel cointegration and causality test. Results indicated that trade openness had a positive impact on energy consumption. Panel causality test results advocate that there also exists a bidirectional causal link between economic growth and energy consumption as well as trade openness and energy consumption.

Rafindadi (2014) attempted to predict the effect on energy consumption by financial development and trade openness for Germany by applying econometric techniques which included Zivot-Andrew structural break unit root test, the Bayer-Hank combined cointegration test, the ARDL bounds test and the VECM Granger causality test from 1970 to 2013. It was concluded that financial development, capital use and trade openness decline energy demand.

Zeren & Koc (2014) examined the relationship between energy consumption and financial development of Newly Industrialised Countries using Hatemi-J asymmetric causality test where segregation of positive and negative shocks is possible. Three indicators were used viz. deposit money bank asset to GDP, financial system deposits to GDP and private credit to GDP were identified for a period from 1971 to 2010. Results of analysis conducted revealed that positive and negative shocks exists for Malaysia and Mexico. For Philippines, energy consumption caused financial development in only negative shocks. A bidirectional causal link between variables was found for India, Turkey and Thailand.

Komal & Abbas (2015) attempted to explore the relationship between financial development, economic growth and energy consumption for Pakistan for a period from 1972 to 2012. GMM estimation technique was employed to identify impact among variables and energy prices as well as urbanization was included in the model. Results proved that a positive impact of urbanization, financial development and economic growth on energy consumption exists and negative impact of energy prices on energy consumption was observed.

Shah et al. (2015) examined the linkages among energy consumption, foreign direct investment, financial development and trade in case of ASEAN countries using techniques such as ARDL testing approach and Granger causality test. Results indicated that there exists a long-run relationship among all variables viz. energy consumption, foreign direct investment, international trade, financial development and short-run unidirectional causality running from FDI inflows to energy consumption, energy consumption to financial development and energy consumption to trade. This study has emphasised upon the need for policy makers to formulate appropriate policies to encourage inflow of foreign Direct Investment, strengthen the financial sector, expand trade and ensure supply of energy while ensuring that sustainable growth and development of ASEAN nations are achieved.

Obadi & Korček (2015) studied what drives energy consumption in the European Union (EU) and made an attempt to verify if energy efficiency plays a major role. The logarithmic mean Divisia index decomposition technique was employed on three different levels of data aggregation for 28 EU countries in pre-crisis period (2004-2008) and crisis period (2008-2012) and it was found that energy intensity effect was the major factor influencing energy consumption. The structural effect had a major influence on energy consumption during the period of oil surge and it was suggested that as the economy moves towards the service sector, the improvements in energy efficiency will decrease.

Shahbaz et al. (2015) investigated into the impact of urbanisation, population, affluence and technology on energy consumption for Malaysia on a quarterly basis from 1970 to 2011. In order to identify unit root properties and nature of relationship in the presence of structural breaks Clemente–Montanes–Reyes structural break unit root test, ARDL bound testing approach and VECM granger causality test was employed. Results indicated that urbanisation, affluence, trade openness and capital stock have a significant impact on energy consumption

Rafindadi (2016) investigated into the nexus between economic growth, energy consumption, financial development, trade openness and CO_2 emissions in Nigeria from 1971 to 2011 by applying ARDL bounds testing approach to cointegration, the Zivot–Andrew structural break test, and the Bayer–Hanck combine cointegration analysis. Analysis advocated that financial development stimulates energy demand but lowers CO2 emissions while economic growth lowers energy demand but increases CO2 emissions. Trade openness increases energy consumption but improves environmental quality by lowering CO2 emissions.

Shahbaz et al. (2016) attempted to explore the relationship between globalization and energy consumption for India with the help of variables such as economic growth, financial development and urbanization. Bayer-Hanck cointegration test was applied to identify cointegration among variables after which ARDL model was employed. Results of analysis applied revealed that acceleration of globalization and financial development is negatively related to energy consumption however economic growth and urbanization lead to increased energy demand**.**

Gamoori et al. (2017) investigated into the links between energy consumption, foreign investment and economic growth for the organisation of the Islamic Conference Countries for a period from 2000 to 2014. Three panel cointegration tests were applied viz. Kao's residual cointegration test results, Pedroni's residual cointegration test and Johansen Fisher panel cointegration test. Results indicate that foreign trade, investment and financial development have a significant positive impact on energy consumption.

Kahouli (2017) analysed the short run and ling run causal links between economic growth, energy consumption and financial development of six South Mediterranean Countries i.e. Algeria, Egypt, Israel, Lebanon, Morocco and Tunisia for a period from 1995 to 2015. Unit root tests such as ADF and PP unit root tests, ARDL bound testing approach to cointegration and VECM was employed. Analysis indicated that long run cointegration exist between the variables. In addition, short run unidirectional causal links exists for countries except for Egypt.

Rafindadi & Ozturk (2017) investigated whether financial development, trade openness and economic growth enhances energy consumption in South Africa by employing econometric techniques such as Ng- Perron unit root test, Zivot -Andrew structural break test, ARDL bounds testing approach to cointegration, Bayer-hanck combines cointegration test and VECM granger causality approach for a period from 1970 to 2011. Results of analysis indicated that all three variables i.e. financial development, trade openness and economic growth lead to energy consumption.

Hassan (2018) examined the impact of world oil price, economic growth, population, urbanisation and energy access on energy consumption for five countries belonging to the Association of Southeast Asian Nations from 2000-2016. Results of panel data techniques employed advocate that economic growth, energy access and urbanization have significant effects on the demand for energy at an aggregate level. This study suggests that policy makers of select countries must impress upon the need for supply of reliable and affordable energy having minimum impact on the environment so as to achieve sustainability of a country's development.

Bashir et al. (2019) investigated the causality between human capital, energy consumption, CO2 emissions, and economic growth for Indonesia from 1985 to 2017 by applying a Vector Error Correction Model. Findings of analysis indicated that human capital, consumption of energy, and economic growth cause CO2 emission and there is causal evidence between CO2 emission and energy consumption in the short- run.

Dumrul (2019) investigated into the impact of financial development on the energy consumption of Turkey from 1961 to 2015 by using Johansen cointegration test FMOLS and DOLS test. Results indicated that financial development and economic growth have a positive effect on energy consumption.

Morelli & Mele (2020) examined the relationship among variables such as GDP, CO2 emissions and energy use for Vietnam from 1970 to 2014. Econometric techniques such as Toda Yamamoto test, Johansen and Juselius approach and Variance decomposition were applied. Analysis indicated that economic growth leads to energy consumption.

Ridzuan et al. (2020) analysed the macroeconomic indicators that influence Malaysia's electrical consumption for a period from 1970 to 2016 by employing ARDL model on macro-economic indicators which included economic growth, foreign direct investment flows, trade liberalization, population growth, urbanization population, financial development, industrialization, inflation and household consumption expenditure. Results indicated that economic progression and urbanization that lead to increase in electrical consumption, whereas financial deepening and higher inflation leads to reduction.

1.2.2 Relationship Between Energy Consumption and Economic Growth

Various studies have been conducted in the area of energy economics from a panel perspective as well as time series perspective.

Benjamin S.Cheng (1999) studied the causality between energy consumption and economic growth using Philip Perrons unit root test, Johansen’s Cointegration test and Hsiao's Granger multivariate causality on variables such as GNP, energy consumption, gross fixed capital formation and population to conclude that causality runs from economic growth to energy consumption both in the short run and in the long run and causality flows from capital to economic growth in the short run.

Fatai et al. (2004) modelled the causal relationship between energy consumption and GDP in New Zealand, Australia, India, Indonesia, Philippines and Thailand using Granger’s causality test, Johansen’s maximum likelihood approach, Toda Yamamoto approach and ARDL approach to find that energy conservation policies may not have significant impacts on real GDP growth in industrialized countries such as New Zealand and Australia compared to some Asian economies.

Lee (2005) with regard to 18 developing countries investigated the co-movement and the causality relationship between energy consumption and GDP by employing panel unit root tests, Pedroni heterogeneous panel cointegration test and FMOLS for a period from 1975 to 2001. concluded that long-run and short-run causalities run from energy consumption to GDP, but not vice versa and energy conservation may harm economic growth in developing countries.

Lee & Chang (2008) re-investigated the co-movement and the causal relationship between energy consumption and real GDP using variables such as Real GDP, energy use, labor force and real gross capital formation with the help of panel unit root tests, heterogenous panel cointegration and panel -based error correction models for 16 Asian countries from 1971 to

2002. Findings of analysis confirmed that there is a positive long-run cointegrated relationship between real GDP and energy consumption as well as long-run unidirectional causality running from energy consumption and economic growth.

Yuan et al. (2008) tested the existence and direction of causality between output growth and energy use in China at both aggregated total energy and disaggregated levels using variables such as total employment and real GDP, net value of fixed assets (capital stock), total energy consumption and as well as electricity as concluded that there exists long-run cointegration among output, labor, capital and energy use.

Adhikari & Chen (2013) examined for 80 developing countries the long run relationship between energy consumption and economic growth from 1990 to 2009 using panel cointegration test and panel dynamic ordinary least squares (DOLS) by categorizing the countries into three income groups viz. upper-middle income countries, lower-middle income countries and low income countries and found out that energy consumption had a positive and statistically significant impact on economic growth in the long-run for the group of 80 countries however for upper-middle income countries and lower -middle income countries a strong relation runs from energy consumption to economic growth and the reverse in case of low income countries.

Shahbaz et al. (2013) investigated the relationship between energy use and economic growth considering factors such as real GDP, energy use, financial development, real trade openness and real capital use for a period from 1971 to 2011 for China by employing ARDL bounds testing approach to cointegration and concluded that all factors considered have a positive impact on economic growth and there exist a unidirectional relationship running from energy use to real GDP. There also exists a bidirectional causal link between energy use and financial development; international trade and energy use as well as capital and energy use.

Nasreen & Anwar (2014b) explored the causal relationship between economic growth, trade openness and energy consumption for 15 Asian countries from 1980 to 2011 by applying panel cointegration and causality test to examine the long run relationship and causal relationship between variables. Results of analysis indicate that there exists a positive impact of economic growth and trade openness on energy consumption and a bidirectional causality between economic growth and energy consumption, trade openness and energy consumption.

Cui (2016) analyzed the relation between China's economic growth and energy consumption using ADF test, Johansen cointegration test and Granger causality test OLS estimation and concluded that there is a linear relationship between economic growth, energy consumption and carbon dioxide emissions. This study confirmed that China still relies on energy consumption which causes environmental pollution to promote economic growth and stress in laid upon the need to aim for a low carbon economy by participating in international environmental cooperation for environment conservation.

Matei & Stamin (2016) for BRICS countries explored the nexus between energy consumption and economic growth from 1989 to 2014 by employing panel data models such as Westerlund panel cointegration test, DOLS, FMOLS and advocated that an increase in real per capita GDP have a positive and statistically significant effect on per capita energy consumption and vice-versa

Mirza & Kanwal (2017) explored the causality between economic growth, carbon emissions and energy consumption for Pakistan from 1971 to 2009 by applying Johansen's cointegration test, ARDL approach to cointegration and Granger's causality test. Results indicated that bidirectional causalities between all variables under study. Therefore, sustainability is to be ensured by employing renewable energy in the energy mix and carbon emissions should be curtailed though appropriate policy implementation as advocated by the study.

Shahbaz, Thi, Kumar, & Roubaud (2017) investigated the asymmetric relationship between energy consumption and economic growth in India on quarterly data from 1960 to 2015 by applying a nonlinear autoregressive distributed lag bounds testing approach to find that negative shocks in energy consumption and financial development have impacts on economic growth while capital formation causes economic growth. On the other hand, symmetric analysis advocated that capital formation causes economic growth.

Bakirtas & Akpolat (2018) investigated the causal relationship between energy consumption, urbanization and economic growth in new emerging market countries using Carrion-iSilvestre et.al panel unit root test and Dumitrescu-Hurlin panel Granger causality test for New

Emerging Market countries from 1971 to 2014 by applying bivariate and trivariate granger causality analysis. Results indicated that economic growth causes energy consumption according to bivariate granger analysis and trivariate granger causality analysis indicated that energy consumption and urbanization causes economic growth; economic growth and urbanisation causes energy consumption; energy consumption and economic growth causes urbanisation indicating various causalities between the variables.

Shahbaz et al. (2018) studies the linter-linkages between energy use and economic growth for the top ten energy consuming countries by employing an approach developed by Sim and Zhou (2015) known as the Quantile-on- Quantile (QQ) approach. For a period from 1960 to 2015. Results indicated that a positive relationship exists between energy consumption and economic growth. For China, India, Germany and France it was concluded that energy as an input has less importance at low levels of economic growth while for United States, Canada, Brazil and South Korea, energy demand decreases with the increase in economic growth.

Bekun et al. (2019) attempted to explore the nexus between energy use and economic growth in South Africa from the year 1960 to 2016 by including variables such as capital, labour and carbondioxide emissions in the model. Econometric techniques such as Bayer and Hanck (2013) combined co- integration approach, Pesaran et al. (2001) bounds test were employed to confirm that a long-run equilibrium relationship exists among variables while Granger causality test indicated a unidirectional causal link running from energy use to economic growth.

Gorus & Aydin (2019) examined the causal relationship between energy consumption and economic growth including carbon emissions for eight MENA countries viz. Algeria, Egypt, Iran, Iraq, Oman, Saudi Arabia, Tunisia and United Arab Emirates from 1975 to 2014 by employing panel frequency domain analysis. Findings indicate that energy conservation policies do not have an adverse effect on economic growth both in the short- and intermediate-run while their effects are negative in the long-run.

Awodumi & Adewuyi (2020) investigated into the role non-renewable energy consumption plays towards economic growth and carbon emissions in the oil producing economies of Africa for a period from 1980 to 2015 by employing ARDL bound test for cointegration.

Findings revealed evidence of an asymmetric effect of petroleum and natural gas per capital consumption on economic growth and carbon emissions for all countries except Algeria.

Ozcan et al. (2020) examined the interdependence among energy consumption, environmental degradation and economic growth among OECD countries from 2000-2014 by employing the GMM framework and Dumitrescu and Hurlin (2012) panel Granger causality test. Results of analysis advocate that the manner of economic development and pattern of energy consumption of these 35 OECD countries align with the environmental policies. Further, efforts should be made to promote sustainable development.

1.2.3 Relationship Between Energy Consumption and Economic Growth in Select Sectors of Newly Industrialised Countries

Research in the domain of energy economics focusing on sectoral energy consumption and economic growth are not conducted extensively. Following are studies identified which have attempted to study energy consumption and economic growth from a sectoral perspective.

Zamani (2007) examined the causal relationship between economic growth, industrial value added, agriculture value added and considered different kinds of energy by applying a Vector error Correction Model for a period from 1967 to 2003. Results of analysis indicated that in the industrial sector, growth causes total energy consumption and consumption of electricity, gas and petroleum products. In the agricultural sector, agriculture value added and total energy, electricity and petroleum products consumption exhibit long-run bidirectional relations. Moreover, overall GDP and industrial value added causes total consumption of energy and petroleum products in the short run for the industrial sector.

Nicholas Bowden & Payne (2009) examined the causal relationship between energy consumption and real GDP from 1949 to 2006 for the US on annual aggregate data as well sectoral primary consumption data. Toda–Yamamoto causality test and Granger causality were employed which indicated that there exists a bidirectional causality between primary energy consumption and real GDP in the commercial and residential sector including a causal relationship running from industrial primary energy consumption to GDP.

N. Bowden & Payne (2010) examined sector-wise causal relationship between renewable and non-renewable energy consumption with GDP for the US from 1949 to 2006 by employing Toda- Yamamoto causality test. Results indicated that bidirectional causality exists between commercial and residential non-renewable energy consumption and real GDP and unidirectional causality from residential renewable energy consumption and industrial non-renewable energy consumption to GDP however no causality is found between real GDP and commercial and industrial renewable energy consumption**.**

Costantini & Martini (2010) studied if there exist a causal relationship between an economy and energy for a large sample of developed and developing countries from 1960 to 2005 by adopting non-stationery cointegrated panel data techniques such as Pedroni cointegration test & Westurlund test, FMOLS and GMM technique on a panel of countries. However, results indicated that for the panel of countries there is negligible causal relations between variables in a multi-sector framework.

Tsani (2010) investigated into the causality between energy consumption and economic growth for Greece at an aggregate and disaggregate level for a period from 1960 to 2006 by employing Toda Yamamoto causality test. Findings of analysis confirmed that there exists a bi-directional causal link between real GDP, industrial energy consumption and residential energy consumption but no causality was found in case of transport energy consumption and real GDP.

Abid & Sebri (2012) investigated into the causal link between energy use and economic growth for the whole Tunisian economy as well as for select sectors such as industry, transport and residential from 1980 to 2007 by applying Johansen's cointegration and VECM grangers causality test. Results of analysis lead to the conclusion that in the short run a unidirectional causality exist from industrial value added to energy consumption however in the long run the neutrality hypothesis holds true. Moreover, there exists bidirectional causality between energy use in residential sector and household income in the short-run, but a unidirectional causality exists in the household sector from income to energy consumption in the long-run**.**

Gross (2012) undertook a multi-variate sectoral analysis in the US by examining the industrial, commercial and transport sector for a period from 1970 to 2007 by employing Granger causality as well as ARDL bounds testing approach by Pesaran and Shin and concluded that a unidirectional long run causality from growth to energy exists in the commercial sector and bidirectional causality in the transport sector.

Abbas & Choudhury (2013) examined the causal link between electricity consumption and economic growth in South Africa, India and Pakistan at an aggregate and disaggregate level focusing on the agricultural sector. A bi-directional causality between the agricultural electricity consumption and the agricultural GDP was found in India, while the reverse was found in Pakistan. At the aggregated level, India confirmed conservation hypothesis while Pakistan confirmed feedback hypothesis.

A. A. N. Z. Meidani (2014) studied the causal link between real GDP and energy consumption in various sectors of the Iranian economy from 1967 to 2010 by employing techniques such as Toda-Yamamoto method, Granger causality test, error correction model and bound testing approach to cointegration and it was concluded that there exists a strong unidirectional causality from energy consumption to real GDP in the industrial sector.

Nadeem & Munir (2016) investigated into the relationship between energy consumption and economic growth for Pakistan at an aggregate and disaggregate level i.e. oil, coal, gas and electricity in various sectors such as commercial, agriculture, industry, power and transport. ARDL bound testing approach and granger causality test was applied on annual data from 1972 to 2014 and results of analysis concluded that the conservation hypothesis holds true for aggregate and disaggregate coal, gas and electricity consumption.

Howarth et al. (2017) assessed the relationship between energy use and GDP at a sector level for GCC countries by analysing variables such as total final energy consumption, population, GDP and five sectors viz. industry, transport, buildings, agriculture and non-energy sector and results indicated that energy use and economic growth are strongly linked in all sectors**.**

Nain et al. (2017) studied the long-run and short-run causal relationships among energy consumption, real GDP and CO2 emissions by using ARDL bound test, Granger non –

causality test as well as Toda Yamamoto causality test on annual data from 1971 to 2011. Results indicated that from energy consumption to GDP for the industrial sector in the short run a unidirectional causality exists and in the short and long run for domestic and commercial sectors.

S. Narayan & Doytch (2017) for a panel of 89 countries studied renewable and non-renewable energy consumption and economic growth nexus in the industrial and residential sector for a period from 1971 to 2011 by employing GMM System and fixed effects to conclude that growth for low and lower middle-income countries is due to residential energy consumption and energy use in the industrial sector is due to economic growth.

Eser Ozen & Hanifi (2018) aimed to analyse the impact of sectoral energy consumption on economic growth from 1972 to 2015 for Turkey by using heterogeneous panel test developed by Dumitrescu and Hurlin. Findings of analysis indicated that a unidirectional causal link exists from growth to energy use in the agricultural sector and between growth and energy consumption in the service sector a bi-directional causality exists.

Fatima et al. (2018) examined the relationships between energy use at an aggregated and disaggregated level in the industrial sector along with carbon emissions for China. Annual data from 1984 to 2015 was used on econometric techniques including Bayer-Hanck combined cointegration, ARDL bound test and VECM granger causality test. It was concluded that energy consumption increases CO2 emission in the long and short run. Besides there exists bidirectional relationships between all variables under study.

Kourtzidis et al. (2018) studied the relationship between total primary energy consumption and GDP both at an aggregate level and at a sectorial level for US by applying an asymmetric threshold cointegration approach on monthly data from January 1991 to May 2016. Results of analysis found that the neutrality hypothesis holds true for all sectors where no causal relationship was identified.

Liu et al. (2018) conducted a study on the sectoral nexus between electricity consumption and economic growth in Beijing on a quarterly basis from 2005 to 2016 by employing Granger causality. Analysis indicated that electricity consumption in the primary sector impacts its growth and the secondary sector and tertiary sector economic growth causes electricity consumption. Economic growth of the secondary sector does not have an impact on the tertiary sector, while the economic growth of the tertiary sector strongly affects that of the secondary sector.

Paramati (2018) examined the impact of renewable and non-renewable energy consumption on three sectors viz. agriculture, industry and serve as well as on overall GDP for G20 countries from 1980 to 2012. A 1% raise in non-renewable energy consumption increase economic output of agriculture, industry, service and total GDP by 0.297, 0.376, 0.301, and 0.385%, respectively'**,** therefore there is a significant long-run equilibrium relationship among variables however the impact is more from renewable energy on economic activities.

Tan & Tan (2018) studied the causal link between real income, energy use and carbon emission for the industrial sector of Malaysia for the period from 1980 to 2014 using Johansen's cointegration test, VECM and Granger causality test. Results indicated that a long run relationship among variables in both short and long-run a unidirectional causal relationship exists from energy consumption and CO2 emissions to real income. Variance decomposition indicate that in the long run the impact of income and energy consumption on carbon emissions is visible.

Chandio et al. (2019) examined the relationship between energy use and economic growth in the agricultural sector of Pakistan from 1984 to 2016 by employing Autoregressive Distributed lag bounds testing approach to cointegration and results indicated that there exists a long run relationship among all variables and a positive impact on agricultural economic growth exists by gas consumption and electricity consumption.

Hutagalung et al. (2019) attempted to understand how Indonesia's domestic gas allocation policy has effects on the economy by applying Computabled General Equilibrium (CGE) and found out that the government's current policy which focused on prioritizing oil production does not maximize added value of natural gas to the Indonesian economy.

Kuhe & Bisu (2019) conducted a review to study the influences of select situational factors on the behavior of household energy consumption through a systematic review of literature of

33 articles and suggested that laws that will encourage energy-saving renovations should be enacted and provision to reduce household energy consumption through recreational facilities should be also encouraged.

Kalu et al. (2019) examined if a relationship exists between energy consumption and value added of the agricultural and industrial sector as well as the overall growth rate of Nigeria by employing ARDL technique and ECM on annual data from 1971 to 2014. Results indicated that economic growth and agricultural value added does adjust to shocks while manufacturing value added was unable to adjust to shocks in energy use. A unidirectional causality from energy consumption to CO2 emission in agriculture and domestic sectors was also identified.

Nugraha & Osman (2019) analysed the causal link between carbon emissions, energy consumption and growth of the agricultural, industrial, service and household sector for a period from 1975 to 2014 for Indonesia. Econometric techniques such as Johansen co-integration test and Granger causality test based on vector error correction modelling was applied and results identified that Indonesian industrial value added and household final consumption expenditure have a significant effect on agriculture and service added value while agriculture added value of increases service value added.

O. Khan & Younas (2019) attempted to analyse the causal relationship between energy consumption and economic growth in Pakistan from 1985 to 2017 by employing ARDL bounds testing approach. Findings of analysis advocate that a positive impact on energy is evident from agriculture and manufacturing while the service sector has a negative impact on energy.

Santillán Vera & de la Vega Navarro (2019) examined how differences in household consumption activities at various income levels lead CO2 emissions to different degrees in Mexico from 1990 to 2014. Results indicated that high income levels are related to more carbon emissions directly and indirectly than the households with low-income levels.

Kalu et al. (2020) investigated into the linkage between energy and growth in Sub-Saharan Africa (SSA) with emphasis on the contribution to aggregate growth by real sectors by employing panel econometric techniques from 1967 to 2016 and found that there is evidence of energy dependence which supports the growth hypothesis.

Nath (2020) re-examined the relationship between electricity consumption and economic growth in India at an aggregate and sectoral level considering the agricultural and industrial sector for a period from 1971 to 2017. Therefore, economic growth was indicated through gross value added and econometric techniques such as Johansen's test of cointegration, Granger causality wald test was employed which confirmed that a unidirectional granger causality from gross value added to electricity consumption exists in the agricultural and industrial sector.

Tamba (2020) examined the causal relationship between LPG consumption and economic growth for a period from 1975 to 2016 for Cameroon by employing Johansen and ARDL bounds approach to cointegration, Toda Yamamoto causality and Granger causality test. Findings of analysis led to the conclusion that there exists a unidirectional causal relationship from LPG consumption to economic growth in the short-run and in the long run causality runs from economic growth to LPG consumption**.**

1.2.4 Relationship between Renewable Energy Consumption and Economic Growth

Numerous studies have been conducted extensively in order to understand the importance of renewable energy consumption in view of the need to achieve sustainable development.

Apergis & Payne (2010) aimed to investigate into the relationship between renewable energy consumption and GDP for a panel of OECD countries from 1985 to 2005 using panel cointegration and error correction model. Results of analysis led to the conclusion that real GDP, renewable energy use, real gross fixed capital formation and labour force share a long run positive relationship and a bidirectional causality running from renewable energy use and real GDP in the long and short run exist.

Apergis & Payne (2011) for Central America examined the relationship between renewable energy consumption, economic growth, real gross capital formation and labour force from 1980 to 2006 by applying panel cointegration test, FMOLS technique for heterogeneous cointegrated panels and panel error correction model and findings revealed that there exists a long run equilibrium relationship and a long run and short run bidirectional causality between GDP and energy consumption**.**

Tugcu et al. (2012) studied the long run causal relationship between renewable and non-renewable energy consumption and economic growth for G7 countries from 1980 to 2009 by applying ARDL approach and causality test by Hatemi-J (2012) and advocated that the augmented production is more effective in explaining the long run relationship between energy use and economic growth. Besides bidirectional causalities were identified for all countries for the classical production function.

Pao & Fu, (2013) explored the causalities between real GDP and four types of energy consumption for Brazil from 1980 to 2010 by applying Johansen maximum likelihood method, Vector Error Correction Model, Granger's causality test and CUSUM and CUSUMQ tests to conclude that 'a unidirectional causality from Non- Hydro Renewable Energy Consumption to economic growth and Bidirectional causality between economic growth and Total renewable Energy Consumption' exists.

Apergis & Danuletiu (2014) attempted to examine for a panel of 80 countries the relationship between clean energy and economic growth by employing Canning and Pedroni (2008) long-run causality test and results advocated that a long-run positive causality running from renewable energy to real GDP is evident and renewable energy is vital for economic growth which in turn encourages the use of clean energy sources.

Ucan et al. (2014) analysed the relationship between renewable and non-renewable energy consumption for a panel of 15 European countries from 1990 to 2011 by employing Pedroni Panel Cointegration test and FMOLS and it was concluded that a boom in renewable energy consumption leads to a boost in real GDP and there is a positive relationship between greenhouse gas emissions and real GDP while conventional energy use has a negative impact on real GDP.

Maji (2015) tried to examine the impact of clean energy on GDP for Nigeria by employing ARDL approach to cointegration on annual data from 1971 to 2011 and found that the relationship between clean energy and economic growth is significantly negative while it was evident that a positive relationship between combustible renewables and waste and GDP exists.

Ahmad et al. (2016) for India, investigated into the long and short run relationship among carbon emissions, energy consumption and economic growth from 1971 to 2014 by applying autoregressive distributed lag model and vector error correction model and it was concluded that there exists a positive relation between energy consumption and carbon emissions while a feedback effect exists between economic growth and carbon emissions.

Alam et al. (2016) examined the impact income, energy consumption and population growth have on CO2 emissions for Brazil, China, India and Indonesia by using ARDL bounds test and they concluded that CO2 emissions have increased significantly with increasing income and energy consumption. Moreover, the relationship between CO2 emissions and population growth was statistically significant for India and Brazil but statistically insignificant for China and Indonesia in both the short run and long run.

Amri (2016) attempted to explore the nexus between renewable and non-renewable energy consumption and economic growth from 1980 to 2012 by applying econometric techniques such as ARDL, Johansen's test, Gregory–Hansen cointegration test and Granger causality test to conclude that renewable energy consumption causes economic growth, capital and non-renewable energy consumption while in the short run a unidirectional link from non-renewable energy consumption to renewable energy consumption.

Destek (2016) investigated the causal link between both positive and negative shocks renewable energy consumption has on economic growth in Newly Industrialized Countries from 1971 to 2011 using ARDL bounds Test and asymmetric causality test and results proved that for South Africa and Mexico positive shocks in real GDP is due to negative shocks in clean energy consumption while for India negative shocks in GDP caused negative shocks in clean energy consumption.

Inglesi-Lotz (2016) tried to estimate the impact economic welfare has on renewable energy consumption for 34 members of the OECD consisting of developed and developing countries on data from 1990 to 2010 by applying panel unit root tests, Pedroni cointegration test and pooled and fixed effects estimation. Results of analysis indicated that the influence of renewable energy consumption on economic welfare is significant and positive.

Rafindadi (2016) investigated the nexus between economic growth, energy consumption, CO2 emissions, financial development and trade openness for Nigeria from 1971 to 2011 by using ARDL bounds testing approach to cointegration, the Zivot–Andrew structural break test, VECM model and the Bayer–Hanck combine cointegration analysis to find that economic growth lowers energy demand but increases CO2 emissions and trade openness increases energy consumption but improves environmental quality by lowering CO2 emissions.

Adewuyi & Awodumi (2017) examined the linkage among renewable energy, non-renewable energy. Economic growth and carbon emissions through a content analysis or review of literature to conclude that the effect of pollution from energy and economic growth should be considered during policy formulation to promote sustainable development.

Alabi et al. (2017) investigated into the relationship between renewable energy consumption and economic growth for African OPEC countries from 1971 to 2011 by employing FMOLS technique for heterogeneous cointegrated panels (Pedroni, 2000). A unidirectional causal link was identified from non- renewable energy consumption to Carbon emission.

Bekareva et al. (2017) assessed the influence of non-conventional energy consumption on GDP in US regions using cluster analysis and panel data analysis from 2000 to 2014 concluded that electricity cost reduction stimulates manufacturing, which boosts GDP and non-conventional energy consumption is one of the factors of GDP.

Bhattacharya et al. (2017) examined the role of renewable energy on economic growth in reducing carbon emissions for 85 developed and developing countries for a period from 1991 to 2012 by employing various panel data econometric techniques such as GMM system and fully modified OLS which advocated that growth of renewable energy consumption has a significant positive impact on economic growth and negative impact on economic output is cause by CO2 emissions besides institutions have a positive influence on economic growth and a reducing effect on CO2 emissions.

Boontome et al. (2017) investigated into the causal link between non-renewable and renewable energy consumption, CO_2 emissions and economic growth for Thailand from 1971 to 2013 by using Johansen test for multivariate cointegration and Granger causality test which confirmed that unidirectional causality from non-renewable energy consumption to CO_2 emissions exists.

Cherni & Essaber Jouini (2017) examined the relationship between CO_2 emissions, renewable energy use and growth for Tunisia from 1990-2015 by applying ARDL model, OLS and granger causality test. Results confirmed that there exists a feedback effect between GDP and CO_2 emissions as well as between renewable energy use and GDP however it was found that no relationship exists between carbon emissions and renewable energy consumption.

Dogan & Ozturk (2017) explored the influence of GDP, renewable energy consumption and non-renewable energy consumption on CO_2 emissions for the USA from 1980 to 2014 by employing Gregory-Hansen cointegration test with a structural break and the ARDL bounds testing for cointegration and concluded that higher renewable energy consumption contributes to mitigating environmental degradation whereas increases in non-renewable energy consumption encourages to CO_2 emissions.

Fotourehchi (2017) for 42 developing countries analysed the long-run causal relationship between clean energy consumption and economic growth from 1990 to 2012 by applying long-run causality test by Canning and Pedroni (2008) panel cointegration test and long run panel grangers causality test and results led to the conclusion that a positive long-run causality runs from clean energy to real GDP.

Ito (2017) examined the link between carbon emissions, renewable and non-renewable energy consumption with economic growth for a panel of 42 developing countries from 2002 to 2011 by using fixed or random effects model and PMG estimator based on the autoregressive distributed lag (ARDL) model. Results indicated that conventional energy consumption leads to a negative impact on economic growth for developing countries while non-conventional energy use leads to a positive impact on economic growth in the long run.

Magazzino (2017) examined the connect between renewable energy consumption and GDP of Italy from 1970 to 2007 with the help of techniques such as Reinsel and Ahn (1992) cointegration test for small samples, Toda and Yamamoto approach and Granger's causality and results confirmed that increase in energy use has a negative impact on Italian GDP.

Rafindadi & Ozturk (2017) investigated into whether the impact of renewable energy contribute to economic growth of Germany by using quarterly data from 1971 to 2013. Econometric techniques such as Clemente- Montanes-Reyes detrended structural break test, the Bayer-Hanck combined cointegration test and the ARDL bounds testing approach to cointegration was employed to conclude that increase in renewable energy consumption boosts GDP by 0.2194% and there is a bidirectional causality between renewable energy consumption and GDP.

Sasana & Ghozali (2017) for BRICS countries attempted to study the effect of fossil fuels i.e. coal, petroleum, and natural gas consumption as well as renewable energy on economic growth from 1995 to 2014 by using multiple linear regression using fixed effect model method and panel data. It was concluded that the effect of fossil consumption more importantly coal energy on economic growth was significantly positive, however renewable energy consumption was found to have a negative effect.

Sciences et al. (2017) explored the relationship between renewable energy consumption and economic growth for Blacksea and Balkan countries from 1990 to 2012 by employing Pedroni (1999, 2004) panel cointegration, Pedroni (2000, 2001) cointegration estimate methods, FMOLS, DOLS and Dumitrescu and Hurlin (2012) heterogeneous panel causality. It was concluded that renewable energy consumption has a positive impact on economic growth.

Taher (2017) examined the impact of renewable energy consumption on GDP for Lebanon by applying the multilinear regression equation using Ordinary Least Squares method on data from 1990 to 2012 and concluded that there exists a statistically significant impact of renewable energy on economic growth

Appiah (2018) examined the interdependence between energy use, economic growth, and CO2 emissions in Ghana from 1960 to 2015 using Johansen and Johansen- Juselius cointegration approach, the Autoregressive Distributed Lag bounds-test approach, Grangers causality test and Toda-Yamamoto causality test and concluded that 'feedback Granger causality between energy consumption and CO_2 emissions exists and an energy conservation-oriented policy not derived from energy efficiency and technological progress may hurt the Ghanaian economy'.

Cai et al. (2018) attempted to investigate into the relationship between clean energy use, economic growth and carbon emissions for G7 countries from 1965 to 2015 by employing bootstrap ARDL bounds test with structural breaks and Granger's causality test. Results of analysis proved that clean energy consumption causes real GDP per capita for Canada, Germany and the US while CO_2 emissions cause clean energy consumption for Germany. Moreover, a unidirectional causal link was found running from clean energy consumption to CO_2 emissions for the US.

Dong et al. (2018) by employing unit root test by Zivot and Andrews (1992), Bayer-Hanck cointegration approach, ARDL bounds testing approach and VECM Granger causality approach for China from 1993 to 2016 concluded that 'in the short and long run, nuclear energy and renewable energy play important roles in mitigating CO_2 emissions, while fossil fuels consumption is indeed the dominant culprit for promoting CO_2 emissions.'

Gozgor et al. (2018) analysed the effect of renewable energy consumption as well as non-renewable energy consumption with the economic growth of OECD countries from 1990 to 2013 by applying panel Autoregressive Distributed Lag and Quantile Regression. Results indicated that higher a rate of economic growth is due to both non-renewable energy consumption and renewable energy consumption.

Marinaş et al. (2018) tested the correlation between economic growth and renewable energy consumption for Central and Eastern European countries from 1990 to 2014 by employing Auto-regressive and Distributed Lag (ARDL) modeling, Error Correction Model and Granger causality. Analysis indicated that in Hungary, Lithuania and Slovenia an increasing renewable energy use improves the economic growth.

Ntanos et al. (2018) attempted to examine the relationship between renewable energy consumption and economic growth of European countries by using cluster analysis and autoregressive distributed lag (ARDL) model from 2007 to 2016. It was found that a higher correlation between renewable consumption and economic growth exist for countries of higher GDP than with those of a lower GDP.

Personal et al. (2018) examined the effects of clean energy consumption on GDP for Indonesia by employing ARDL bounds test approach and VECM granger causality for a period from 1990 to 2014 and results confirmed that a long run causality running from clean energy consumption, CO2 emissions, capital and employment to GDP exists.

Soava et al. (2018) attempted to examine the between economic growth and renewable energy consumption for a panel of 28 countries of the European Union from 1995 to 2015. Econometric techniques such as Johansen's cointegration test and Pedroni cointegration test, Granger causality test, FMOLS were applied which indicated that there exist a positive impact of renewable energy consumption on economic growth.

Bao & Xu (2019) explored the cause and effect of renewable energy consumption on urbanization and economic growth in China by using the Bootstrap panel causality test on data from 1997 to 2015 and results of analysis indicated that no causality is found in 80% of provinces and 71% of geographical regions when analysing renewable energy consumption and urbanization, and no causality is found in 53% of provinces and 43% of geographical regions when analysing renewable energy consumption and economic growth.

Tuna & Tuna (2019) analysed the causality between renewable and non- renewable energy consumption and economic growth in the ASEAN-5 countries from 1980 to 2015 by using Hacker and Hatemi-J (2006) and Hatemi-j (2012) test to conclude that economic growth of the Philippines increases renewable energy consumption while the reverse is in the case of Malaysia. For Negative shocks, economic growth increases renewable energy consumption for Thailand and renewable energy consumption causes economic growth for positive shock in Indonesia.

Banday & Aneja (2020) examined the causal link between renewable and non-renewable energy, GDP and CO2 emissions for BRICS countries from 1990 to 2017 by employing bootstrap panel causality test by Dumitrescu and Hurlin and results indicated that for India, China, Brazil and South Africa a unidirectional causal link from GDP to CO2 exist and no causality for Russia while there was evidence of bidirectional causality between renewable energy consumption and GDP for China and Brazil , for Russia growth hypothesis, for South Africa conservation hypothesis and no causality for India was found.

Chen et al. (2020) studied the causal link between renewable energy use and economic growth for a panel of 103 countries by applying second-generation panel cointegration methods, linear GMM and threshold estimation methods from 1995 to 2015. Results of analysis indicated that the effect of renewable energy consumption is positive on economic growth only when developing countries achieve a certain threshold of renewable energy consumption while there is no effect of renewable energy consumption on economic growth for developed countries by the reverse is in case of OECD countries.

Dogan et al. (2020) analysed the impact of renewable energy consumption on economic growth for OECD countries from 1990 to 2010 by applying OLS, Pedroni panel cointegration test, Westerlund (2007) panel cointegration test and Powell's (2016) panel quantile regression. A negative impact of renewable energy consumption to economic growth was found in OECD countries.

Le et al. (2020) reexamined the interaction between energy consumption, economic growth and emissions for a panel of 102 countries from 1996 to 2012 and advocated that conventional energy consumption significantly raised emissions levels and renewable energy sources helped reduce emissions in developed countries but the same was not in case of developing countries.

Musibau et al. (2020) studied the relationship among environmental degradation, energy consumption and GDP for Nigeria from 1981 to 2014 by employing the Non-linear ARDL technique and results indicated that a deterioration in environmental quality is due to energy, given that ‘CO2 rises by 0.002% for a unit increase in the consumption of energy’.

M. K. Khan et al. (2020) investigated the nexus between energy use, growth and carbon emission for Pakistan from 1965 to 2015 using ARDL model and results indicated that energy use and GDP increase CO2 emissions in the long run and short run.

Odugbesan (2020) examined the interaction between economic growth, carbon emissions, urbanization, and energy use for Mexico, Indonesia, Nigeria and Turkey from 1993 to 2017 through ARDL Bounds test approach and Granger Causality test and results advocated that the causal relationship between energy consumption and CO2 emissions to real income is unidirectional.

Rahman & Velayutham (2020) explored the relation between renewable energy consumption, non-renewable energy consumption and economic growth for South Asia from 1990 to 2014 by applying econometric techniques such as Pedroni (1999, 2004) and Kao (1999) tests, DOLS and FMOLS and Dumitrescue-Hurlin (2012) panel causality test. It was concluded that there exists a positive impact of renewable energy consumption, non-renewable energy consumption and fixed capital formation on economic growth while a unidirectional causal link exists from economic growth to renewable energy consumption.

Shahbaz et al. (2020) examined the effect of renewable energy consumption on economic growth for 38 renewable energy consuming countries based on the Renewable Energy Country Attractive Index. Econometric techniques such as DOLS, FMOLS., Pedroni Panel Cointegration Test and heterogeneous non-causality approaches were applied on data from 1990 to 2018. Results of analysis indicated that renewable energy, non-renewable energy, capital and labor have a positive impact on economic growth of selected countries.

Venkatraja (2020) studied the impact of changes in the share of renewable energy in the total energy mix of BRIC countries to check whether energy consumption leads to economic growth i.e. whether the growth hypothesis is valid by employing pooled panel OLS regression from 1990 to 2015. Results of analysis advocated that a decrease in renewable energy in the total energy mix contributes to the faster economic growth of BRIC countries.

Watthanabut & Jermsittiparsert (2020) for countries like Malaysia, Myanmar, Vietnam and Thailand examined the causal relationships between emissions, energy use and output and test results indicated that there is a statistically significant and positive impact of energy use on CO2 emissions. In addition, there is a consumption–emissions bidirectional strong causality and a unidirectional causal link running from both emissions and energy use to output.

Radmehr et al. (2021) explored the relationships between economic growth, carbon emissions and renewable energy consumption for a panel of European Union countries from

1995 to 2014 by using panel spatial simultaneous equations models with a generalized spatial two-stage least squares (GS2SLS) method to conclude that a bidirectional relationship between economic growth and carbon emissions and between economic growth and renewable energy consumption exists while a unidirectional causal link running from economic growth to renewable energy consumption exists.

1.3 IMPORTANCE OF THE STUDY

The Newly Industrialised Countries (NIC's) are at a stage of transition from developing to developed countries and therefore the growth and development of such countries requires the consumption of energy to support this transition. It is important to understand and evaluate the relationship between energy consumption and economic growth and verify whether economic growth is dependent on availability of energy so that these countries have ensured supply of energy to support growth and development.

If a country is dependent on energy for growth and development, it is also essential to identify and analyse the factors that determine energy consumption in the country so that the identified factors can be monitored favorably as per individual country needs. The economy of a country is divided into sectors which collectively contribute towards the overall growth of a country. Therefore, it becomes evident that one should understand whether these sectors are dependent on energy for growth and sustainability.

Ultimately, energy consumption is inevitable for sustaining economic activities and from time in memorial, the use of conventional energy has increased leading to adverse effects on the natural environment. In addition, conventional energy is non-renewable where such sources of energy will deplete in the long run jeopardizing sustainability of economic activities. Thus, the use of renewable energy becomes vital to ensure that an economy continues to grow and prosper without causing a negative impact on the environment and contributing to various environmental issues such as climate change, environmental pollution, destruction of natural resources, loss of flora and fauna etc.

1.4 RESEARCH GAP

Previous studies have not analysed the energy consumption and economic growth nexus in totality. This is a holistic study which analyses energy consumption and economic growth from the factors that lead to energy consumption, the relationship between energy consumption and economic growth at an aggregate level as well as sectoral level including the relationship between renewable energy consumption and economic growth with carbon emissions. Therefore, the Newly Industrialised countries being emerging economies with increasing energy requirements can accordingly formulate and implement energy policies to ensure sustainable growth and development and continue to strive to achieve Sustainable Development Goals (SDG's).

1.5 OBJECTIVES OF THE STUDY

i) To identify and analyse the determinants of energy consumption for the Newly Industrialised Countries of Asia.

ii) To examine the relationship between energy consumption and economic growth for Newly Industrialised Countries of Asia.

iii) To analyse the relationship between energy consumption and economic growth in select sectors of Newly Industrialised Countries of Asia.

iv) To examine the relationship between renewable energy consumption, carbon emissions and economic growth for Newly Industrialised Countries of Asia.

1.6 HYPOTHESIS DEVELOPMENT

1.6.1 Hypothesis supporting Objective 1

1.6.1.1 Hypothesis supporting Regression analysis of Objective 1

CHINA

H_{1a}: There exists no significant impact of GDP on energy consumption.

H_{1b}: There exists no significant impact of Industrialisation on energy consumption.

H_{1c}: There exists no significant impact of Exchange rate on energy consumption.

H_{1d}: There exists no significant impact of Financial development on energy consumption.

H_{1e}: There exists no significant impact of Trade openness on energy consumption.

INDIA

H_{1f}: There exists no significant impact of GDP on energy consumption.

H_{1g}: There exists no significant impact of Industrialisation on energy consumption.

H_{1h}: There exists no significant impact of Exchange rate on energy consumption.

H_{1i}: There exists no significant impact of Financial development on energy consumption.

H_{1j}: There exists no significant impact of Trade openness on energy consumption.

INDONESIA

H_{1k}: There exists no significant impact of GDP on energy consumption.

H_{1l}: There exists no significant impact of Industrialisation on energy consumption.

H_{1m}: There exists no significant impact of Exchange rate on energy consumption.

H_{1n}: There exists no significant impact of Financial development on energy consumption.

H_{1o}: There exists no significant impact of Trade openness on energy consumption.

MALAYSIA

H_{1p}: There exists no significant impact of GDP on energy consumption.

H_{1q}: There exists no significant impact of Industrialisation on energy consumption.

H_{1r}: There exists no significant impact of Exchange rate on energy consumption.

H_{1s}: There exists no significant impact of Financial development on energy consumption.

H_{1t}: There exists no significant impact of Trade openness on energy consumption.

PHILIPPINES

H_{1u}: There exists no significant impact of GDP on energy consumption.

H_{1v}: There exists no significant impact of Industrialisation on energy consumption.

H_{1w}: There exists no significant impact of Exchange rate on energy consumption.

H_{1x}: There exists no significant impact of Financial development on energy consumption.

H_{1y}: There exists no significant impact of Trade openness on energy consumption.

THAILAND

H_{1z}: There exists no significant impact of GDP on energy consumption.

H_{1aa}: There exists no significant impact of Industrialisation on energy consumption.

H_{1ab}: There exists no significant impact of Exchange rate on energy consumption.

H_{1ac}: There exists no significant impact of Financial development on energy consumption

H_{1ad}: There exists no significant impact of Trade openness on energy consumption.

1.6.1.2 Hypothesis supporting Johansen's Cointegration test of Objective 1

H_{2a}: Variables are not cointegrated in the long run for China.

H_{2b}: Variables are not cointegrated in the long run for India.

H_{2c}: Variables are not cointegrated in the long run for Indonesia.

H_{2d}: Variables are not cointegrated in the long run for Malaysia.

H_{2e}: Variables are not cointegrated in the long run for Philippines.

H_{2f}: Variables are not cointegrated in the long run for Thailand.

1.6.1.3 Hypothesis supporting Toda Yamamoto causality test of Objective 1

CHINA

H_{3a}: Industrialisation does not cause energy consumption.

H_{3b}: GDP does not cause energy consumption.

H_{3c}: Exchange rate does not cause energy consumption.

H_{3d}: Financial development does not cause energy consumption.

H_{3e}: Trade Openness does not cause energy consumption.

INDIA

H_{3f}: Industrialisation does not cause energy consumption.

H_{3g}: GDP does not cause energy consumption.

H_{3h}: Exchange rate does not cause energy consumption.

H_{3i}: Financial development does not cause energy consumption.

H_{3j}: Trade Openness does not cause energy consumption.

INDONESIA

H_{3k}: Industrialisation does not cause energy consumption.

H_{3l}: GDP does not cause energy consumption.

H_{3m}: Exchange rate does not cause energy consumption.

H_{3n}: Financial development does not cause energy consumption.

H_{3o}: Trade Openness does not cause energy consumption.

MALAYSIA

H_{3p}: Industrialisation does not cause energy consumption.

H_{3q}: GDP does not cause energy consumption.

H_{3r}: Exchange rate does not cause energy consumption.

H_{3s}: Financial development does not cause energy consumption.

H_{3t}: Trade Openness does not cause energy consumption.

PHILIPPINES

H_{3u}: Industrialisation does not cause energy consumption.

H_{3v}: GDP does not cause energy consumption.

H_{3w}: Exchange rate does not cause energy consumption.

H_{3x}: Financial development does not cause energy consumption.

H_{3y}: Trade Openness does not cause energy consumption.

THAILAND

H_{3z}: Industrialisation does not cause energy consumption.

H_{3aa}: GDP does not cause energy consumption.

H_{3ab}: Exchange rate does not cause energy consumption.

H_{3ac}: Financial development does not cause energy consumption.

H_{3ad}: Trade Openness does not cause energy consumption.

1.6.2 Hypothesis supporting analysis of objective 2

1.6.2.1 Hypothesis to test the cointegration of energy consumption and economic growth

H_{4a}: Variables are not cointegrated in the long run for China.

H_{4b}: Variables are not cointegrated in the long run for India.

H_{4c}: Variables are not cointegrated in the long run for Indonesia.

H_{4d}: Variables are not cointegrated in the long run for Malaysia.

H_{4e}: Variables are not cointegrated in the long run for Philippines.

H_{4f}: Variables are not cointegrated in the long run for Thailand.

1.6.2.2 Hypothesis to test VECM & VAR of energy consumption and economic growth

H_{5a}: There is no long run relationship between energy consumption and GDP of China.

H_{5b}: Energy consumption (Lag 1 & Lag 2) of India is not significant to explain GDP.

H_{5c}: Energy consumption (Lag 1 & Lag 2) of Indonesia is not significant to explain GDP.

H_{5d}**:** Energy consumption (Lag 1 & Lag 2) of Malaysia is not significant to explain GDP.

H_{5e}: Energy consumption (Lag 1 & Lag 2) of Philippines is not significant to explain GDP.

H_{5f}: Energy consumption (Lag 1 & Lag 2) of Thailand is not significant to explain GDP.

1.6.2.3 Hypothesis supporting Toda Yamamoto causality test of Objective 2

H_{6a}: Energy consumption does not cause GDP of China.

H_{6b}: GDP does not granger cause energy consumption of China.

H_{6c}: Energy consumption does not cause GDP of India.

H_{6d}: GDP does not granger cause energy consumption of India.

H_{6e}: Energy consumption does not cause GDP of Indonesia.

H_{6f}: GDP does not granger cause energy consumption of Indonesia.

H_{6g}: Energy consumption does not cause GDP of Malaysia.

H_{6h}: GDP does not granger cause energy consumption of Malaysia.

H_{6i}: Energy consumption does not cause GDP of Philippines.

H_{6j}: GDP does not granger cause energy consumption of Philippines.

H_{6k}: Energy consumption does not cause GDP of Thailand.

H_{6l}: GDP does not granger cause energy consumption of Thailand.

1.6.3 Hypothesis supporting analysis of objective 3

1.6.3.1 Hypothesis to test the cointegrating properties of sectoral energy consumption and economic growth

CHINA

H_{7a}: Agricultural energy consumption and value added are not cointegrated in the long run.

H_{7b}: Industrial energy consumption and value added are not cointegrated in the long run.

H_{7c}: Service sector energy consumption and value added are not cointegrated in the long run.

H_{7d}: Residential energy consumption and value added are not cointegrated in the long run.

INDIA

H_{7e}: Agricultural energy consumption and value added are not cointegrated in the long run.

H_{7f}: Industrial energy consumption and value added are not cointegrated in the long run.

H_{7g}: Service sector energy consumption and value added are not cointegrated in the long run.

H_{7h}: Residential energy consumption and value added are not cointegrated in the long run.

INDONESIA

H_{7i}: Agricultural energy consumption and value added are not cointegrated in the long run.

H_{7j}: Industrial energy consumption and value added are not cointegrated in the long run.

H_{7k}: Service sector energy consumption and value added are not cointegrated in the long run.

H_{7l}: Residential energy consumption and value added are not cointegrated in the long run.

MALAYSIA

H_{7m}: Agricultural energy consumption and value added are not cointegrated in the long run.

H_{7n}: Industrial energy consumption and value added are not cointegrated in the long run.

H_{7o}: Service sector energy consumption and value added are not cointegrated in the long run.

H_{7p}: Residential energy consumption and value added are not cointegrated in the long run.

PHILIPPINES

H_{7q}: Agricultural energy consumption and value added are not cointegrated in the long run.

H_{7r}: Industrial energy consumption and value added are not cointegrated in the long run.

H_{7s}: Service sector energy consumption and value added are not cointegrated in the long run.

H_{7t}: Residential energy consumption and value added are not cointegrated in the long run.

THAILAND

H_{7u}: Agricultural energy consumption and value added are not cointegrated in the long run.

H_{7v}: Industrial energy consumption and value added are not cointegrated in the long run.

H_{7w}: Service sector energy consumption and value added are not cointegrated in the long run.

H_{7x}: Residential energy consumption and value added are not cointegrated in the long run.

1.6.3.2 Hypothesis to test VECM of sectoral energy consumption and economic growth

CHINA

H_{8a}: Agricultural energy consumption and value added do not have a long-run relationship.

H_{8b}: Industrial energy consumption and value added do not have a long-run relationship.

H_{8c}: Residential energy consumption and value added do not have a long-run relationship.

H_{8d}: Service sector energy consumption and value added do not have a long-run relationship.

INDIA

H_{8e}: Agricultural energy consumption and value added do not have a long-run relationship.

H_{8f}: Industrial energy consumption and value added do not have a long-run relationship.

H_{8g}: Residential energy consumption and value added do not have a long-run relationship.

H_{8h}: Service sector energy consumption and value added do not have a long-run relationship.

INDONESIA

H_{8i}: Agricultural energy consumption and value added do not have a long-run relationship.

H_{8j}: Industrial energy consumption and value added do not have a long-run relationship.

H_{8k}: Residential energy consumption and value added do not have a long-run relationship.

H_{8l}: Service sector energy consumption and value added do not have a long-run relationship.

MALAYSIA

H_{8m}: Agricultural energy consumption and value added do not have a long-run relationship.

H_{8n}: Industrial energy consumption and value added do not have a long-run relationship.

H_{8o}: Residential energy consumption and value added do not have a long-run relationship.

H_{8p}: Service sector energy consumption and value added do not have a long-run relationship.

PHILIPPINES

H_{8q}: Agricultural energy consumption and value added do not have a long-run relationship.

H_{8r}: Industrial energy consumption and value added do not have a long-run relationship.

H_{8s}: Residential energy consumption and value added do not have a long-run relationship.

H_{8t}: Service sector energy consumption and value added do not have a long-run relationship.

THAILAND

H_{8u}: Agricultural energy consumption and value added do not have a long-run relationship.

H_{8v}: Industrial energy consumption and value added do not have a long-run relationship.

H_{8w}: Residential energy consumption and value added do not have a long-run relationship.

H_{8x}: Service sector energy consumption and value added do not have a long-run relationship.

1.6.3.3 Hypothesis to test causality between sectoral energy consumption and economic growth

CHINA

H_{9a}: Agricultural energy consumption causes agricultural value added.

H_{9b}: Agricultural value added causes agricultural energy consumption.

H_{9c}: Industrial energy consumption causes industrial value added.

H_{9d}: Industrial value added causes industrial energy consumption.

H_{9e}: Residential energy consumption causes residential value added.

H_{9f}: Residential value added causes residential energy consumption.

H_{9g}: Service sector energy consumption causes service value added.

H_{9h}: Service value added causes service sector energy consumption.

INDIA

H_{9a}: Agricultural energy consumption causes agricultural value added.

H_{9b}: Agricultural value added causes agricultural energy consumption.

H_{9c}: Industrial energy consumption causes industrial value added.

H_{9d}: Industrial value added causes industrial energy consumption.

H_{9e}: Residential energy consumption causes residential value added.

H_{9f}: Residential value added causes residential energy consumption.

H_{9g}: Service sector energy consumption causes service value added.

H_{9h}: Service value added causes service sector energy consumption.

INDONESIA

H_{9i}: Agricultural energy consumption causes agricultural value added.

H_{9j}: Agricultural value added causes agricultural energy consumption.

H_{9k}: Industrial energy consumption causes industrial value added.

H_{9l}: Industrial value added causes industrial energy consumption.

H_{9m}: Residential energy consumption causes residential value added.

H_{9n}: Residential value added causes residential energy consumption.

H_{9o}: Service sector energy consumption causes service value added.

H_{9p}: Service value added causes service sector energy consumption.

MALAYSIA

H_{9q}: Agricultural energy consumption causes agricultural value added.

H_{9r}: Agricultural value added causes agricultural energy consumption.

H_{9s}: Industrial energy consumption causes industrial value added.

H_{9t}: Industrial value added causes industrial energy consumption.

H_{9u}: Residential energy consumption causes residential value added.

H_{9v}: Residential value added causes residential energy consumption.

H_{9w}: Service sector energy consumption causes service value added.

H_{9x}: Service value added causes service sector energy consumption.

PHILIPPINES

H_{9y}: Agricultural energy consumption causes agricultural value added.

H_{9z}: Agricultural value added causes agricultural energy consumption.

H_{9aa}: Industrial energy consumption causes industrial value added.

H_{9ab}: Industrial value added causes industrial energy consumption.

H_{9ac}: Residential energy consumption causes residential value added.

H_{9ad}: Residential value added causes residential energy consumption.

H_{9ae}: Service sector energy consumption causes service value added.

H_{9af}: Service value added causes service sector energy consumption.

THAILAND

H_{9ag}: Agricultural energy consumption causes agricultural value added.

H_{9ah}: Agricultural value added causes agricultural energy consumption.

H_{9ai}: Industrial energy consumption causes industrial value added.

H_{9aj}: Industrial value added causes industrial energy consumption.

H_{9ak}: Residential energy consumption causes residential value added.

H_{9al}: Residential value added causes residential energy consumption.

H_{9am}: Service sector energy consumption causes service value added.

H_{9an}: Service value added causes service sector energy consumption.

1.6.4 Hypothesis supporting Objective 4

1.6.4.1 Hypothesis to support analysis of China

H_{10a}: Renewable energy consumption and GDP are not cointegrated in the long run.

H_{10b}: Renewable energy consumption and CO2 emissions are not cointegrated in the long run.

H_{10c}: GDP does not have an impact on CO2 emissions.

1.6.4.2 Hypothesis to support analysis of India

H_{10a}: Renewable energy consumption and CO2 emissions are not cointegrated in the long run.

H_{10b}: CO2 emissions and GDP are not cointegrated in the long run.

H_{10c}: Renewable energy consumption does not have an impact on GDP.

1.6.4.3 Hypothesis to support analysis of Indonesia

H_{10a}: Renewable energy consumption and GDP are not cointegrated in the long run.

H_{10b}: Renewable energy consumption and CO2 emissions are not cointegrated in the long run.

H_{10c}: CO2 emissions and GDP are not cointegrated in the long run.

1.6.4.4 Hypothesis to support analysis for Malaysia

H_{10a}: Renewable energy consumption and GDP are not cointegrated in the long run.

H_{10b}: CO2 emissions and GDP are not cointegrated in the long run.

H_{10c}: Renewable energy consumption and CO2 emissions are not cointegrated in the long run.

1.6.4.5 Hypothesis to support analysis for Philippines

H_{10a}: Renewable energy consumption and GDP are not cointegrated in the long run.

H_{10b}: Renewable energy consumption and CO2 emissions are not cointegrated in the long run.

H_{10c}: CO2 emissions and GDP are not cointegrated in the long run.

1.6.4.6 Hypothesis to support analysis of Thailand

H_{10a}: Renewable energy consumption and GDP are not cointegrated in the long run.

H_{10b}: CO2 emissions and GDP are not cointegrated in the long run.

H_{10c}: Renewable energy consumption and CO2 emissions are not cointegrated in the long run.

1.6.4.7 Hypothesis to support causality between renewable energy consumption, CO2 emissions and GDP

CHINA

H_{11a}: Renewable energy consumption does not cause GDP.

H_{11b}: GDP does not cause renewable energy consumption.

H_{11c}: Renewable energy consumption does not cause CO2 emissions.

H_{11d}: CO2 emissions does not cause renewable energy consumption.

H_{11e}: CO2 emissions does not cause GDP.

H_{11f}: GDP does not cause CO2 emissions.

INDIA

H_{11g}: Renewable energy consumption does not cause GDP.

H_{11h}: GDP does not cause renewable energy consumption.

H_{11i}: Renewable energy consumption does not cause CO2 emissions.

H_{11j}: CO2 emissions does not cause renewable energy consumption.

H_{11k}: CO2 emissions does not cause GDP.

H_{11l}: GDP does not cause CO2 emissions.

INDONESIA

H_{11m}: Renewable energy consumption does not cause GDP.

H_{11n}: GDP does not cause renewable energy consumption.

H_{11o}: Renewable energy consumption does not cause CO2 emissions.

H_{11p}: CO2 emissions does not cause renewable energy consumption.

H_{11q}: CO2 emissions does not cause GDP.

H_{11r}: GDP does not cause CO2 emissions.

MALAYSIA

H_{11s}: Renewable energy consumption does not cause GDP.

H_{11t}: GDP does not cause renewable energy consumption.

H_{11u}: Renewable energy consumption does not cause CO2 emissions.

H_{11v}: CO2 emissions does not cause renewable energy consumption.

H_{11w}: CO2 emissions does not cause GDP.

H_{11x}: GDP does not cause CO2 emissions.

PHILIPPINES

H_{11y}: Renewable energy consumption does not cause GDP.

H_{11z}: GDP does not cause renewable energy consumption.

H_{11aa}: Renewable energy consumption does not cause CO2 emissions.

H_{11ab}: CO2 emissions does not cause renewable energy consumption.

H_{11ac}: CO2 emissions does not cause GDP.

H_{11ad}: GDP does not cause CO2 emissions.

THAILAND

H_{11ae}: Renewable energy consumption does not cause GDP.

H_{11af}: GDP does not cause renewable energy consumption.

H_{11ag}: Renewable energy consumption does not cause CO2 emissions.

H_{11ah}: CO2 emissions does not cause renewable energy consumption.

H_{11ai}: CO2 emissions does not cause GDP.

H_{11aj}: GDP does not cause CO2 emissions.

1.7 DATA / VARIABLES IDENTIFIED FOR THE STUDY

1.7.1 Data description and period

Table 1: Data description and period

Objective	Variable	Description/Measurement	Period
1	Energy Consumption	*Primary Energy Consumption Exajoules	1980-2020
	Economic growth	Real GDP per capita in constant 2010 USD	1980-2020
	Exchange rate	Official exchange rate (LCU per US$, period average)	1980-2020
	Financial development	Domestic credit to private sector (% of GDP)	1980-2020
	Industrialisation	Industry (including construction) value added (% of GDP)	1980-2020
	Trade Openness	Trade (% of GDP)	1980-2020
2	Energy Consumption	*Primary energy consumption in Gigajoule per capita	1965-2020
	Economic growth	Real GDP per capita in constant 2010 USD	1965-2020
3	Agricultural energy consumption	Terrajoules	1990-2018
	Industrial energy consumption	Terrajoules	1990-2018
	Residential energy consumption	Terrajoules	1990-2018
	Services energy consumption	Terrajoules	1990-2018
	Agriculture value added	Constant 2010 USD	1990-2018
	Industry value added	Constant 2010 USD	1990-2018
	Residential value added	Constant 2010 USD	1990-2018
	Service value added	Constant 2010 USD	1990-2018

***** Primary energy comprises commercially-traded fuels, including modern renewables used to generate electricity

Objective 4	Country	Variable	Description/Measurement	Period
	China	Renewable energy consumption	Exajoules (input-equivalent)	1990- 2020
		GDP	Constant 2010 USD	1990- 2020
		CO_2 emissions	Million tonnes of carbon dioxide	1990- 2020
	India	Renewable energy consumption	Exajoules (input-equivalent)	1990- 2020
		GDP	Constant 2010 USD	1990- 2020
		CO_2 emissions	Million tonnes of carbon dioxide	1990- 2020
	Indonesia	Renewable energy consumption	Exajoules (input-equivalent)	1990- 2020
		GDP	Constant 2010 USD	1990- 2020
		CO_2 emissions	Million tonnes of carbon dioxide	1990- 2020
	Malaysia	Renewable energy consumption	Exajoules (input-equivalent)	2000-2020
		GDP	Constant 2010 USD	2000-2020
		CO_2 emissions	Million tonnes of carbon dioxide	2000-2020
	Philippines	Renewable energy consumption	Exajoules (input-equivalent)	1977-2020
		GDP	Constant 2010 USD	1977-2020
		CO_2 emissions	Million tonnes of carbon dioxide	1977-2020
	Thailand	Renewable energy consumption	Exajoules (input-equivalent)	1987-2020
		GDP	Constant 2010 USD	1987-2020
		CO_2 emissions	Million tonnes of carbon dioxide	1987-2020

1.7.2 SOURCES OF DATA

Data is sourced from World Development Indicators- World Bank, British Petroleum Statistical Review of World Energy June 2021 and International Energy Agency.

1.7.3 RESEARCH METHODOLOGY

i) To identify and analyse the determinants of energy consumption of Newly Industrialised Countries.

Unit root tests such as Augmented Dickey Fuller test and Philips Perron unit root test are employed to ascertain whether data is stationery over a time period. Correlation test is used to understand the relationship between variable viz. positive or negative correlation. Regression is applied to analyse the impact of various select factors on energy consumption and Toda Yamamoto causality test is employed to identify causal relationships between variables.

ii) To examine the relationship between energy consumption and economic growth of Newly Industrialised Countries.

The Augmented Dickey Fuller (ADF) test and Philip Perron (PP) test is employed to test for stationarity of variables. If variables have a mixed order of integration, we employ the ARDL model to test for cointegration. If the F value lies higher than the upper critical bound then we concluded that the variables are cointegrated. However, if the F value is lesser than the lower critical bound, the variables are said to be non-cointegrated and if the F value falls between the upper and lower critical bound, on can concluded that results are inconclusive. **Pesaran et al. (2001)** proposed critical values which can be applied only to large sample sizes and not for small sample sizes. Hence**, P. K. Narayan (2005)** provides critical values for small sample sizes which are 2.496 - 3.346, 2.962 – 3.910, and 4.068 – 5.250 at 90%, 95%, and 99% resp. Since the sample size of this study is small, we employ the same. Johansen’s Cointegration test is applied if variables are found to be intergrated of order 1. If variables are integrated, Vector Error Correction Model (VECM) is employed to check how quickly variables return to long run equilibrium after a deviation. In case variables are not found to be integrated we employ a VAR model to check if a variable is affected by its own lags or the past values of another variable.

Finally, to identify if there exist a causal relationship between energy consumption and economic growth, we employ the Toda Yamamoto causality test which can be applied irrespective of the order of integration of variables.

iii) To analyse the relationship between energy consumption and economic growth in select sectors of Newly Industrialised Countries.

To understand the stationarity properties of data under study, unit root tests are employed such as Augmented Dickey Fuller (ADF) test, Philips Perron (PP) and Kwiatkowski Phillips Schmidt Shin (KPSS) test. 'KPSS test checks for stationarity of a series around a deterministic trend where the null hypothesis is that the series is stationary unlike ADF test' **Kwiatkowski et al. (1992).** In terms of literature, 'tests designed on the basis of the null hypothesis that a series is I (1) have a low power of rejecting the null. Hence, KPSS is sometimes used to complement the widely used ADF and PP tests to obtain robust results.' **Pao & Fu (2013)**.

$$\Delta Yt = \alpha^0 + \beta_o T + \beta^1 Y_{t-1} + \sum_{i-1}^{m} \alpha_1 \Delta Y_{t-1} + \mathcal{E}_t$$

The above equation refers to the KPSS test for stationery. Y indicates the variables under testing for unit root, Δ refers to the first difference, T is the linear trend, t indicates time, $\mathcal{E}_t$ is the error term and m refers to white noise residuals.

Analysis is sensitive to the lags considered. Therefore, we consider Akaike information criterion (AIC) and Schwarz criterion (SC) and Hannan Quinn (HC) lag selection criteria. ARDL bound testing approach to cointegration is applied to confirm if energy consumption and value added are cointegrated in each select sector of the economy of each country. This approach to cointegration is applicable to variables when the order of integration is mixed however one should ensure that variables are not stationery at second difference. If variables have a long run cointegrating relationship, VECM (Vector Error Correction Model) can be applied to find out how long a variable correct itself towards equilibrium after a shock in the previous period. To check for causality between variables, Toda Yamamoto causality test is employed which is a causality test that is applicable irrespective of the order of integration of the variables under study.

iv) To examine the relationship between renewable energy consumption and economic growth of Newly industrialised Countries

Variables are analysed in pairs viz. Renewable Energy Consumption (REC) and GDP, Renewable Energy Consumption and CO2 emissions and CO2 emissions and GDP to tackle non-uniform time periods of each variable. Thus, analysis is presented for each individual country with respect to these three pairs of variables. The stationarity properties of the data are identified by employing unit root test such as Kwiatkowski Phillips Schmidt Shin (KPSS) test, Augmented Dickey Fuller (ADF) test and Philips Perron (PP). Stationarity tests are applied to understand whether mean and variance of variables are constant over time**.** Since analysis is sensitive to the lags considered, this study considers Akaike information criterion (AIC) and Schwarz criterion (SC) and Hannan Quinn (HC) lag selection criteria. ARDL bound testing approach to cointegration is applied to find out if non-conventional energy use, GDP and carbon emissions are cointegrated. This approach is applicable to variables irrespective of the order of integration however variables cannot be stationery at second difference. When variables are integrated of order one, linear regression is applied where it makes use of one independent variable to explain and/or predict the outcome of the dependent variable. To check for causal links between the variables, Toda Yamamoto causality test is employed which can be applied irrespective of the order of integration of the variables under study.

1.8 LIMITATIONS OF THE STUDY

The period of the study for each objective is subject to availability of data. Besides, the factors selected as those that influence energy consumption are based on availability of data for the select period of the study. There is scope to include additional variables/factors**.**

1.9 CHAPTERISATION

Chapter I focuses on an introduction to energy consumption and economic growth, importance of the study, objectives of the study, Data and methodology of the study and chapterisation and elaborates into the literature review relating to the factors that determine energy consumption in select Newly Industrialized Countries, literature review on the relationship between energy consumption and economic growth, literature review on sectoral energy consumption and economic growth and relationship between renewable energy consumption and economic growth followed by research gap.

Chapter II incorporates results and discussion pertaining factors influencing energy consumption.

Chapter III incorporates results and discussion pertaining to relationship between energy consumption and economic growth.

Chapter IV incorporates results and discussion pertaining to sectoral energy consumption and economic growth.

Chapter V incorporates results and discussion of renewable energy consumption and economic growth.

Chapter VI summarizes conclusion, policy implications of study, contribution of the study, limitations of the study and scope of further research.

CHAPTER 2

DETERMINANTS OF ENERGY CONSUMPTION

The consumption of energy whether renewable or non-renewable is the outcome of certain macro-economic factors of an economy that contribute towards or stimulates energy consumption. Numerous studies have been conducted considering an individual macro-economic factor and its interaction with energy consumption of a country. If a country is highly dependent on the consumption of energy which is conventional, efforts should be made to reduce over-dependence on conventional energy and a transition to clean energy should be achieved. Understanding which factors cause energy consumption helps in the formulation of energy policies and framing goals towards a sustainable future.

This chapter covers the impact of select macro-economic variables on energy consumption for the six Newly Industrialised countries. The variables are selected with the objective of obtaining a data set with a uniform time period. Therefore, five factors have been selected viz. GDP, exchange rate, financial development, industrialization and trade openness. As an economy grows and develops, the energy requirements are believed to increase to sustain economic activities. If a country is not self-sufficient in meeting her energy needs, the strength of the currency of a country has an impact on energy consumption as a country will not be able to import energy if her currency is weak. When a country has achieved a certain level of financial development, the various sectors of the economy will be able to financially support economic activities which will lead to increased energy requirements. If the exports of a country are increasing due to increased demand for produce of a country or finished products manufactured, the energy requirements will again increase to satisfy export demand.

Various econometric techniques are applied such as correlation, OLS regression, Johansens's cointegration test, Vector Error Correction model and Toda Yamamoto causality test by considering data for a period from 1980 to 2020.

2.1 UNIT ROOT TESTS

Unit root tests are conducted to find out if a variable is time invariant i.e. whether the mean, variance and auto- covariance of the variable are the same in different lags. Augmented Dickey Fuller test and Philip Perron test **Phillips & Perron (1988)** is employed to check for stationarity of variables

Table 2: Unit root test for determinants of energy consumption

		ADF unit	**root test**	**PP unit**	**root test**
Country	Variable	Test statistic level	Test statistic 1st difference	Test statistic level	Test statistic 1st difference
China	Energy Consumption	(0.9710)	**(2.816)****	0.0556	**(3.024)***
	GDP	(2.872)	**(4.180)****	(1.9517)	**(3.4636)****
	Exchange Rate	(1.7374)	**(5.5256)****	(1.8097)	**(5.5009)****
	Financial Development	(2.6129)	**(5.6639)****	(2.5974)	**(5.8228)****
	Industrialization	(1.9126)	**(4.0487)****	(1.8581)	**(3.9791)****
	Trade Openness	(1.4273)	**(5.4014)****	(1.4490)	**(5.3906)****
India	Energy Consumption	(1.7546)	**(6.4913)****	(2.0012)	**(6.4909)****
	GDP	(0.6546)	**(5.1698)****	(0.5184)	**(15.6573)****
	Exchange Rate	(1.0622)	**(4.8409)****	(1.2199)	**(4.8665)****
	Financial Development	**(4.5987)****	(2.4128)	(1.5489)	**(5.4927)****
	Industrialisation	(2.3180)	**(2.6003)***	(2.019)	**(5.8330)****
	Trade Openness	(1.3536)	**(4.9075)****	(1.8429)	**(4.9388)****
Philippines	Energy Consumption	(1.5967)	**(4.4506)****	(2.0274)	**(4.4599)****
	GDP	(0.2246)	**(8.6989)****	(0.8991)	**(4.1915)****
	Exchange Rate	(2.0790)	**(4.5691)****	(2.0830)	**(4.5772)****
	Financial Development	(2.5844)	**(3.9152)****	(1.9900)	**(3.8850)****
	Industrialisation	(2.1501)	**(6.9745)****	(2.0887)	**(6.9645)****
	Trade Openness	(0.9051)	**(4.6678)****	(1.2376)	**(4.7044)****
Malaysia	Energy Consumption	0.8531	**(3.4273)***	0.0967	**(7.6755)****
	GDP	(1.8.73)	**(5.0777)****	(2.0088)	**(5.0777)****
	Exchange Rate	(2.4899)	**(4.7440)****	(1.9856)	**(4.6548)****
	Financial Development	(2.9353)	**(5.5405)****	(2.9156)	**(5.5312)****
	Industrialisation	(1.4361)	**(6.5976)****	(1.4861)	**(6.6300)****
	Trade Openness	(0.1810)	**(4.2758)****	(0.1811)	**(4.1009)****
Indonesia	Energy Consumption	(0.3268)	**(5.1994)****	(0.2581)	**(5.1344)****

	GDP	(2.2718)	**(4.6402)****	(1.9531)	**(4.6362)****
	Exchange Rate	(1.8444)	**(6.5069)****	(1.8059)	**(6.5069)****
	Financial Development	(2.4036)	**(4.4939)****	(2.2735)	**(4.4703)****
	Industrialisation	(1.1799)	**(5.4061)****	(1.7634)	**(5.3416)****
	Trade Openness	(2.6748)	**(8.3524)****	(2.6327)	**(8.8411)****
Thailand	Energy Consumption	(0.0368)	**(4.4436)****	(0.4861)	**(4.4095)****
	GDP	(1.9539)	**(3.5696)****	(1.4622)	**(3.5910)****
	Exchange Rate	(1.3460)	**(4.7029)****	(1.6063)	**(4.6432)****
	Financial Development	(2.3015)	**(3.4219)***	(1.7774)	**(3.4219)***
	Industrialisation	(1.3004)	**(6.5642)****	(1.3104)	**(6.5383)****
	Trade Openness	(0.8383)	**(5.0298)****	(1.0209)	**(5.7275)****

* Indicates significance at 10% significance level
** Indicates significance at 5% significance level

From the above table 2, both tests indicate that variables are stationery at first difference and therefore we reject the null hypothesis that each variable has a unit root.

2.2 LAG LENGTH SELECTION CRITERIA

Lag refers to lapse in time. The least lag is considered to be appropriate for the purpose of analysis.

Table 3: Lag selection criteria for Objective 1

CHINA						
Lag	**Logl**	**LR stat**	**FPE**	**AIC**	**SC**	**HQ**
0	320.0699	NA	6.47e-16	-17.94685	-17.68022	-17.85481
1	619.1720	478.5633	1.98e-22	-32.98126	-31.11484	-32.33697
2	669.9258	63.80485	1.03e-22	-33.82433	-30.35813	-32.62780
3	738.7606	62.93464*	2.76e-23	-35.70061	-30.63461	-33.95183
4	825.1739	49.37904	6.25e-24*	**-38.58137***	**-31.9156***	**-36.2803***
INDIA						
0	191.0574	NA	1.82e-12	-10.00310	-9.741872	-9.911006
1	496.9445	496.0332	8.65e-19	-24.59160	**-22.7630***	-23.94693
2	538.0296	53.29962	7.71e-19	-24.86647	-21.47048	-23.66922
3	590.5748	51.12497*	5.00e-19	-25.76080	-20.79743	-24.01098
4	655.1063	41.85829	3.20e-19*	-27.30304*	-20.77229	-25.0007*
INDONESIA						
0	92.48324	NA	3.76e-10	-4.674770	-4.413540	-4.582674

1	354.9361	425.5992	1.87e-15	-16.91546	**-15.0869***	-16.27079
2	408.6125	69.63430*	8.42e-16	-17.87095	-14.47496	-16.67370
3	441.3431	31.84600	1.59e-15	-17.69422	-12.73086	-15.94440
4	516.1702	48.53649	5.85e-16*	-19.79299*	-13.26224	-17.4906*
MALAYSIA						
0	155.9819	NA	1.21e-11	-8.107129	-7.845899	-8.015033
1	425.0649	436.3508*	4.21e-17	-20.70621	**-18.8777***	-20.06154
2	454.7585	38.52135	6.95e-17	-20.36532	-16.96933	-19.16808
3	501.1115	45.10026	6.29e-17	-20.92495	-15.96158	-19.17513
4	567.5066	43.06709	3.65e-17*	-22.56792*	-16.03718	-20.2655*
PHILIPPINES						
0	170.1240	NA	5.65e-12	-8.871565	-8.610335	-8.779470
1	439.6428	437.0576	1.92e-17	-21.49421	**-19.6657***	-20.84953
2	475.8103	46.92004	2.23e-17	-21.50326	-18.10727	-20.30602
3	529.7695	52.50085*	1.34e-17	-22.47403	-17.51066	-20.72421
4	599.4631	45.20664	6.48e-18*	-24.29530*	-17.76455	-21.9929*
THAILAND						
0	190.6145	NA	1.87e-12	-9.979160	-9.717930	-9.887065
1	466.8971	448.0258	4.39e-18	-22.96741	**-21.1388***	-22.32274
2	497.7237	39.99130	6.81e-18	-22.68777	-19.29178	-21.49052
3	537.2829	38.49004	8.91e-18	-22.88016	-17.91679	-21.13034
4	647.5543	71.52742*	4.82e-19*	-26.89483*	-20.36408	-24.5924*

*Lag selection

Table 3 indicates the lag selection criteria according to Akaike Information Criterion (AIC), Schwartz Information Criterion (SIC) and Hannan Quinn Criterion (HQ) which is applied to select the appropriate lags for the purpose of analysis. In case of China, Lag four is selected based on all three criteria i.e. AIC, SIC and HQ. In case of India, Indonesia, Malaysia, Philippines and Thailand, lag one is selected based on Shwartz Information Criterion.

2.3 CORRELATION

Correlation measures the association among variables. The association between energy consumption and the five determinants for each Newly Industrialised Country is measured by employing correlation test.

Table 4: Correlation for the determinants of energy consumption

	EC CHINA	EC INDIA	EC INDONESIA	EC MALAYSIA	EC PHILIPPINES	EC THAILAND
GDP	**0.992852**	**0.991081**	**0.957242**	**0.980850**	**0.773138**	**0.994677**
Industrialization	-0.276960	0.533567	0.495878	0.267888	**-0.700328**	**0.771328**
Exchange Rate	0.652703	**0.933498**	**0.960813**	**0.836903**	0.695094	**0.731504**
Financial Development	**0.934869**	**0.905934**	0.393648	**0.711091**	**0.820790**	**0.877992**
Trade Openness	**0.776364**	**0.932795**	-0.007690	0.586957	0.587869	**0.966438**

Source: Researchers Compilation

According to table 4, GDP, Financial development and trade openness are highly positively correlated with energy consumption in case of China. The same is the case for India in addition to exchange rate. In case of Indonesia GDP and exchange rate are highly positively correlated. The same is the case of Malaysia where financial development is also positively correlated. Correlation results for Philippines indicates a negative correlation for industrialization and energy consumption however GDP and financial development is positively correlated. Moreover, the energy consumption of Thailand is positively correlated with all variables under study.

2.4 OLS REGRESSION

CHINA_EC_LOG = **0.705822*CHINA_GDP_LOG** -
0.368097*CHINA_INDUSTRIALISATION_ **-**
0.197223*CHINA_LOG_EXCHANGE_RATE - 0.302790*CHINA_LOG_FD +
0.234096*CHINA_TRADE_OPENESS_LOG – 13.82357

INDIA_EC_LOG = **0.138310*INDIA_EXCHANGE_RATE_LOG** +
0.452593*INDIA_INDUSTRIALISATION_ -0.035521*INDIA_LOG_FD +
0.737692*INDIA_LOG_GDP -0.070270*INDIA_TRADE_OP_LOG -1.774627

INDONESIA_EC_LOG = **0.559986187182*INDONESIA__GDP_LOG** +
0.213003141631*INDONESIA_EXCHANGE_RATE_ +
0.597529946157*INDONESIA_INDUSTRIALISAT +
0.0691177829398*INDONESIA_LOG_FD -
0.0519144752016*INDONESIA_TRADE_OP_LOG - 2.40105492863

MALAYSIA_EC_LOG = 0.102321970337*MALAYSIA__INDUSTRIALISAT +
0.0916229067461*MALAYSIA_EXCHANGE_RATE_L +
1.0610289205*MALAYSIA_GDP_LOG - 0.0439322878018*MALAYSIA_LOG_FD +
0.27425514624*MALAYSIA_TRADE_OP_LOG - 2.86997569294

PHILIPPINES_EC_LOG = -0.0400968777434*PHILIPPINES_EXCHANGE_RAT +
0.433738314966*PHILIPPINES_GDP_LOG -
0.696052281808*PHILIPPINES_INDUSTRIALIS +
0.161311823803*PHILIPPINES_LOG_FD +
0.285208415197*PHILIPPINES_TRADE_OPENES + 0.0361129753543

THAILAND_EC_LOG = **0.243878920341*THAILAND_EXCHANGE_RATE_L** +
1.05965892383*THAILAND_GDP_LOG -
0.188791518478*THAILAND_INDUSTRIALISATI +
0.128934537752*THAILAND_LOG_FD +
0.291784230579*THAILAND_TRADE_OP_LOG - 3.07145728454

Table 5: Regression results on the determinants of energy consumption

Multiple regression identifies the impact an independent variable has on dependent variables. The dependent variable is energy consumption and the independent variables include Gross Domestic product (GDP), Industrialisation, Exchange rate, Financial development and Trade openness.

	Coefficient	**Std. Error**	**t-Statistic**	**Prob.**
CHINA				
GDP	0.705822	0.036206	19.49445	**0.0000****
Industrialisation	-0.368097	0.237613	-1.549145	0.1303
Exchange Rate	-0.197223	0.043233	-4.561845	**0.0001****
Financial Development	-0.302790	0.147174	-2.057364	**0.0472****
Trade Openness	0.234096	0.057787	4.051011	**0.0003****
Constant	-13.82357	1.028496	-13.44056	0.0000
R-squared	***0.995165***			
INDIA				
GDP	0.737692	0.079907	9.231929	**0.0000****
Industrialisation	0.452593	0.205526	2.202124	**0.0348****
Exchange Rate	0.138310	0.030645	4.513341	**0.0001****
Financial Development	-0.035521	0.083067	-0.427617	0.6717
Trade Openness	-0.070270	0.047646	-1.474831	0.1497
Constant	-1.774627	0.345719	-5.133154	0.0000
R-squared	***0.993964***			
INDONESIA				
GDP	0.559986	0.131830	4.247785	**0.0002****
Industrialisation	0.597530	0.236679	2.524645	**0.0166****
Exchange Rate	0.213003	0.037711	5.648312	**0.0000****
Financial Development	0.069118	0.037324	1.851853	0.0730
Trade Openness	-0.051914	0.138570	-0.374645	0.7103

Constant	-2.401055	0.367800	-6.528153	0.0000
R-squared	***0.979848***			
MALAYSIA				
GDP	1.061029	0.059576	17.80963	**0.0000****
Industrialisation	0.102322	0.339966	0.300977	0.7653
Exchange Rate	0.091623	0.109669	0.835448	0.4095
Financial Development	-0.043932	0.068679	-0.639674	0.5268
Trade Openness	0.274255	0.116960	2.344865	**0.0252****
Constant	-2.869976	0.495932	-5.787036	0.0000
R-squared	***0.981068***			
PHILIPPINES				
GDP	0.433738	0.072213	6.006376	**0.0000****
Industrialisation	-0.696052	0.170250	-4.088417	**0.0003****
Exchange Rate	-0.040097	0.038908	-1.030563	0.3102
Financial Development	0.161312	0.043238	3.730760	**0.0007****
Trade Openness	0.285208	0.074572	3.824593	**0.0006****
Constant	0.036113	0.351600	0.102710	0.9188
R-squared	***0.959037***			
THAILAND				
GDP	1.059659	0.054081	19.59384	**0.0000****
Industrialisation	-0.188792	0.110925	-1.701974	0.0982
Exchange Rate	0.243879	0.043983	5.544859	**0.0000****
Financial Development	0.128935	0.031483	4.095362	**0.0003****
Trade Openness	0.291784	0.067551	4.319494	**0.0001****
Constant	-3.071457	0.167377	-18.35053	0.0000
R-squared	***0.997942***			

**5% level of significance

Table 5 displays the results of regression test applied where in case of China, economic growth, exchange rate, financial development and trade openness have a significant impact on energy consumption. A 1% increase in GDP and trade openness leads to 0.70% and 0.23%

resp. increase in energy consumption. A 1% increase in exchange rate and financial development will each cause a decrease in energy consumption by 0.19% and 0.30% resp. Therefore, we reject H_{1a}, H_{1c}, H_{1d} and H_{1e} hypothesis and accept H_{2b} hypothesis.

In case of India, GDP, Industrialization and exchange rate have a significant impact on energy consumption. A 1% increase in economic growth, industrialization and exchange rate will each lead to an increase in energy consumption by 0.73%, 0.45% and 0.14% resp. We reject H_{2f}, H_{2g} and H_{2h} hypothesis. The same is in the case of Indonesia where a 1% increase in GDP, industrialization and exchange rate will each increase energy consumption by 0.55%, 0.59% and 0.21% resp. Therefore, we reject H_{1k}, H_{1l} and H_{1m} while H_{1n} and H_{1o} hypothesis are accepted.

GDP and trade openness have a significant impact on energy consumption of Malaysia therefore we reject the null hypothesis i.e. H_{2p} and H_{2t}, where a 1% increase in the variables will cause energy consumption to increase by 1.06% and 0.27% resp. GDP, Industrialization, financial development and trade openness have a significant impact on the energy consumption of Philippines. A 1% increase in GDP financial development and trade openness will each cause energy consumption to increase by 0.43%, 0.16% and 0.28% resp. while industrialization will decrease energy consumption by 0.69% as we reject H_{1u}, H_{1v}, H_{1x} and H_{1y} hypothesis.

GDP, exchange rate, financial development and trade openness has a significant impact on energy consumption of Thailand. Therefore, we reject the null hypothesis i.e. H_{1z}, H_{1ab}, H_{1bc} and H_{1cd}. A 1% increase in these variables will lead to an increase in energy consumption by 1.05%, 0.24%, 0.12% and 0.29% resp.

2.5 JOHANSEN'S COINTEGRATION TEST

Johansen's Cointegration test is applied to understand whether variables have a long run cointegrating relationship. This test is applied to identify whether a cointegrating relationship exists among the determinants of energy consumption.

Table 6: Results of Johansen's cointegration test on determinants of energy consumption

Country	Hypothesised no. of cointegrating equations	**Eigen value**	**Trace statistic**	**Critical value @ 5% (p value)**	**Max Eigen statistic**	**Critical value @ 5% (p value)**
China	None	0.672286	138.9605	**95.7537 (0.000)**	43.509	**40.07757 (0.0198)**
	At most 1	0.654717	95.45153	**69.8189 (0.0001)**	41.472	**33.87687 (0.0051)**
India	None	0.780068	148.8716	**95.75366 (0.0000)**	56.03415	**40.07757 (0.0004)**
	At most 1	0.658735	92.83742	**69.81889 (0.0003)**	39.77850	**33.87687 (0.0088)**
Indonesia	None	0.746577	135.7644	**95.75366 (0.0000)**	50.78977	**40.07757 (0.0022)**
	At most 1	0.615253	84.97460	**69.81889 (0.0019)**	35.34123	**33.87687 (0.0332)**
Malaysia	None	0.662928	116.7574	**95.75366 (0.0009)**	40.23602	**40.07757 (0.0480)**
	At most 1	0.594869	76.52141	**69.81889 (0.0132)**	33.43115	**33.87687 (0.0564)**
Philippines	None	0.718112	136.0521	**95.75366 (0.0000)**	46.85115	**40.07757 (0.0075)**
	At most 1	0.617659	89.20094	**69.81889 (0.0000)**	35.57333	**33.87687 (0.0311)**
Thailand	None	0.982123	273.9532	**95.75366 (0.0000)**	140.8488	**40.07757 (0.0001)**
	At most 1	0.839631	133.1044	**69.81889 (0.0000)**	64.05970	**33.87687 (0.0000)**

Source: Authors compilation

Johansen's Cointegration test reveals that the variables under study are integrated in the long run towards equilibrium which is supported by trace statistic and max eigen value as indicated in table 6. Therefore, we reject the null hypothesis viz. H_{2a}, H_{2b}, H_{2c}, H_{2d}, $H_{2e}$and H_{2f}.

2.6 VECTOR ERROR CORRECTION MODEL

VECM indicates the speed at which energy consumption returns to equilibrium after a change in the independent variables viz. GDP, industrialization, exchange rate, financial development and trade openness.

Table 7: Results of Vector Error Correction Model on the determinants of energy consumption

	ECT Coefficient	Std Error	t- Statistic	Prob.
China	**-0.273651**	0.081028	-3.377227	**0.0036****
India	0.181179	0.090903	1.993095	0.0557
Indonesia	-0.067305	0.155462	-0.432936	0.6712
Malaysia	**-0.107820**	0.049879	-2.161634	**0.0390****
Philippines	-0.040591	0.168186	-0.241348	0.8110
Thailand	-0.017373	0.017753	-0.978585	0.3359

**5% level of significance

Table 7 indicates the results of VECM. In case of China and Malaysia there exists a long run relationship among the variables. For China, energy consumption is corrected towards long run equilibrium by 27% each year while for Malaysia energy consumption is corrected towards long run equilibrium by 11% each year.

2.7 TODA YAMAMOTO CAUSALITY TEST

The Toda Yamamoto causality test is considered to be an advanced causality test as pretests for unit root and cointegration is not a prerequisite. This test follows the method of adding extra lags intentionally in the estimation. The usual strategy that one tests some economic hypothesis conditioned on the estimation of a unit root, a cointegrating rank, and a cointegrating vector(s) may suffer from severe pretest biases. **(Toda & Yamamoto, 1995)**.

Table 8: Results of Toda Yamamoto Causality test for determinants of energy consumption

Country	**Industrialisation causes EC**	**GDP causes EC**	**Exchange rate causes EC**	**Financial development causes EC**	**Trade Openness causes EC**
China	0.9055	0.4738	**0.0282****	0.4488	**0.1447***
India	0.7024	**0.0144****	0.5918	**0.1187***	0.7076
Indonesia	**0.0469****	0.4850	0.6960	0.2536	**0.0613***
Malaysia	**0.1015***	0.4264	0.9957	0.1679	**0.0418****
Philippines	0.5742	0.4719	0.4814	0.8553	0.4471
Thailand	0.4108	**0.0290****	0.5983	0.9932	0.8259

**5% level of significance *10% level of significance

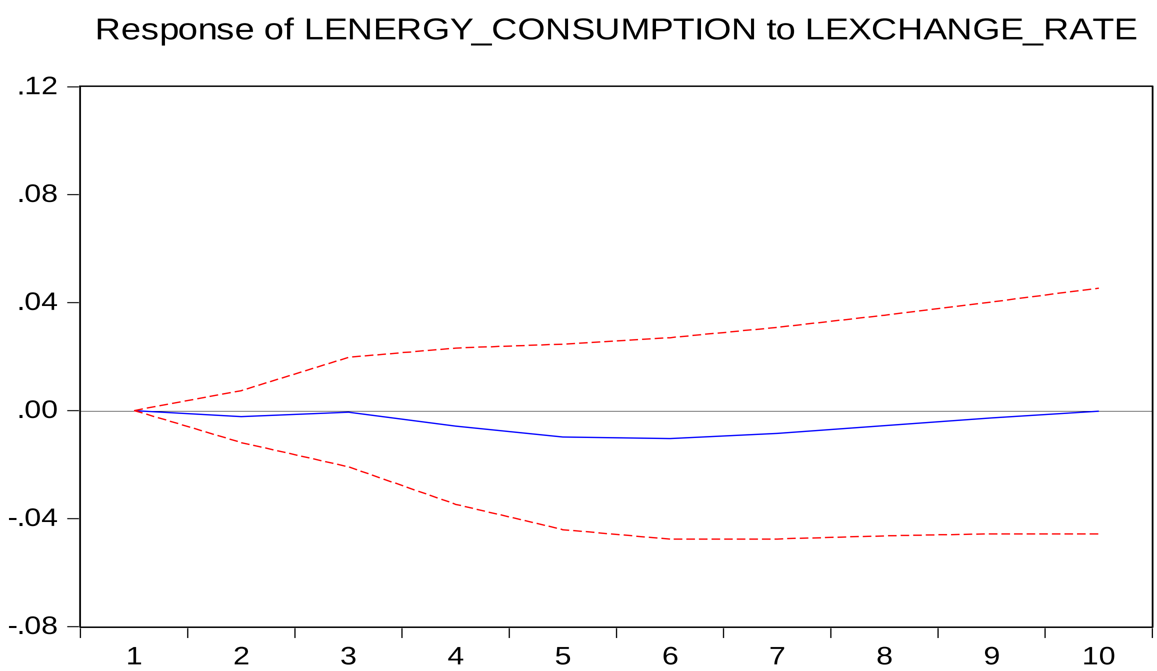
The above table 8 indicates which variable causes energy consumption with respect to each country under study. Exchange rate and trade openness causes energy consumption in China. However, in India GDP and Financial development causes energy consumption. In Indonesia and Malaysia, industrialization and trade openness causes energy consumption. The energy consumption of the Philippines is not caused by any of the select factors while in Thailand only GDP causes energy use. For China we reject H_{3c} and H_{3e} hypothesis, for India we reject H_{3g} and H_{3i}. For Malaysia and Indonesia we reject H_{3k}, H_{3o}, H_{3p} and H_{3t} hypothesis. Lastly for Thailand, we reject H_{3z} hypothesis.

2.8 IMPULSE RESPONSE FUNCTION

Impulse response function measures the extent to which a variable has an impact on another variable as well the duration of the impact in the form of a graph. This is represented by a blue line whose dynamics indicate whether a positive or negative impact exists in addition to the time period of the impact.

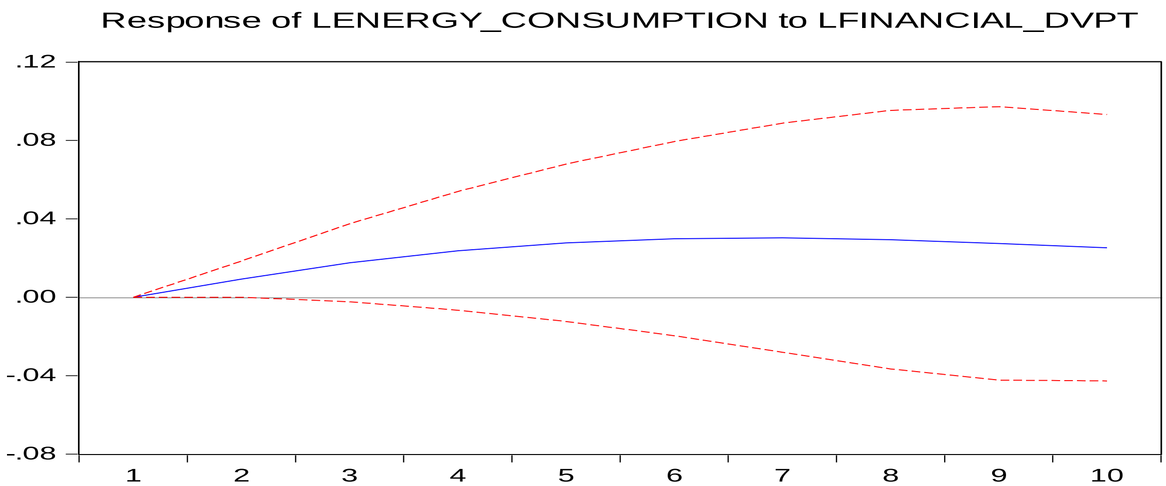
CHINA

Figure 3: Results of impulse response function between energy consumption and exchange rate of China



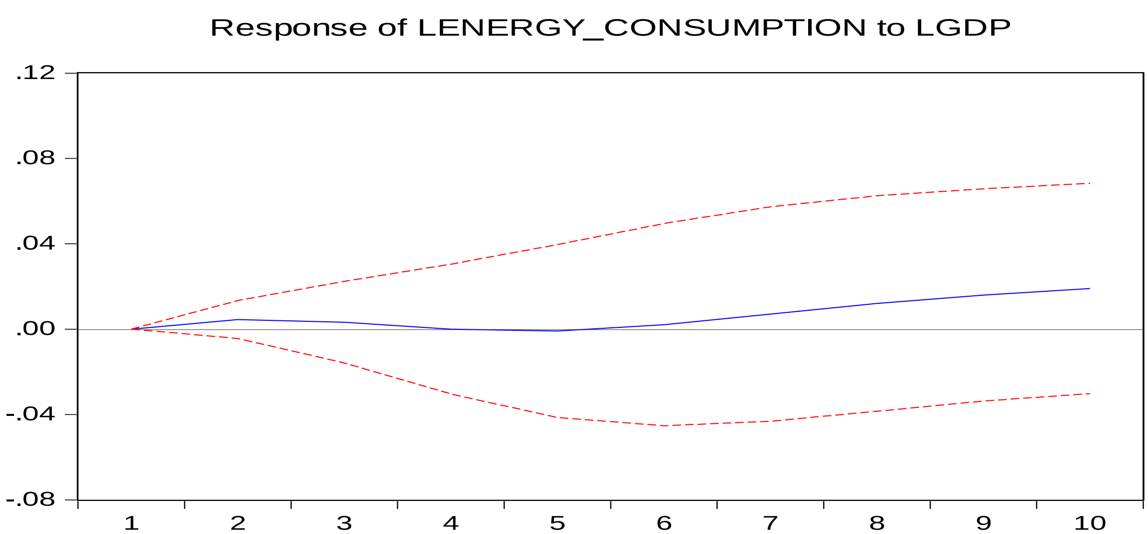
The above figure 3 exhibits the response of energy consumption to exchange rate. The consumption of energy up to three periods indicates a mild decrease and increase followed by a further decrease which ultimately increases by the tenth period. Therefore, shocks to exchange rate has a positive impact on energy consumption.

Figure 4: Results of Impulse response function of energy consumption and financial development of China



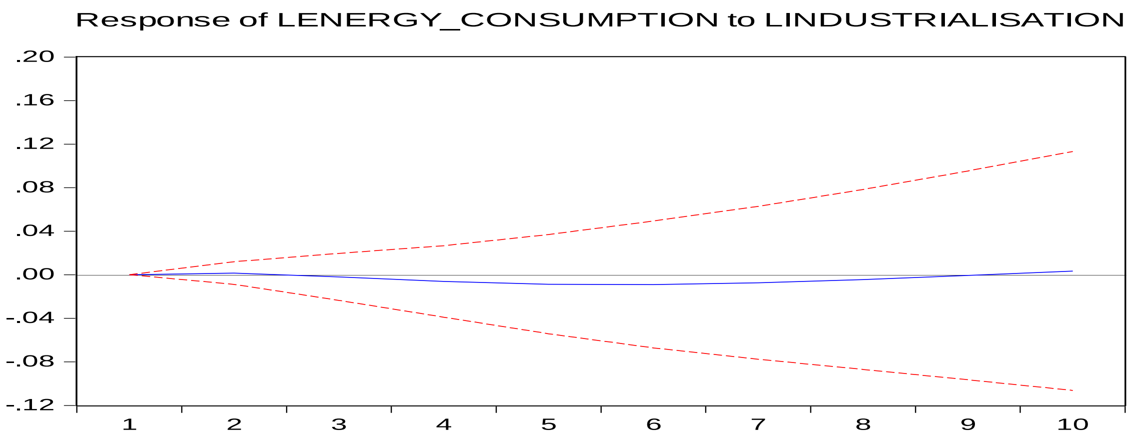
The impact of shocks in financial development to energy consumption is indicated in the above figure 4. From period one to ten, energy consumption has positively reacted to shocks in financial development as a gradual increase can be observed followed by it achieving a constant trend over the 10- year period.

Figure 5: Results of Impulse response function of energy consumption and GDP of China



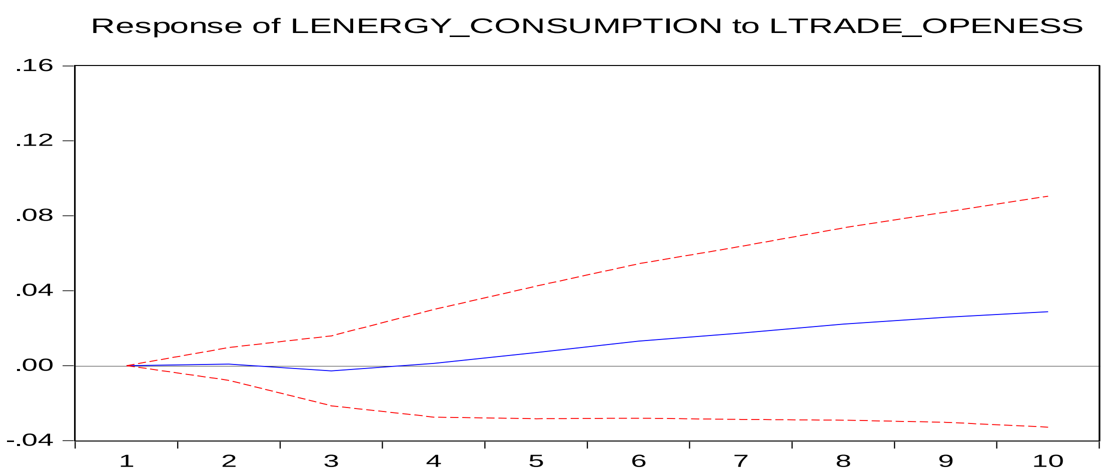
GDP has a positive impact on energy consumption. Within the first five periods, energy consumption increases and decreases. However, after the fifth period energy consumption shows an increasing trend as indicated in figure 5.

Figure 6: Results of Impulse response function of energy consumption and industrialization of China



The above figure 6 indicates the response of energy consumption to shocks in Industrialisation of China. Shocks in industrialization leads to a decrease in energy consumption and after nine periods energy consumption increases therefore industrialization has a positive impact in energy consumption.

Figure 7: Results of Impulse response function of energy consumption and trade openness of China

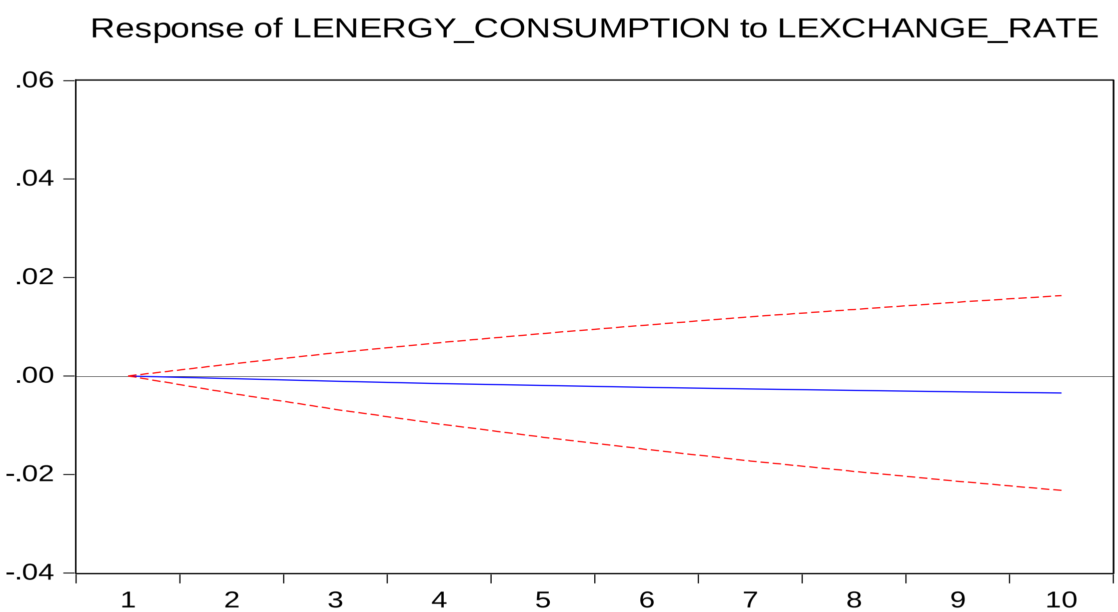


The above figure 7 indicates the response of energy consumption to a shock in trade openness. There is a mile decrease within the first three periods however after the completion of three periods there is a distinct increase in energy consumption indicating that trade openness has a positive impact on energy consumption.

Energy consumption is affected by shocks in all select variables positively. GDP, Trade openness, industrialization, financial development and exchange rate have a positive impact on energy consumption in China.

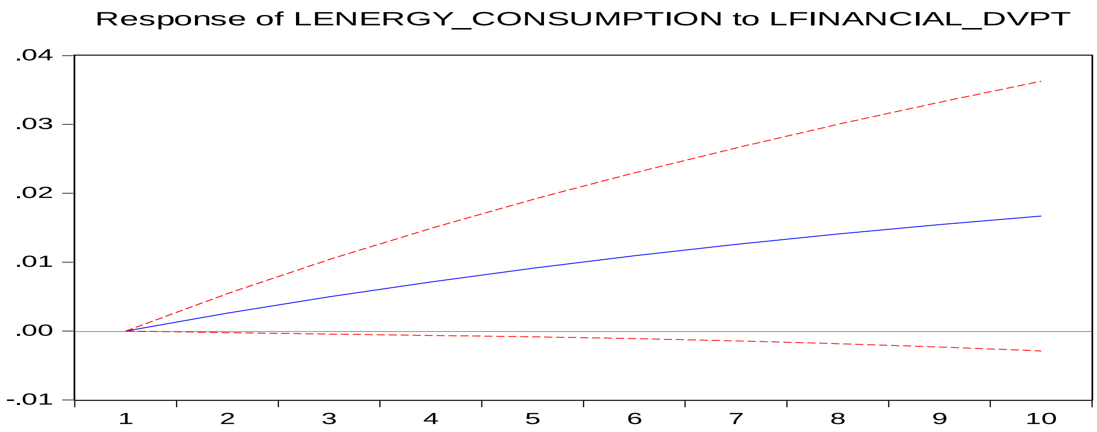
INDIA

Figure 8: Results of Impulse response function of energy consumption and exchange rate of India



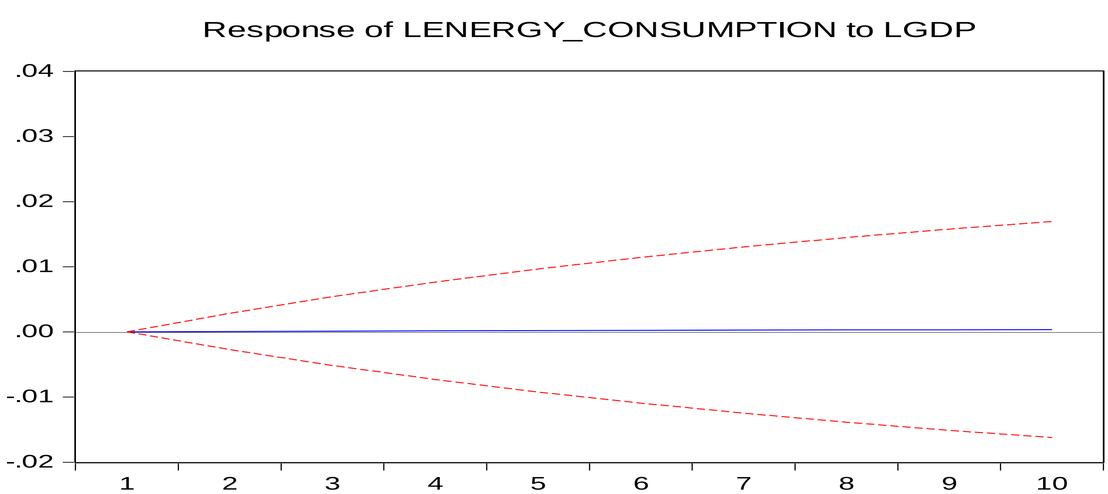
Throughout the period, energy consumption indicates a decreasing trend. Thus, deviation in exchange rate leads to a decline in the consumption of energy for India in the long run as indicated in figure 8.

Figure 9: Results of Impulse response function of energy consumption and financial development of India



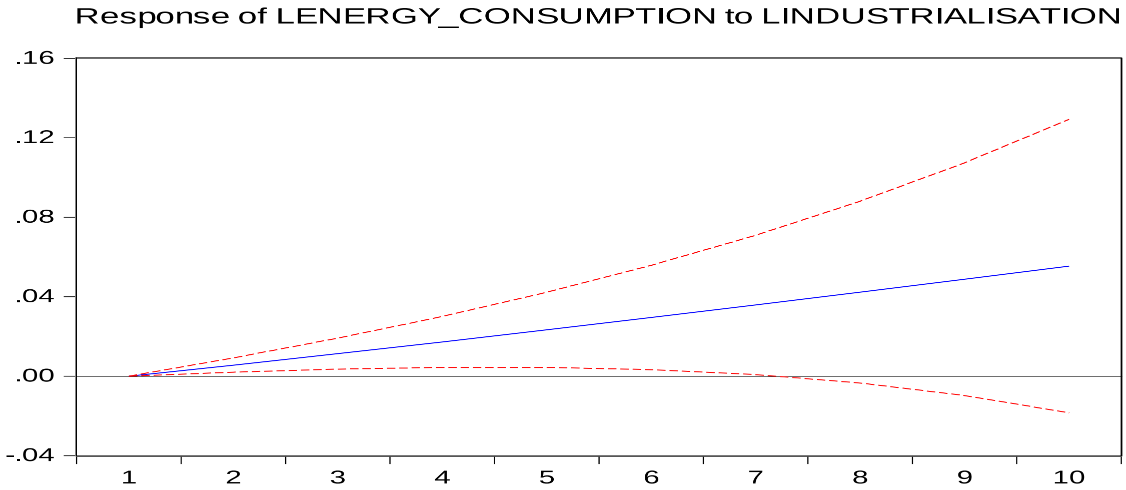
Similar to the effect of exchange rate deviations on energy consumption, financial development has a positive effect on consumption of energy in the long run. In the above figure 9, energy consumption indicates an increasing trend as a response to changes in financial development.

Figure 10: Results of Impulse response function of energy consumption and GDP of India.



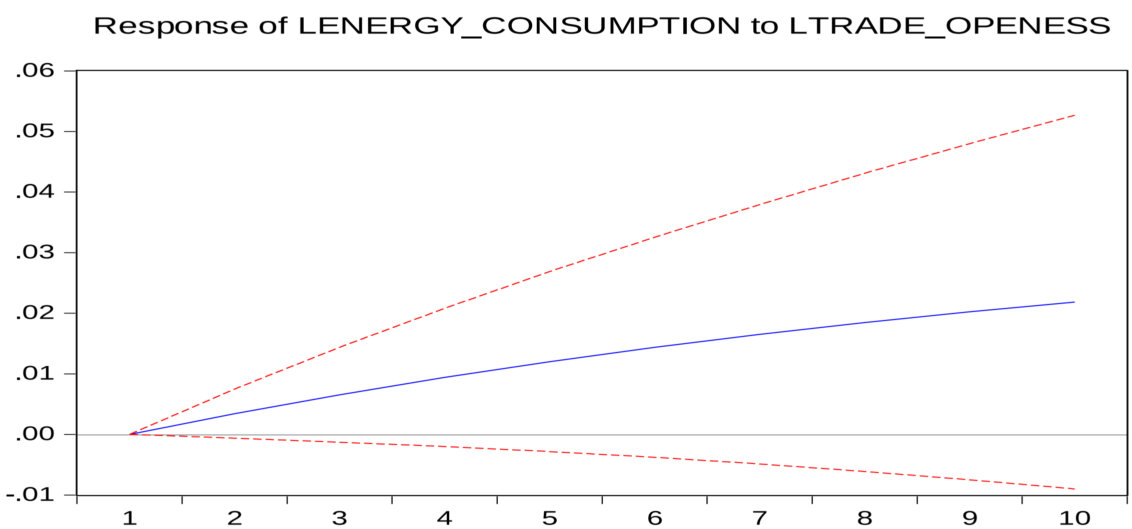
In the above figure 10 which represents the effect of deviations in economic growth has on energy consumption, indicates that economic growth which is represented by GDP has a steady positive effect in the long run while in the short run it remains constant i.e. upto 4 periods.

Figure 11: Results of Impulse response function of energy consumption and industrialization of India



Industrialisation has a positive effect on energy consumption. This is indicated by the blue line in figure11 above. In the long run there is an increasing trend in energy consumption in response to a standard deviation change in industrialization of India.

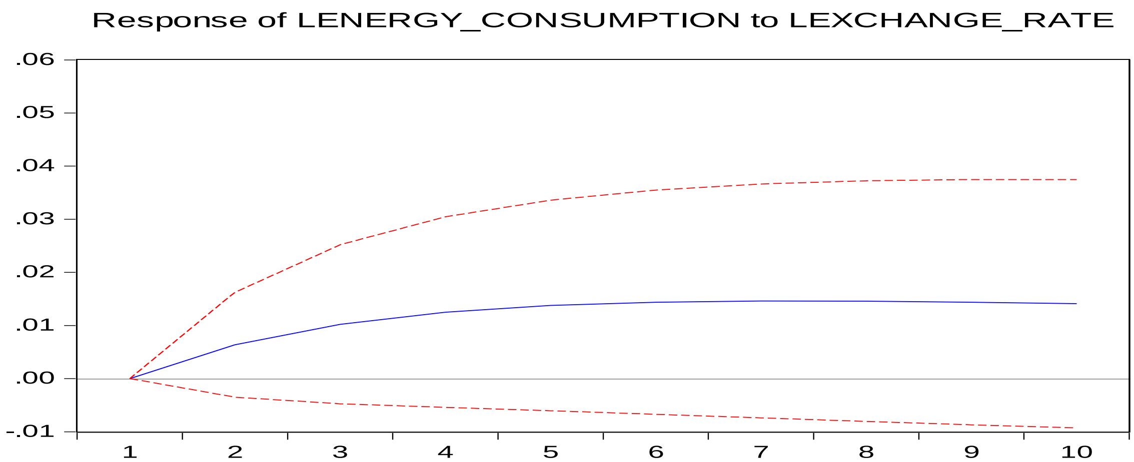
Figure 12: Results of Impulse response function of energy consumption and trade openness of India



Similar to the effect of industrialization on energy consumption, deviation in trade openness leads to an increase in energy consumption in the long run as indicated in figure 12.

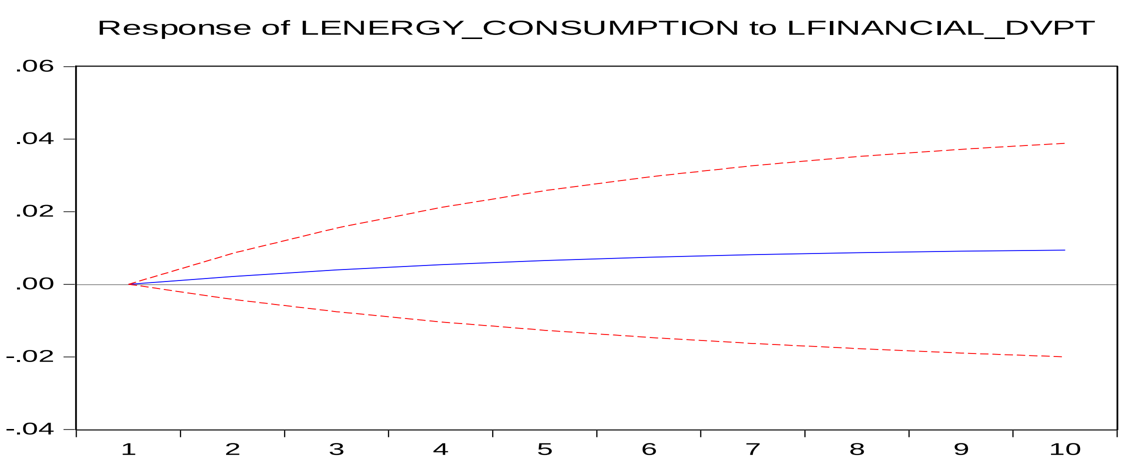
INDONESIA

Figure 13: Results of Impulse response function of energy consumption and exchange rate of Indonesia



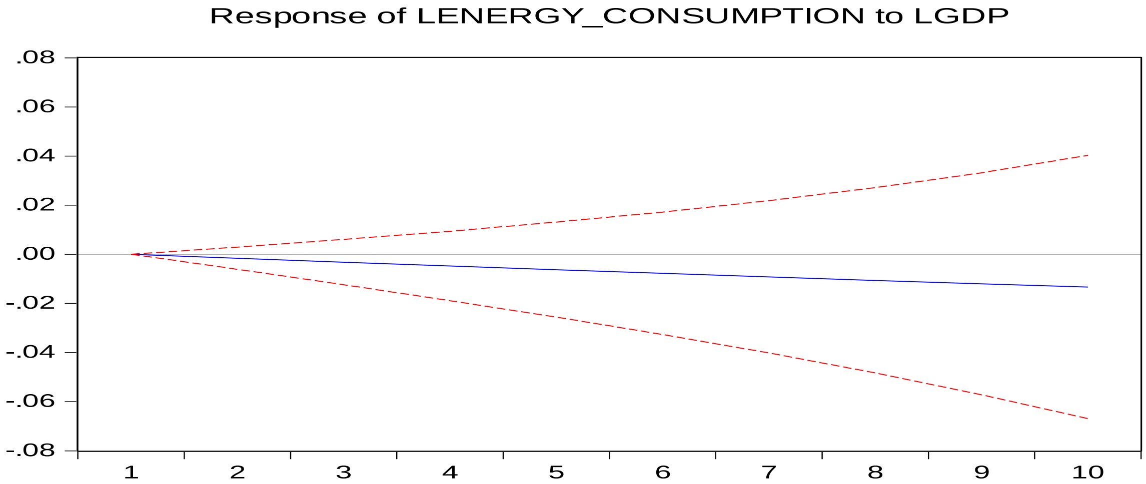
Energy consumption responds positively to deviations in exchange rate in the short run and maintains a constant trend in the long run. This is represented by an increasing trend in the short run which can be observed by the blue line in the above figure 13.

Figure 14: Results of Impulse response function of energy consumption and financial development of Indonesia



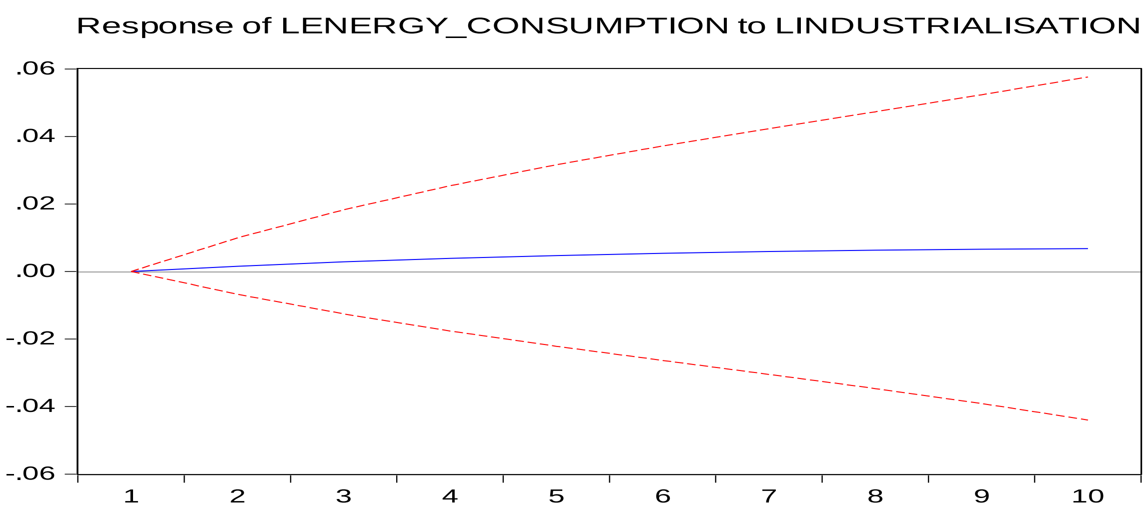
Energy consumption responds positive by an increasing trend in the long run to changes in financial development in Indonesia. This is represented by an constant increasing trend in energy consumption indicated by the blue in the above figure 14.

Figure 15: Results of Impulse response function of energy consumption and GDP of Indonesia



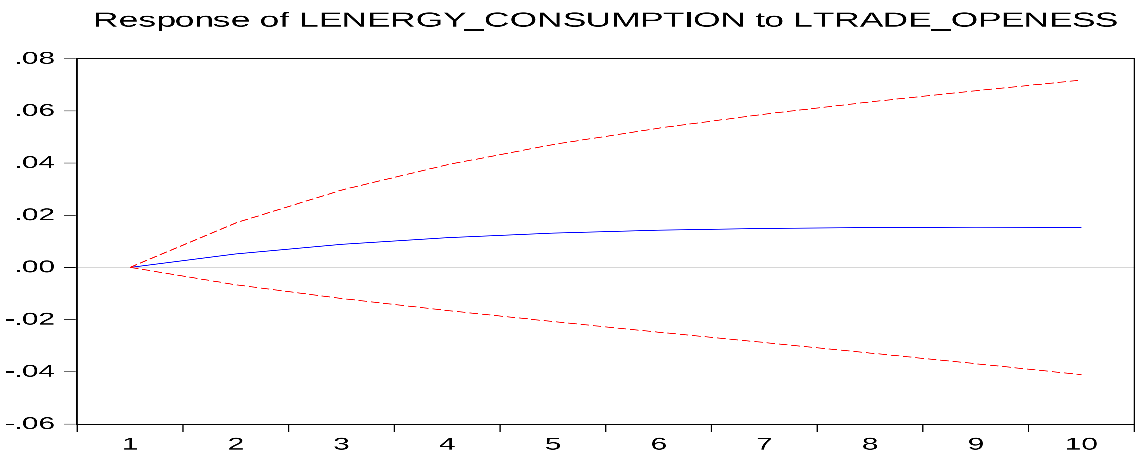
Changes in economic growth of Indonesia represented by Gross Domestic Product (GDP) leads to a negative impact in energy consumption of the country as exhibited in figure 15. This indicates that growth of the country does not lead to energy consumption.

Figure 16: Results of Impulse response function of energy consumption and industrialization of Indonesia



Industrialisation of Indonesia leads to increase in energy consumption for the country. In the long run, energy consumption steadily increases in response to deviation in industrialization as indicate figure 16.

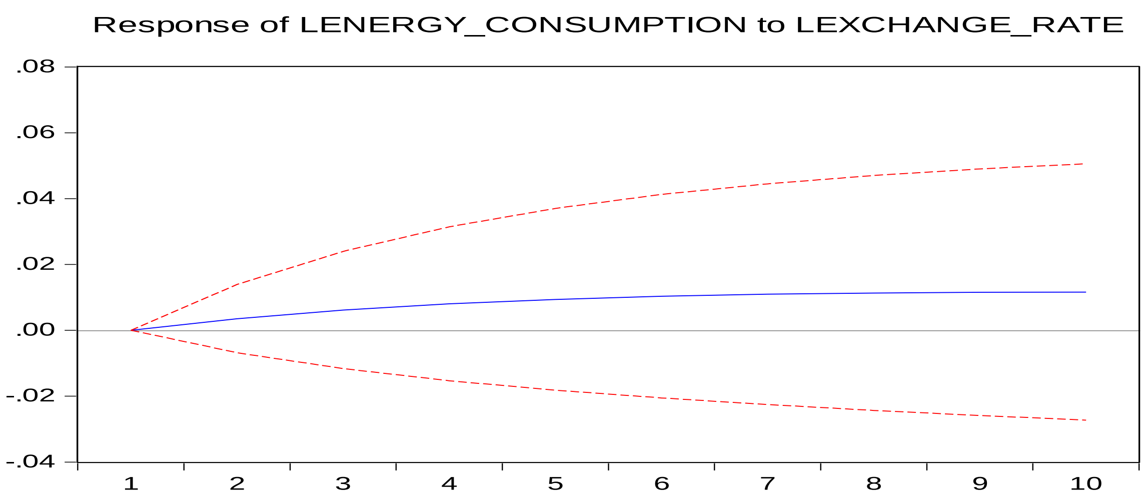
Figure 17: Results of Impulse response function of energy consumption and trade openness of Indonesia



Variation in trade openness leads to an increase in energy consumption. This is represented by the blue line in the above figure 17 where in the short run energy consumption increases but remains constant in the long run.

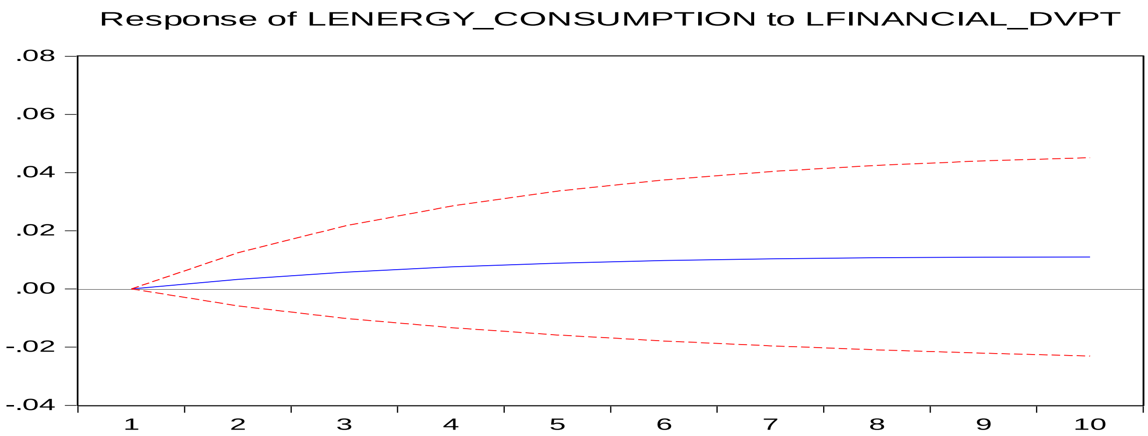
MALAYSIA

Figure 18: Results of Impulse response function of energy consumption and exchange rate of Malaysia



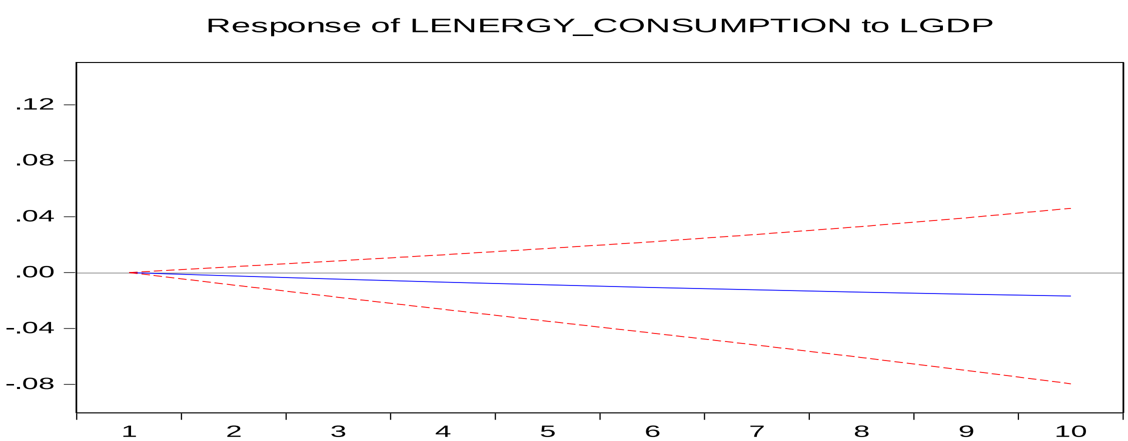
In case of Malaysia, energy consumption increases in the short run in response to a deviation in exchange rate and remains constant in the long run. Therefore, energy consumption positively responds to deviations in exchange rate as indicated in figure 18.

Figure 19: Results of Impulse response function of energy consumption and financial development of Malaysia



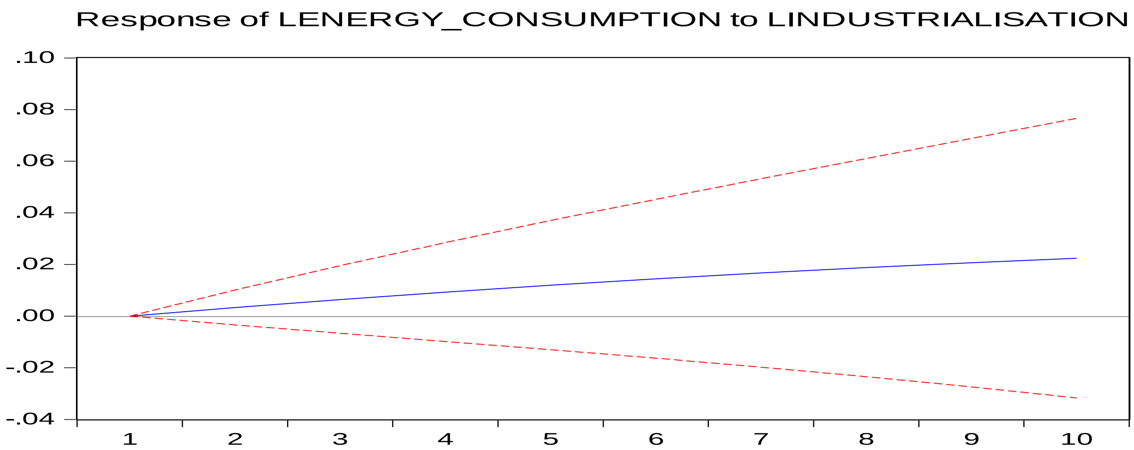
The above figure 19 indicates that similar to exchange rate, energy consumption responds positively to deviations in financial development. This is represented by a blue line which increases in the short run and gains consistency on the long run.

Figure 20: Results of Impulse response function of energy consumption and GDP of Malaysia



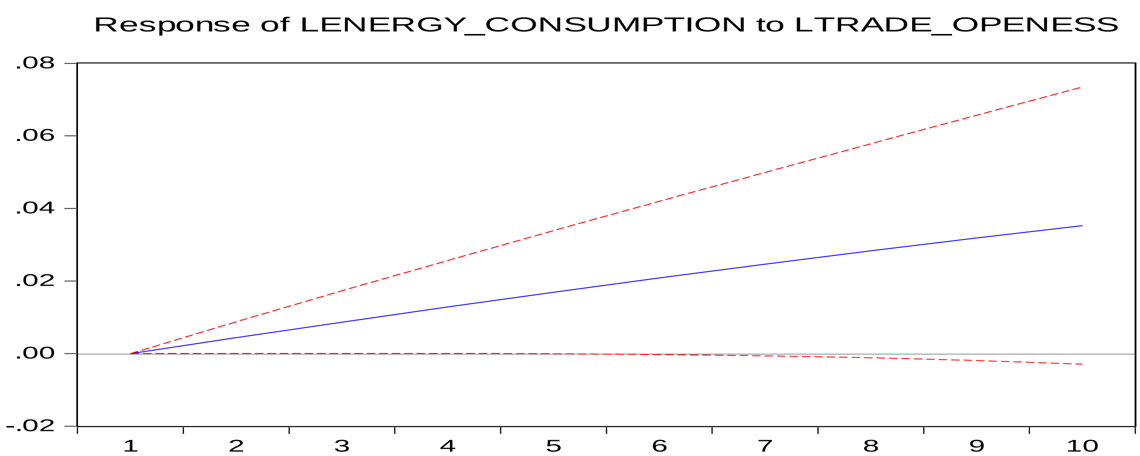
The energy consumption of Malaysia responds negatively to economic growth i.e. GDP. In the long run, energy consumption decreases as a response to variations in GDP of the country as exhibited in figure 20.

Figure 21: Results of Impulse response function of energy consumption and industrialization of Malaysia



Energy consumption increases in the long run as response to deviations in industrialization of Malaysia. In the long run there is a constant increase in energy consumption represented by the blue line in figure 21.

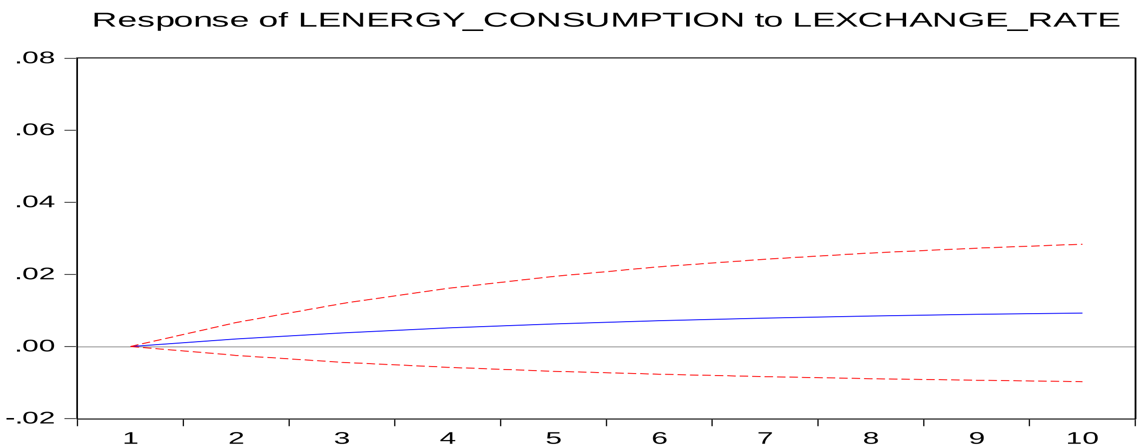
Figure 22: Results of Impulse response function of energy consumption and trade openness of Malaysia



In case of deviations in trade openness, energy consumption responds positively which can be observed by a sharp increase in energy consumption over the 10 year period as indicated in figure 22.

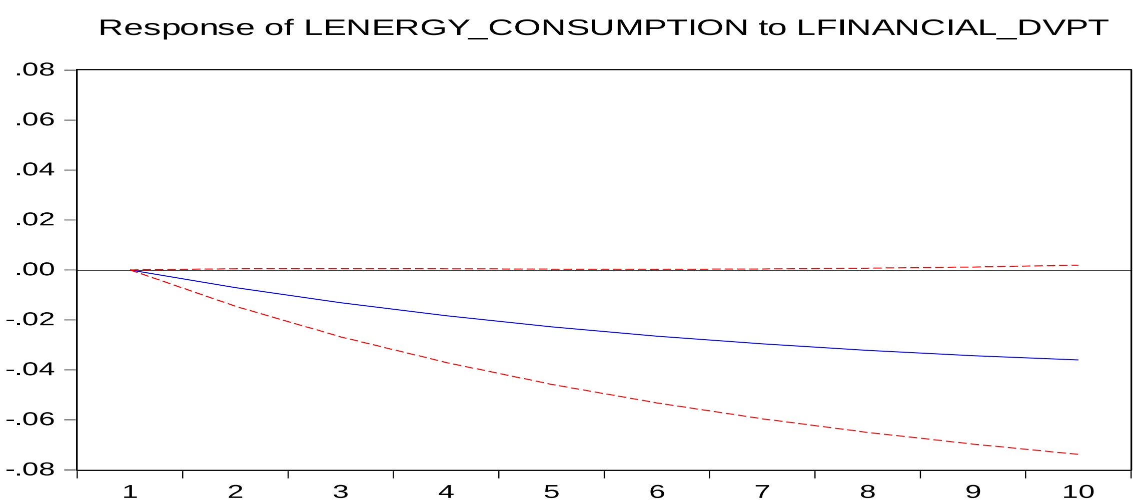
PHILIPPINES

Figure 23: Results of Impulse response function of energy consumption and exchange rate of Philippines



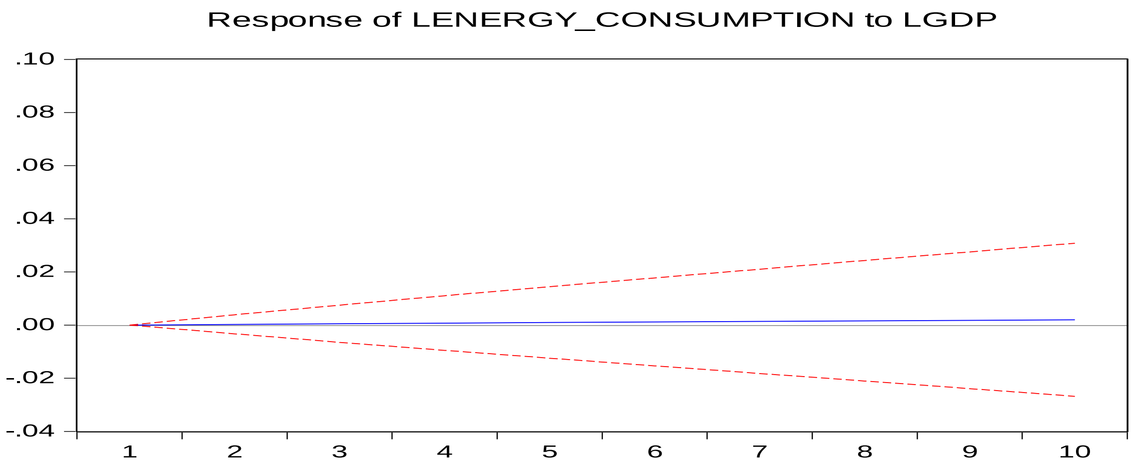
In the long run exchange rate has a positive impact on energy consumption of the Philippines. There is a steady increase in energy consumption from the first period to the tenth period and indicated by the blue line in the above figure 23.

Figure 24: Results of Impulse response function of energy consumption and financial development of Philippines



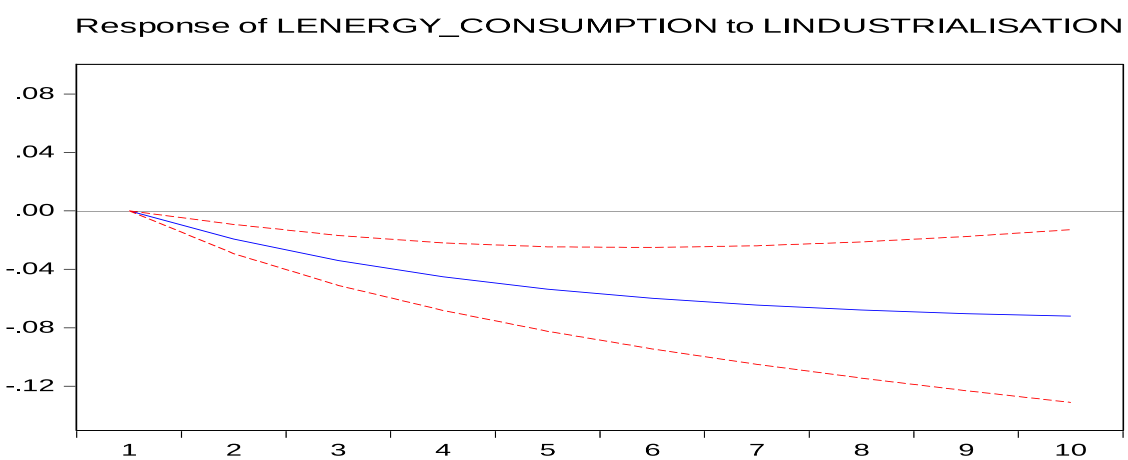
Energy consumption responds negatively to variation in financial development in the Philippines. In the long run, energy consumption exhibits a downward trend indicating that financial development has a negative impact on the variable as indicated in figure 24.

Figure 25: Results of Impulse response function of energy consumption and GDP of Philippines



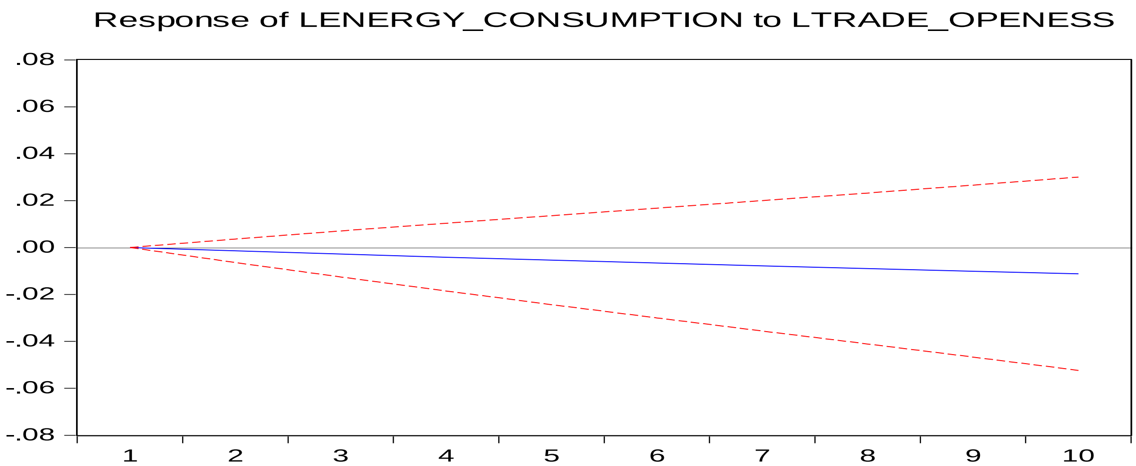
With respect to economic growth, energy consumption indicates a gradual positive response to deviation in GDP of the country. Initially up to the third period, energy consumption shows no reaction to GDP however after the fourth period there is a gradual constant increase in energy consumption which can be observed by the blue line in the above figure 25.

Figure 26: Results of Impulse response function of energy consumption and industrialization of Philippines



The response of energy consumption to Industrialisation is negative as indicated by a decreasing trend in the above figure 26.

Figure 27: Results of Impulse response function of energy consumption and trade openness of Philippines



Trade openness has a negative impact on energy consumption in case of the Philippines. In the long run energy consumption decreases as a response to a deviation in trade openness as indicated in figure 27.

<u>THAILAND</u>

Figure 28: Results of Impulse response function of energy consumption and exchange rate of Thailand

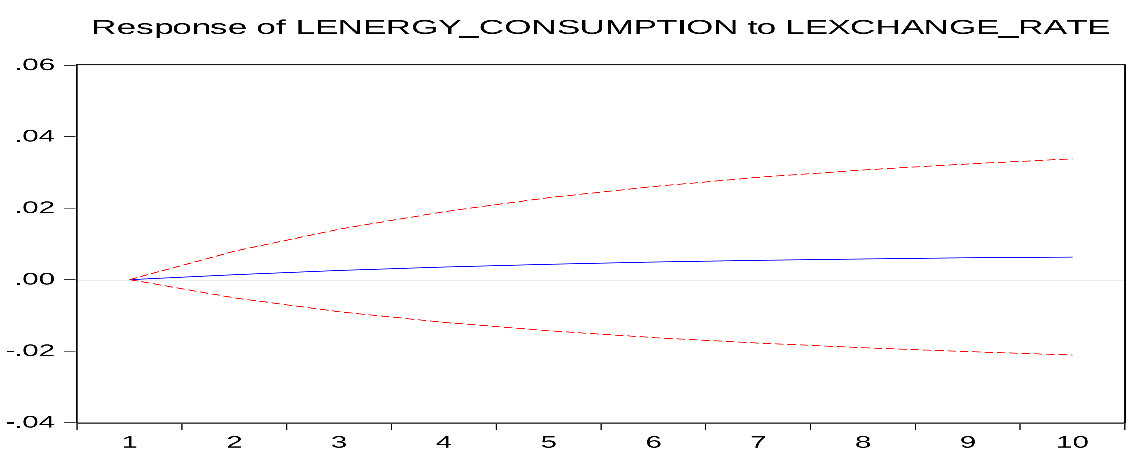
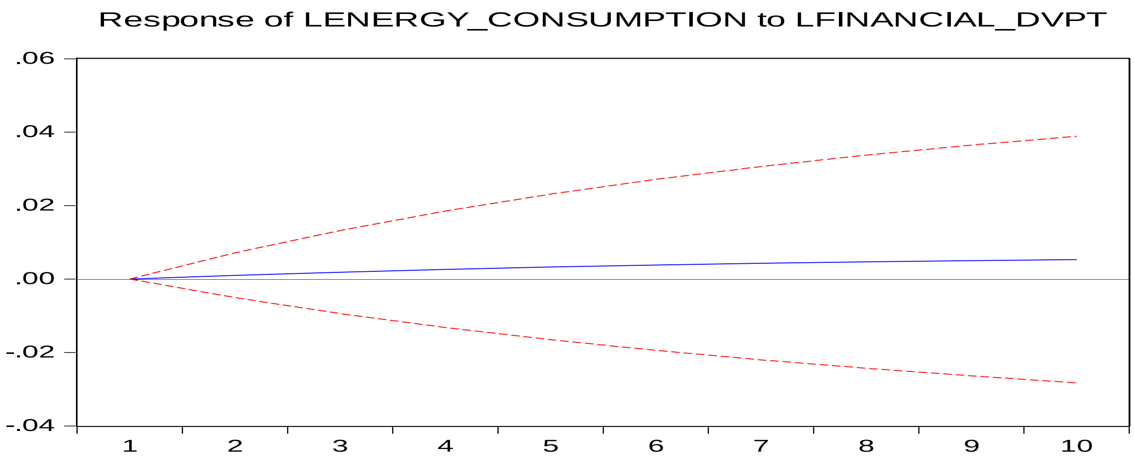


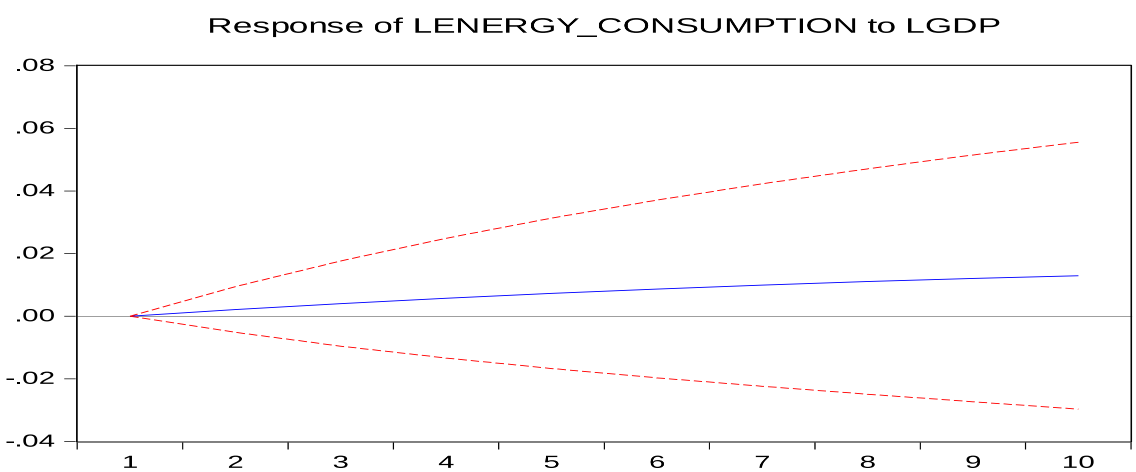
Figure 28 exhibits in case of Thailand, exchange rate has a positive impact on energy consumption which is represented by a constant increase in energy consumption over till the tenth period.

Figure 29: Results of Impulse response function of energy consumption and financial development of Thailand



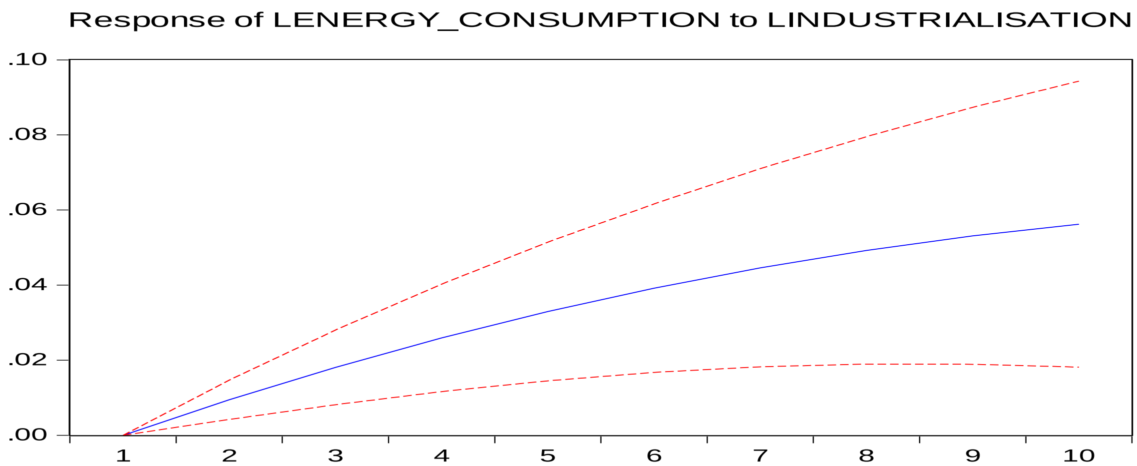
Similar to exchange rate. Financial development has a positive impact on energy consumption according to figure 29. In the long run energy consumption increases as a response to deviation in the financial development of Thailand.

Figure 30: Results of Impulse response function of energy consumption and GDP of Thailand



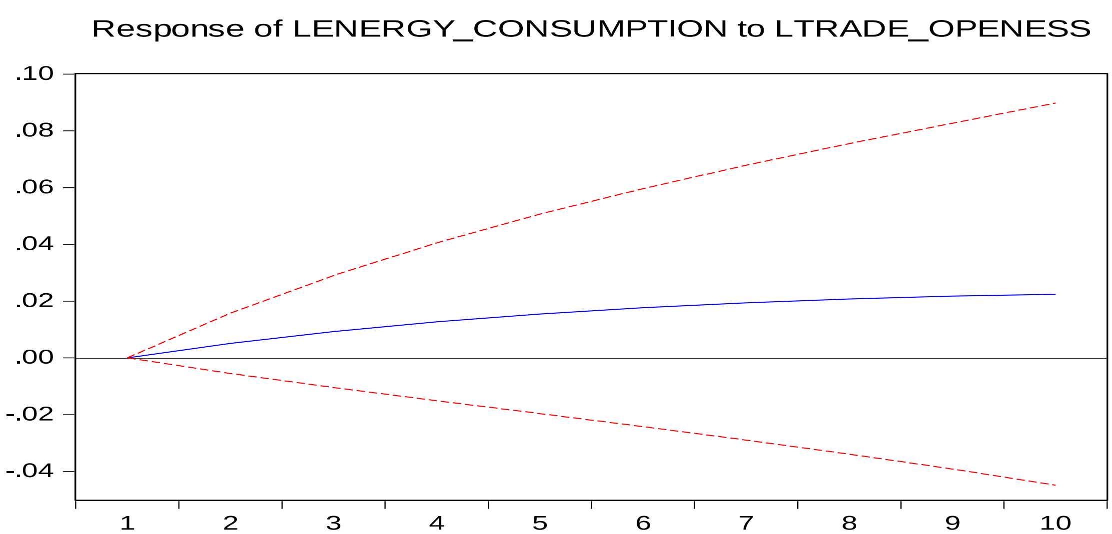
The economic growth of Thailand represented by GDP has a positive impact on energy consumption in the long run. This can be observed by the blue line in the above figure 30 which shows a constant increase in energy consumption.

Figure 31: Results of Impulse response function of energy consumption and industrialization of Thailand



The Industrialisation of Thailand has a positive impact on the consumption of energy in Thailand. In the above figure 31, on can observe that a deviation in industrialization leads to an instant increase in energy consumption in the long run.

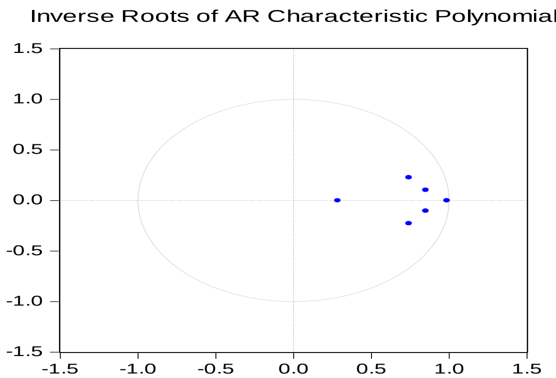
Figure 32: Results of Impulse response function of energy consumption and trade openness of Thailand



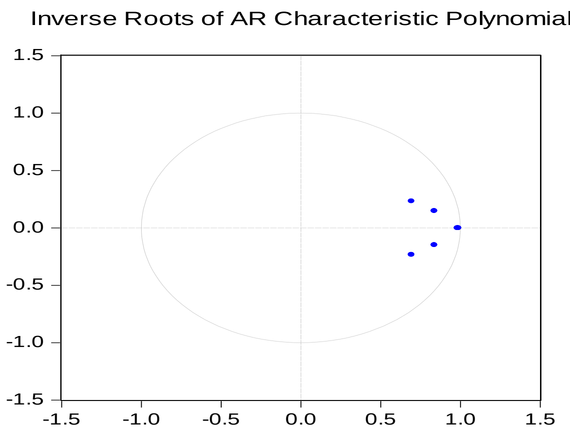
Variation in trade openness has a positive impact on energy consumption. In the long run energy consumption increases as a response to deviations in trade openness of Thailand as indicated in figure 32.

2.9 STABILITY TEST

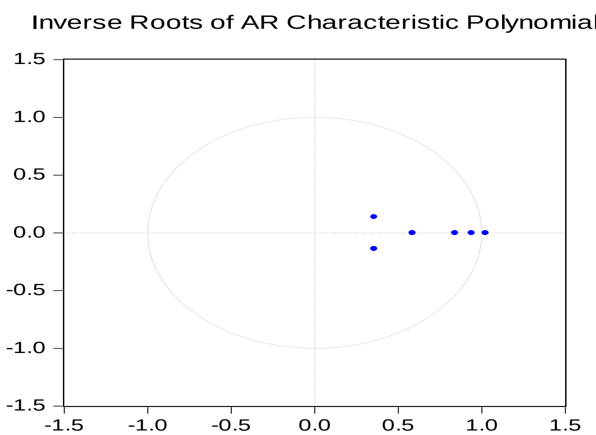
Figure 33: Results of stability test



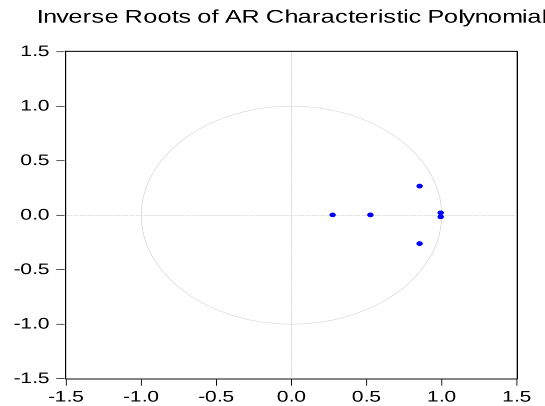
A) CHINA



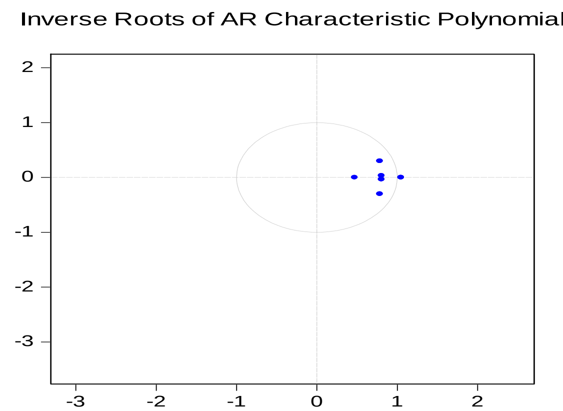
B) INDIA



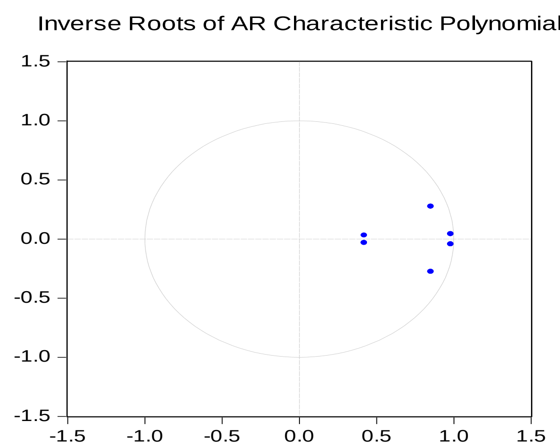
C) INDONESIA



D) MALAYSIA



E) PHILIPPINES



F) THAILAND

Inverse roots of AR characteristic polynomial is applied to check for stability of the model. It plots the roots within a unit circle. If the model is stable all the roots will appear within the circle. Figure 33 indicates the results of stability test for all countries under study. Since the roots are within the circle, it is concluded that the model is stable.

CHAPTER 3
RELATIONSHIP BETWEEN ENERGY CONSUMPTION AND ECONOMIC GROWTH

The oil crisis of the 1970 caused due to events which took place like the Yom-Kippur war in the year 1973 to the Iranian revolution in 1978 followed by the Iraq war in 1980 led to acute shortage of energy to major nations of the world. This resulted in escalation in oil prices. Moreover, the Organization of Oil Exporting Countries (OPEC) were the suppliers of oil to 56% of oil demand in the world by the year 1970. This crisis crippled the industrial sector of oil importing countries who relied on these oil exporting countries to satisfy production requirements thereby leading to economic and political instability worldwide.

This crisis led to a pioneering study conducted by John Kraft and Arthur Kraft in the year 1978 who attempted to analyse the relationship between energy and Gross National Product (GNP) thereby understanding how energy has an impact on the economic growth. This study resulted in the formulation of four hypothesis viz. growth hypothesis, conservative hypothesis, feedback hypothesis and neutrality hypothesis which explained that energy consumption could lead to economic growth, economic growth could lead to energy consumption, bidirectional causality could exists between the variables or there could be no relationship between energy consumption and economic growth.

Since the study conducted in 1978, researchers have attempted to understand this relationship however no consensus has been reached on the relationship between energy consumption and economic growth. This study examines the relationship between energy consumption and economic growth for the six Newly Industrialised Countries from 1965 to 2020 by employing econometric techniques such as ARDL bound testing approach, Johansen’s cointegration test, VECM, VAR and Toda Yamamoto causality test.

3.1 STATIONARITY TEST

Stationarity tests are conducted to find our whether the mean, variance and auto- covariance of variables are the same in different lags i.e. the variables are time invariant/independent. This is necessary to ensure results of analysis are not spurious.

Table 9: Results of stationarity tests on relationship between energy consumption and economic growth

		ADF unit root test		**PP unit root test**	
Country	Variable	Test statistic-Level	Test statistic 1st difference	Test statistic level	Test statistic 1st difference
China	LEC	-2.4613	**-3.1503***	-1.7813	**-3.1868***
	LGDP	**-3.237***	-	**-3.838****	**-**
India	LEC	-2.0940	**-7.388****	-2.2436	**-7.3732****
	LGDP	-1.5668	**-8.651****	-1.7122	**-15.050****
Philippines	LEC	-1.2383	**-6.448****	-1.6021	**-6.5397****
	LGDP	-0.7293	**-3.5012***	-0.1394	**-3.6951****
Malaysia	LEC	-0.5896	**-6.116****	-0.5767	**-6.1676****
	LGDP	-2.4374	**-6.000****	-2.5678	**-5.9993****
Indonesia	LEC	-1.1587	**-7.733****	-1.0498	**-7.6679****
	LGDP	-2.6451	**-5.032****	-2.2849	**-4.9982****
Thailand	LEC	-1.0370	**-4.698****	-0.9404	**-4.873****
	LGDP	-1.7574	**-4.2827***	-1.2831	**-4.3230***

* Indicates significance at 10% significance level
** Indicates significance at 5% significance level

The above tables indicate According to the Augmented Dickey Fuller (ADF) unit root test and Philip Perrons (PP) unit root test, energy consumption and Real GDP of India, Indonesia, Malaysia, Philippines and Thailand are stationery at first difference. However, in case of China, energy consumption is stationery at levels and Real GDP is stationery at first difference. Both stationery tests indicate similar results for all countries under study. In case of India, Indonesia, Malaysia, Philippines and Thailand we reject the null hypothesis.

3.2 LAG LENGTH SELECTION CRITERIA

Analysis is sensitive to lags which refers to lapse in time. Lag selection criteria helps in choosing the number of lags which should be considered with the help of various criterion.

Table 10: Results of lag selection criteria on Objective 2

CHINA						
Lag	**Logl**	**LR stat**	**FPE**	**AIC**	**SC**	**HQ**
0	-31.88796	NA	0.012948	1.328940	1.404697	1.357889
1	200.7811	437.9653	1.65e-06	-7.638474	-7.411200	-7.551626
2	233.4196	58.87727*	5.38e-07	-8.761552	***-8.38276****	***-8.61681****
3	238.5250	8.809321	5.16e-1*	-8.80490*	-8.274596	-8.602256
4	241.3845	4.709736	5.42e-07	-8.760175	-8.078354	-8.499631
5	243.1952	2.840320	5.94e-07	-8.674320	-7.840984	-8.355878
INDIA						
0	12.27809	NA	0.002291	-0.403063	-0.327305	-0.374113
1	225.0975	400.6013*	6.36e-1*	***-8.59206****	***-8.36479****	***-8.50521****
2	228.8055	6.688825	6.44e-07	-8.580606	-8.201817	-8.435860
3	229.0323	0.391399	7.49e-07	-8.432639	-7.902334	-8.229994
4	230.6446	2.655631	8.25e-07	-8.339006	-7.657185	-8.078462
5	234.8255	6.558146	8.25e-07	-8.346097	-7.512760	-8.027654
INDONESIA						
0	-17.37620	NA	0.007329	0.759851	0.835609	0.788800
1	184.0234	379.1051*	3.19e-1*	***-6.98119****	***-6.75403****	***-6.89446****
2	186.9351	5.252558	3.33e-06	-6.938632	-6.559843	-6.793886
3	189.4561	4.349905	3.53e-06	-6.880631	-6.350326	-6.677986
4	189.7653	0.509339	4.10e-06	-6.735896	-6.054075	-6.475352
5	190.4278	1.039159	4.70e-06	-6.605012	-5.771675	-6.286569
MALAYSIA						
0	-10.95580	NA	0.005698	0.508070	0.583828	0.537020
1	180.5930	360.5624*	3.64e-1*	***-6.84678****	***-6.61951****	***-6.75994****
2	182.7776	3.940895	3.92e-06	-6.775591	-6.396802	-6.630845
3	184.4335	2.857188	4.30e-06	-6.683665	-6.153360	-6.481020
4	186.0486	2.660188	4.74e-06	-6.590140	-5.908319	-6.329596
5	188.5887	3.984444	5.06e-06	-6.532888	-5.699552	-6.214446
PHILIPPINES						
0	43.51627	NA	0.000673	-1.628089	-1.552331	-1.599140
1	184.0608	264.5545	3.18e-06	-6.982778	***-6.75550****	-6.895930
2	189.9641	10.64896	2.96e-06	-7.057415	-6.678625	-6.912668
3	196.0469	10.49590*	2.73e-1*	-7.13909*	-6.608790	-6.93645*
4	196.8404	1.306979	3.11e-06	-7.013351	-6.331530	-6.752807
5	198.3213	2.322848	3.45e-06	-6.914559	-6.081223	-6.596117
THAILAND						
0	6.284284	NA	0.002898	-0.168011	-0.092253	-0.139062
1	198.0857	361.0379	1.84e-06	-7.532772	***-7.30549****	-7.445924

2	203.8808	10.45386*	1.71e-1*	-7.60317*	-7.224377	-7.45842*
3	207.2247	5.770033	1.76e-06	-7.577441	-7.047136	-7.374796
4	210.6149	5.583800	1.81e-06	-7.553526	-6.871705	-7.292982
5	215.6800	7.945212	1.75e-06	-7.595294	-6.761957	-7.276851

*Lag selection

According to Akaike Information Criterion, Shwartz Information Criterion and Hannin Quinn Criterion, in case of China, lag 2 is selected based on SC and HQ criteria. In case of India, Indonesia and Malaysia, Lag one is selected based on AIC, SC and HQ criteria and in case of Philippines and Thailand, lag 2 is selected based on SC criterion. The least lags are desirable for the purpose of analysis.

3.3 COINTEGRATION TESTS

Auto Regressive Distributed Lag (ARDL) - bounds testing approach

Since the order of integration for is mixed, we cannot apply Ordinary Least Square method nor can we apply Johansen's cointegration test. This is because in order to apply OLS, all variables should be stationery at level and in case of Johansen's Cointegration test, all variables should stationery at first difference. Therefore, we adopt ARDL bound test to find out if there exists long run relationship between energy consumption and Real GDP

Table 11: Results of ARDL bound testing approach to cointegration for China

	Critical value bounds					
K	90% level		***95% level***		99% level	
1	2.496	3.346	2.962	3.910	4.068	5.250
Country	***China***					
F Statistic	4.347656*					
	Reject H0					

*significance at the 5% level

In case of China, because energy consumption of China is integrated of order 1 and Real GDP is integrated at levels i.e. there exists mixed order of integration.

According to bounds cointegration test, if the F statistic is more than the upper bound critical value, then Null hypothesis is to be rejected as there is cointegration. However, if the F statistic is less than the lower bound critical value then we accept the Alternate hypothesis as there is no cointegration and if the F statistic is between the lower bound and upper bound, the test results are inconclusive.

According to **P. K. Narayan (2005)** the existing critical values in **Pesaran et al. (2001)** which is meant for large sample size cannot be applied for small sample sizes. Hence, **P. K. Narayan (2005)** provides a set of critical values for sample sizes which are small which are 2.496 - 3.346, 2.962 – 3.910, and 4.068 – 5.250 at 90%, 95%, and 99%, respectively.

Since 4.347656 is more than 3.910 which is the higher bound at 5% level of significance, we reject the null hypothesis i.e. H_{4a} where we can conclude that there is cointegration between energy consumption and GDP for China.

3.4 JOHANSEN COINTEGRATION TEST

As the variables are stationery at first difference for India, Indonesia, Malaysia, Philippines and Thailand, we can test for long term relationship using Johansen's Cointegration test.

Table 12: Results of Johansen's cointegration test between energy consumption and economic growth

Country	Hypothesised no. of cointegrating equations	**Eigen value**	**Trace statistic**	**Critical value @ 5% (p value)**	**Max Eigen statistic**	**Critical value @ 5% (p value)**
India	None	0.319582	10.08194	15.49471 (0.2745)	8.118179	14.26460 (0.3668)
	At most 1	0.035713	1.962760	3.841466 (0.1611)	1.963760	3.841466 (0.1611)
Indonesia	None	0.088602	5.932201	15.49471 (0.7035)	5.009863	14.26460 (0.7406)
	At most 1	0.016935	0.922338	3.841466 (0.3369)	0.922338	3.841466 (0.3369)
Malaysia	None	0.083477	7.183110	15.49471 (0.5565)	4.707099	14.26460 (0.7783)

	At most 1	0.044817	2.476011	15.49471 (0.5565)	2.476011	3.841466 (0.1156)
Philippines	None	0.162463	10.88803	15.49471 (0.2185)	9.573653	14.26460 (0.2415)
	At most 1	0.024046	1.314378	3.841466 (0.2516)	1.314378	3.841466 (0.2516)
Thailand	None	0.179300	13.15792	15.49471 (0.1091)	10.67028	14.26260 (0.1715)
	At most 1	0.045022	2.487644	3.841466 (0.1147)	2.487644	3.841466 (0.1147)

Source: Researcher's compilation

The results of Johansen's cointegration test indicates no cointegration between energy consumption and economic growth as the P value is more than 0.05 which is supported by Trace test and Max Eigen values, Therefore the null hypothesis of no cointegration cannot be rejected at 5% level of significance i.e. H_{4b}, H_{4c}, H_{4d}, H_{4e} and H_{4f} are accepted.

3.5 VECTOR ERROR CORRECTION MODEL (VECM)

Since China are cointegrated according to ARDL, we can run VECM to test how quickly variables correct itself towards equilibrium after a shock where energy consumption is the independent variable and Real GDP the dependent variable.

Table 13: Results of Vector Error Correction Model for China

	ECT Coefficient	Std Error	t- Statistic	Prob.
China	-0.023634	0.04885	-0.48378	0.6312

The coefficient should be negative and significant to reject H0. The coefficient error term of China is negative but not significant and hence it could be concluded that there is no long term relationship between the variables. Therefore, we accept H_{5a} hypothesis which states that no long run relationship exists between energy consumption and GDP for China.

3.6 VECTOR AUTOREGRESSION MODEL (VAR)

Equation 1:

INDIA_EC = **0.913828665411*INDIA_EC(-1)** + 0.122665825882*INDIA_EC(-2) + 0.25319921187*INDIA_GDP(-1) **- 0.29584893504*INDIA_GDP(-2)** + 0.220094353271

Equation 2:

INDONESIA_EC = **1.07781693751*INDONESIA_EC(-1) -** 0.0813227948265*INDONESIA_EC(-2) - 0.0398494123126*INDONESIA_GDP(-1) + 0.0135299811706*INDONESIA_GDP(-2) + 0.244244609105

Equation 3:

MALAYSIA_EC = **1.18307509826*MALAYSIA_EC(-1) -** 0.217187736811*MALAYSIA_EC(-2) - 0.267421168648*MALAYSIA_GDP(-1) + 0.285992933371*MALAYSIA_GDP(-2) + 0.0209775880753

Equation 4:

PHILIPPINES_EC = **0.870896292083*PHILIPPINES_EC(-1)** + 0.000545850725656*PHILIPPINES_EC(-2) + **0.509140518421*PHILIPPINES_GDP(-1)** - 0.480809585558*PHILIPPINES_GDP(-2) + 0.112129908395

Equation 5:

THAILAND_EC = **0.978835063299*THAILAND_EC(-1) -** 0.120828468703*THAILAND_EC(-2) + **0.438066349491*THAILAND_GDP(-1)** - 0.272930367538*THAILAND_GDP(-2) - 0.800703547604

VAR Coefficients and Probabilities

Table 14: Results of VAR

	India	Prob.	**Indonesia**	Prob.	**Malaysia**	Prob.	**Philippines**	Prob.	**Thailand**	Prob.
C(1)	**0.9138**	**0.000**	**1.0778**	**0.000**	**1.1830**	**0.000**	**0.8709**	**0.000**	**0.9788**	**0.000**
C(2)	0.1227	0.462	-0.0813	0.615	-0.2172	0.204	0.0005	0.997	-0.1208	0.4575
C(3)	0.2532	0.111	-0.0398	0.880	-0.2674	0.363	**0.5091**	**0.095**	**0.4381**	**0.0852**
C(4)	**-0.2958**	**0.062**	0.0135	0.961	0.2860	0.350	-0.4808	0.123	-0.2729	0.3052
C(5)	0.2201	0.196	0.2442	0.587	0.0210	0.970	0.1121	0.726	-0.8007	0.1725

*Significance at 5% level

In case of India, Indonesia, Malaysia, Philippines and Thailand there is no long run relationship between energy consumption and GDP. Therefore, we run a VAR model to check if GDP is affect by the past values of energy consumption and GDP itself at different lags.

In Equation 1 for India, the Coefficients associated with energy consumption Lag (1) and Lag (2) are C (1) and C (2) for which probability values are 0.000 & 0.462 respectively. Since the P-Value of C(1) is less than 5%, the null hypothesis that energy consumption lag 1 is significant to influence GDP could be accepted. This proves that GDP are being affected by the past values of energy consumption at lag 1.

Further, the coefficient associated with lag (1) of Real GDP is 0.111 which is more than 0.05 we accept the null hypothesis, which proves that GDP is not affected by its past values at lag 1. The p- value associated with lag (2) of C (4) is 0.062 which is less than 0.10. Therefore, we reject H_{5b} and GDP is significant to explain its past values at lag 2.

In equation 2 and 3 for Indonesia and Malaysia resp., the Coefficients associated with energy consumption Lag (2) is C (2) for which probability values are 0.000. Since the P-Value for C (1) is less than 5%, the null hypothesis that energy consumption lag (1) is not significant to influence GDP could be rejected. This proves that GDP is affected by the past values of energy consumption at lag 1.

Further, The p- value associated with C(3) and C(4) is more than 0.05. Therefore, we accept H_{5d} and GDP is not significant to explain its past values at lag1and 2.

Equation 4 and 5 for Philippines and Thailand the Coefficient associated with energy consumption Lag (1) is C (1) which probability values are 0.000 each. Since the P-Values are less than 5%, the null hypothesis that energy consumption lag (1) are not significant to influence GDP could be rejected. This proves that GDP is affected by the past values of energy consumption at lag 1. Further, the coefficient associated with lag (1) of Real GDP is 0.000 which is less than 0.05 we reject the null hypothesis, which proves that GDP is affect by its past values at lag 1.

3.7 TODA YAMAMOTO CAUSALITY TEST

Toda Yamamoto causality test is applied to identify the existence of a causal relationship between variables. This test is applicable to variables irrespective of the level of integration or stationarity.

Table 15: Results of Toda Yamamoto causality test between energy consumption and economic growth

Country	**EC Granger causes GDP**	**GDP Granger causes EC**	**Direction of causality**
India	0.1096	**0.0787***	**GDP→EC**
China	0.5213	**0.0060****	**GDP→EC**
Indonesia	0.1916	0.9355	No causality
Malaysia	**0.0600***	0.7623	**EC→GDP**
Philippines	0.6409	**0.0463****	**GDP→EC**
Thailand	**0.0607***	**0.0156****	**GDP↔EC**

** and * indicate significance at the 5% and 10% level, respectively

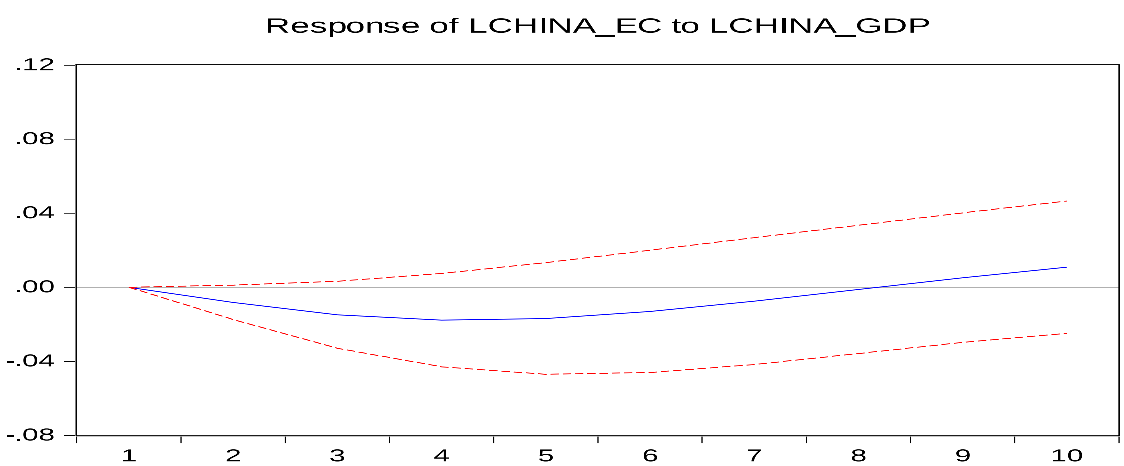
In the above table the p-values of India, China, Thailand and Philippines are less than 5% significance level which indicates that there is a unidirectional causality from economic growth to energy consumption supporting the conservative hypothesis. Hypothesis H8a, H_{6c}, H_{6i} and H_{6k} is accepted

In case of Malaysia, there is a unidirectional causality running from energy consumption to GDP at 10% significance level resp. supporting the growth hypothesis. Therefore, we reject hypothesis H_{6g}. This indicates that energy conservation will be a hindrance to economic growth in these countries. However, in case of Indonesia, there is no causality between energy consumption and economic growth supporting the neutrality hypothesis.

3.8 IMPULSE RESPONSE FUNCTION

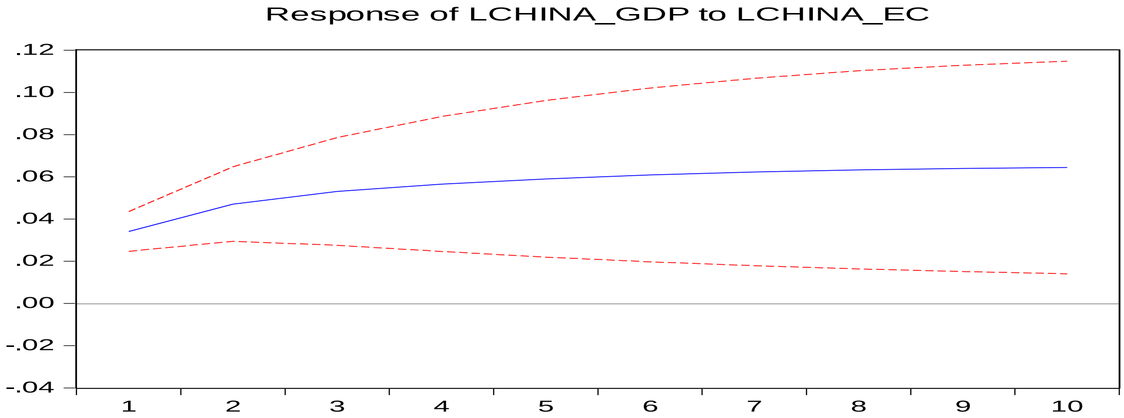
Impulse response function identifies the manner in which a variable responds to another variable. It also indicates the extent of impact a variable has on another in terms of the time period.

Figure 34: Results of Impulse response function of energy consumption and GDP of China



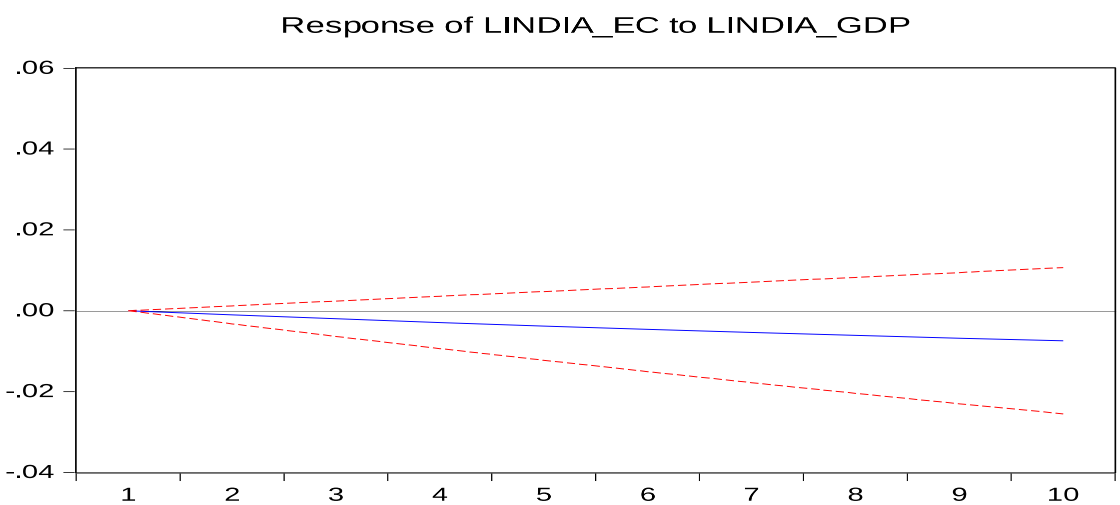
A indicated in figure 34, in the initial periods, economic growth of China has a negative impact on energy consumption upto four periods, however from the fifth period onwards energy consumption responds positive to energy consumption in the long run.

Figure 35: Results of Impulse response function of GDP and energy consumption of China



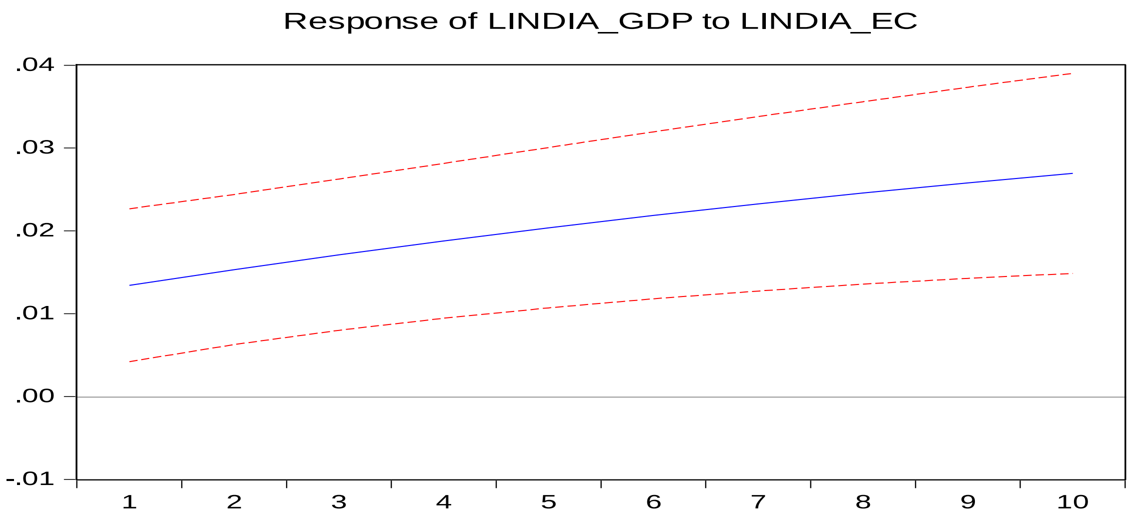
In case of Economic growth represented by GDP, in the short run economic growth indicates a rapid increase in response to energy consumption but stabilizes in the long run by a gradual increase as indicated in figure 35.

Figure 36: Results of Impulse response function of energy consumption and GDP of India



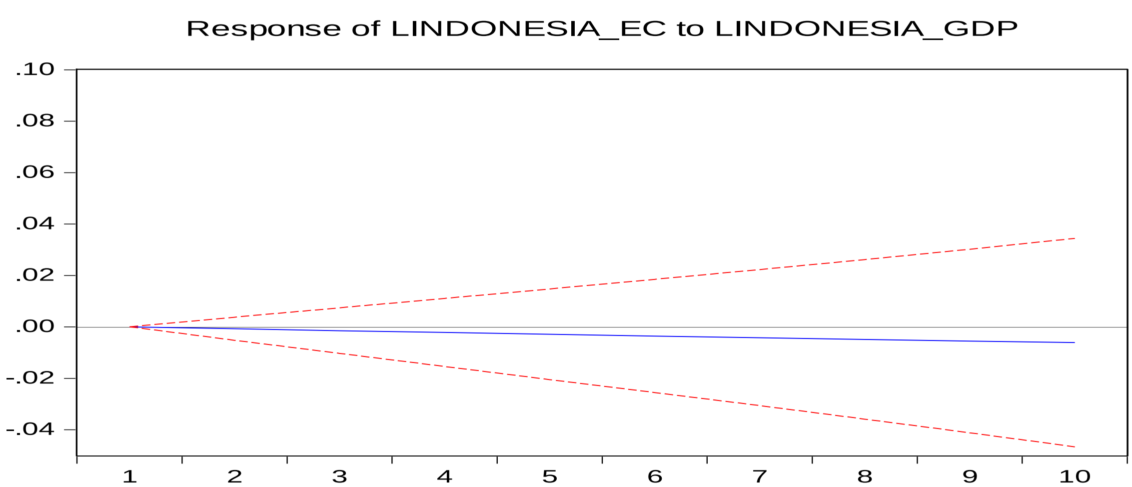
In figure 36, energy consumption of India responds negatively to economic growth in the long run. This is indicated by the blue line gradually falling in the long run which is a decrease in energy consumption over the ten -year period.

Figure 37: Results of Impulse response function of GDP and energy consumption of India



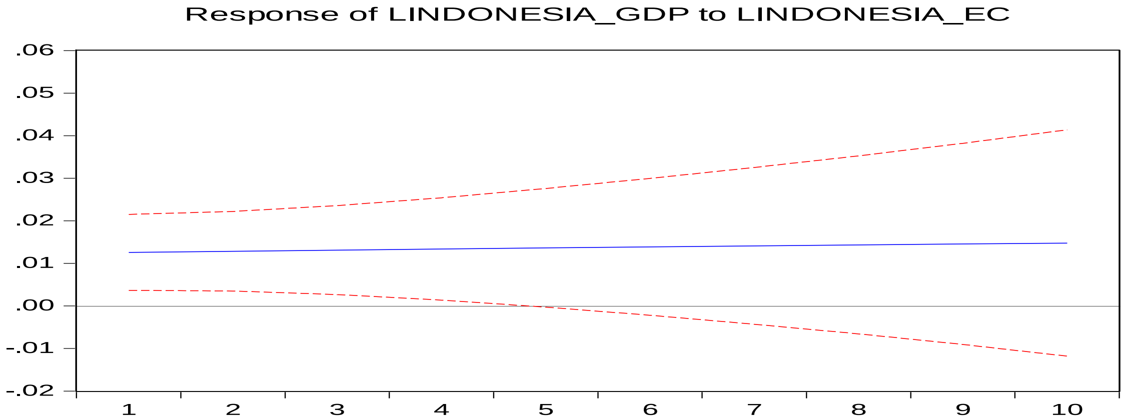
On the contrary, economic growth of India responds positive to energy consumption in the long run indicated by an increasing blue trend line over the ten year period in figure 37.

Figure 38: Results of Impulse response function of energy consumption and GDP of Indonesia



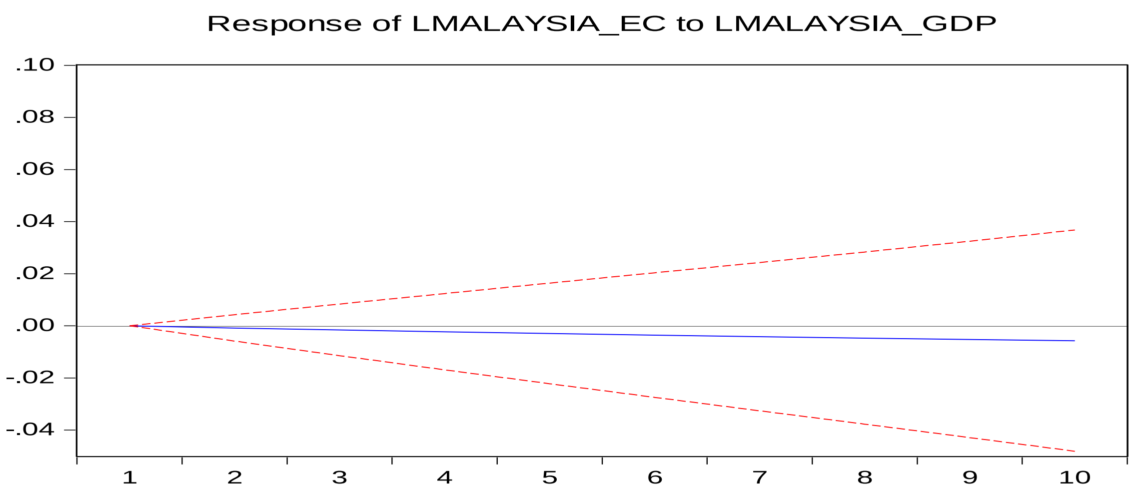
Energy consumption of Indonesia responds negatively to economic growth of the country. This indicates that economic growth of Indonesia does not depend upon energy consumption of the country in the long run as per figure 38.

Figure 39: Results of Impulse response function of GDP and energy consumption of Indonesia



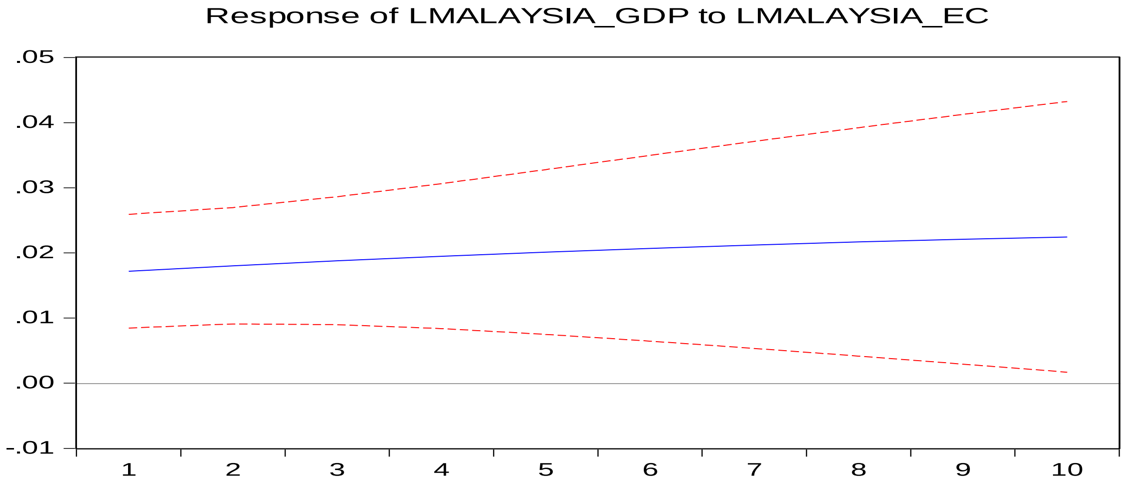
In figure 39, energy consumption of Indonesia has a positive impact on economic growth of the country in the long run where energy consumption does contribute to the economic growth gradually over the ten- year period.

Figure 40: Results of Impulse response function of energy consumption and GDP of Malaysia



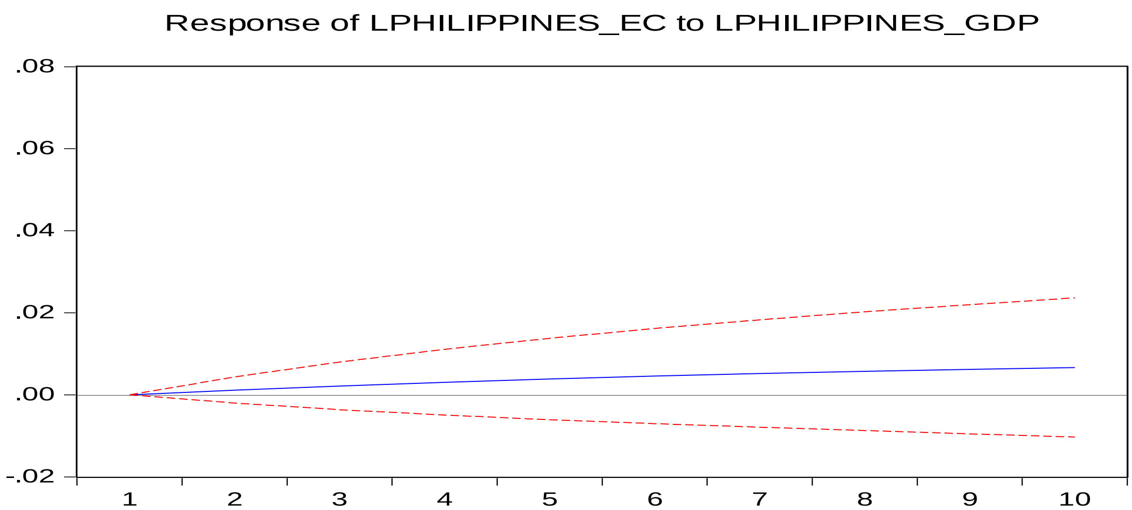
Energy consumption has a negative impact on economic growth of Malaysia. In the long run, energy consumption does not depend upon economic growth of the country as indicated in figure 40.

Figure 41: Results of Impulse response function of GDP and energy consumption of Malaysia



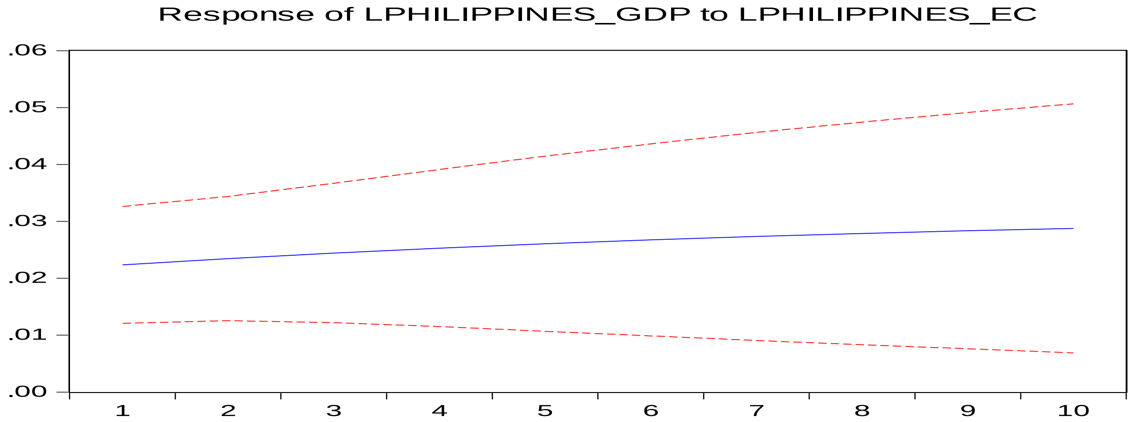
Economic growth gradually increases in the long run as a response to consumption of energy in Malaysia. This is represented by the blue line in figure 41 which indicates an increasing trend over the ten -year period.

Figure 42: Results of Impulse response function of energy consumption and GDP of Philippines



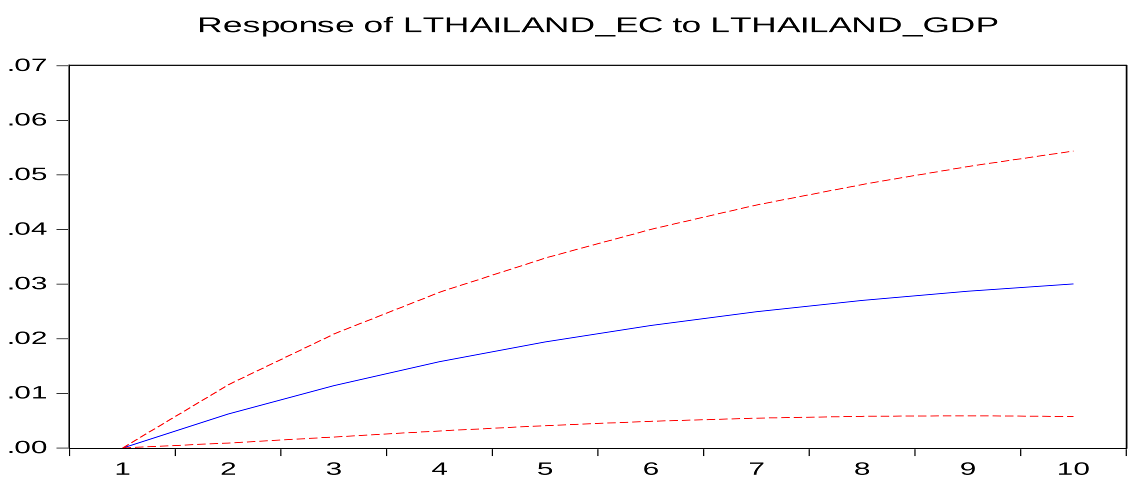
In case of the Philippines, energy consumption increases in the long run as a response to economic growth of the country. This is indicated by the blue line in figure 42 which increases over the ten- year period.

Figure 43: Results of Impulse response function of GDP and energy consumption of Philippines



Similarly, economic growth of Philippines progresses in responses to consumption of energy in the country. Thus, economic growth of the Philippines depends on energy consumption as indicated in figure 43.

Figure 44: Results of Impulse response function of energy consumption and GDP of Thailand



In figure 44, energy consumption of Thailand depends upon economic growth which is indicated by the uptrend in energy consumption in the long run in response to economic growth.

Figure 45: Results of Impulse response function of GDP and energy consumption of Thailand

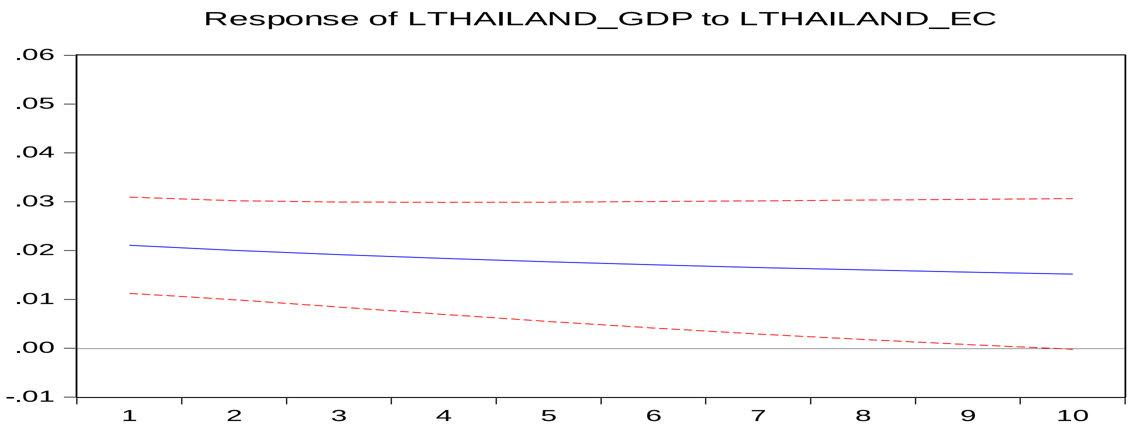
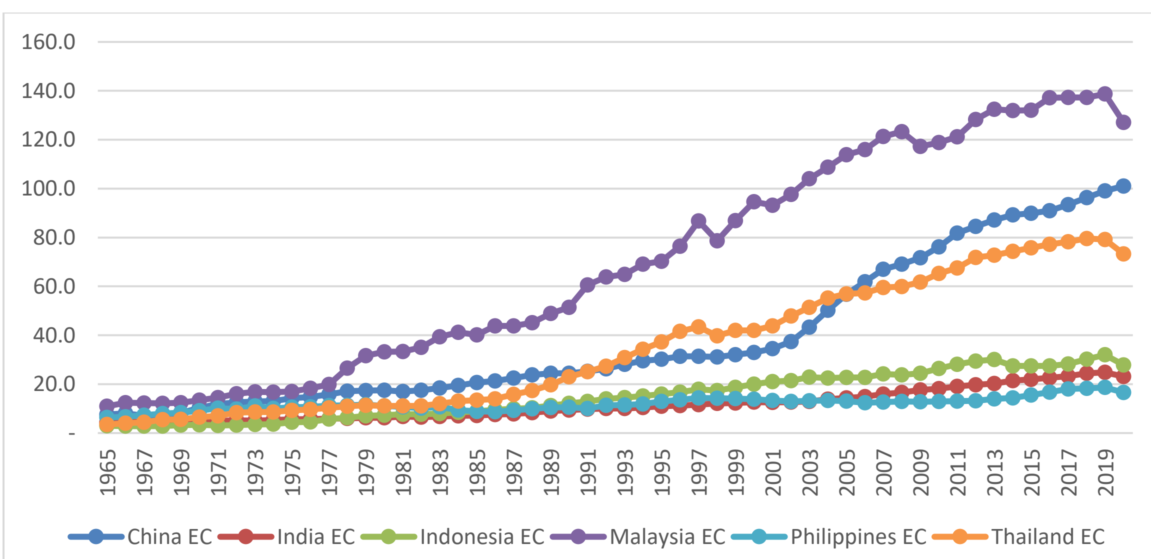


Figure 45 indicates that economic growth of Thailand does not depend on consumption of energy. In the long run, economic growth of Thailand indicates a gradual decrease in response to consumption of energy in the country.

3.9 TREND ANALYSIS OF Energy Consumption

Trend analysis displays the manner in which a variable behaves in the long run i.e. variations in a variable due to various factors over a period of time.

Figure 46: Results of Trend analysis for Energy consumption



In the above figure 46 which displays the trend of energy consumption. X axis indicates the quantum of energy consumption by each country measured in gigajoules per capita while the Y axis indicates the time period in years from 1965 to 2019. Malaysia is the highest consumer of energy followed by China and Thailand. India has scope to expand energy consumption which will be visible in the future since the countries GDP is increasing and as analysis indicate that GDP leads to energy consumption. The consumer of the least energy consumption comparatively is the Philippines.

TREND ANALYSIS of GDP

Figure 47: Results of Trend analysis for GDP

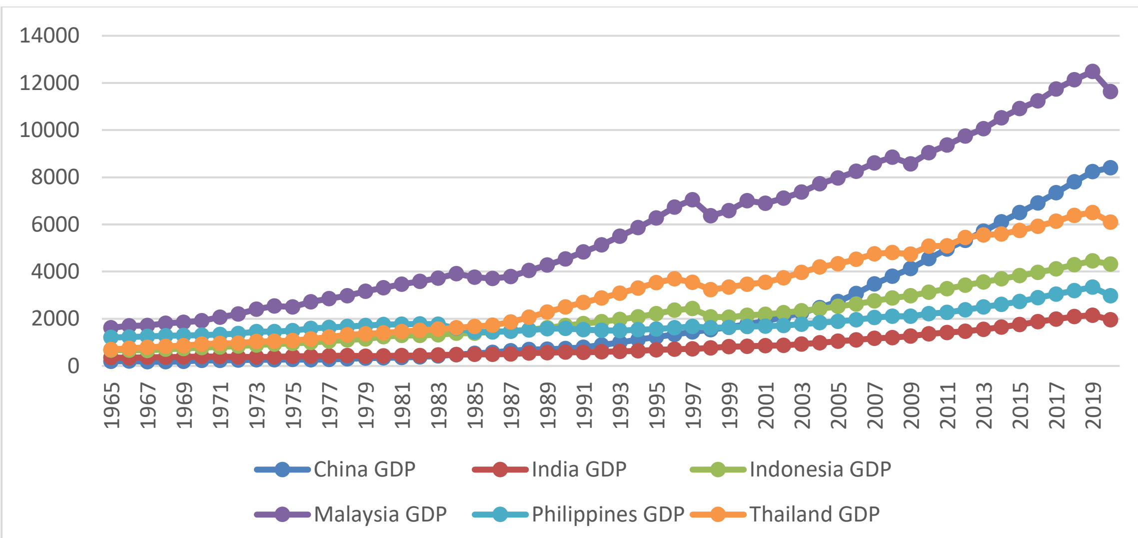
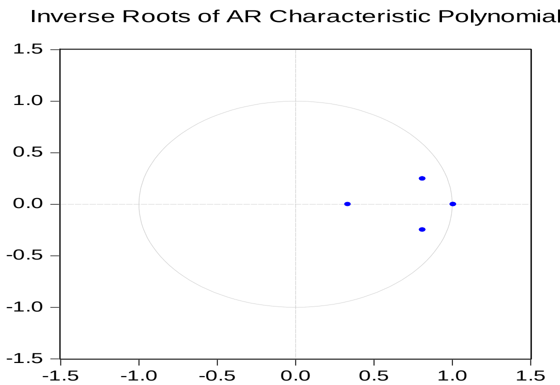


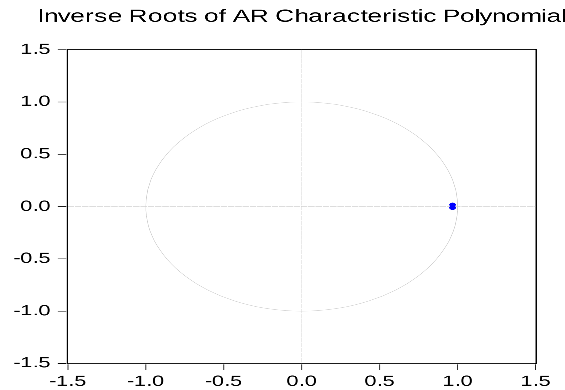
Figure 47 indicates the trend of economic growth for the Newly Industrialised Countries where the X axis indicates the GDP measured in constant 2010 USD and the X axis displays the time period from 1965 to 2019. The economic growth of Malaysia has increased rapidly over the last 55 years followed by China showing the second highest in term of GDP. The GDP of India is the least which indicates that the country is not exploiting resources sufficiently and there not being able to explore her potential to achieve growth and development of the country.

3.10 STABILITY TEST

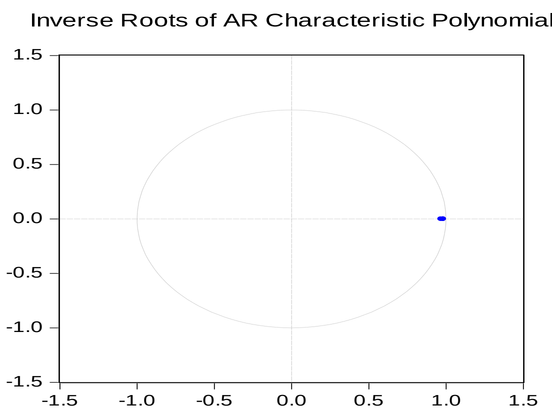
Figure 48: Results of Stability test



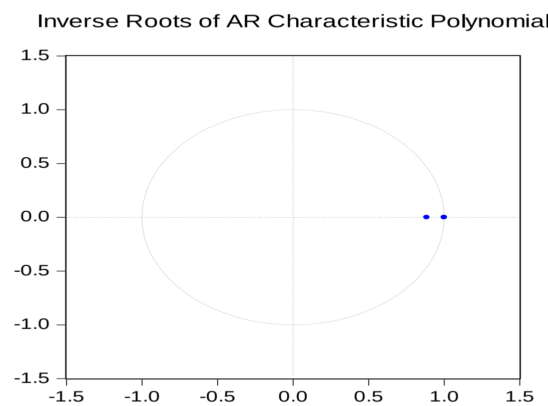
CHINA



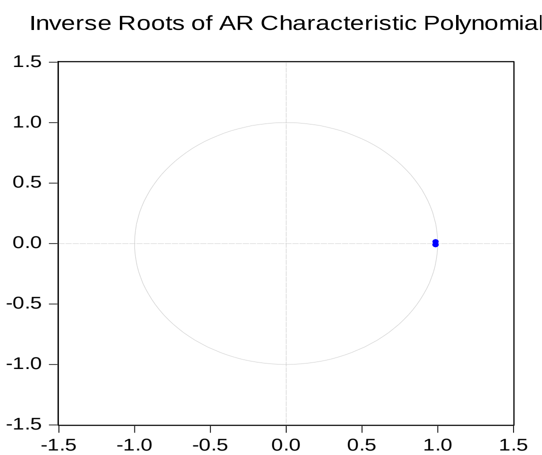
MALAYSIA



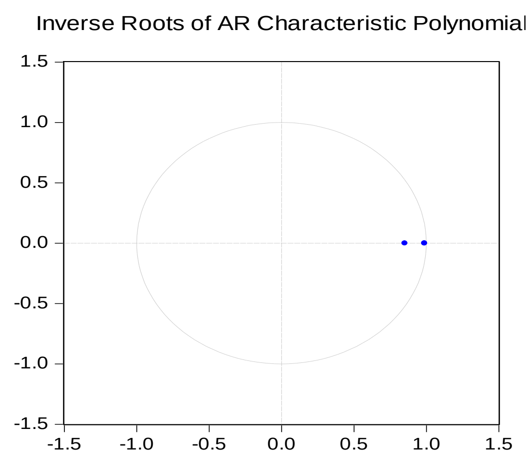
INDIA



PHILIPPINES



INDONESIA



THAILAND

Figure 48 indicates the results of stability test for all countries under study. Since the roots are within the circle, it is concluded that the model is stable. Inverse roots of AR characteristic polynomial is applied to check for stability of the model. It plots the roots within a unit circle. If the model is stable all the roots will appear within the circle.

CHAPTER 4

SECTORAL ENERGY CONSUMPTION AND ECONOMIC GROWTH

The growth and development of the sectors of an economy collectively contribute towards its aggregate growth. The growth and development of a sector of an economy is measured by value added which refers to the contribution of that particular sector towards the overall GDP of the country. It is the net output of a sector after adding up all outputs and subtracting intermediate inputs. This chapter focuses on understanding and analysing the relationship between energy consumption and economic growth at a sectoral level for all six Newly Industrialised Countries under study. Four sectors are selected viz. agriculture, industry, residential and service. These sectors require energy in various forms for various purposes in order to contribute towards the GDP of the country.

Agriculture value added includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Industry value added includes manufacturing and it comprises of value added in mining, manufacturing, construction, electricity, water, and gas. Residential value added is represented by household final consumption expenditure is the market value of all goods and services, including durable products (such as cars, washing machines, and home computers) purchased by households. It excludes purchases of dwellings but includes imputed rent for owner-occupied dwellings. It also includes payments and fees to governments to obtain permits and licenses. Here, household consumption expenditure includes the expenditures of non-profit institutions serving households. Service value added include value added in wholesale and retail trade (including hotels and restaurants), transport, and government, financial, professional, and personal services such as education, health care, and real estate services. It also includes imputed bank service charges and import duties.

Understanding the relationship between energy consumption and economic growth at a sectoral level is important to identify which sector is energy dependent so that the economic growth and development of a country is ensured in the long run.

4.1 UNIT ROOT TESTS

Analysis is sensitive to the stationarity properties of variables. In addition to Augmented Dickey Fuller (ADF) unit root test and Philip Perron (PP) unit root test, Kwiatkowski Phillips Schmidt Shin (KPSS) is employed which is a stationarity test used in addition to ADF and PP tests to obtain robust results.

Table 16: Results of stationarity tests on sectoral energy consumption and economic growth

Country	Variable	**ADF unit root**		**PP unit root**		**KPSS unit root**	
		Level	1st difference	Level	1st difference	Level	1st Difference
China	EC Agriculture	(2.898)	**(4.885)****	(2.898)	**(7.533)****	0.151	**0.080****
	EC Industry	(0.921)	**(2.707)***	(0.719)	**(2.707)***	0.629	**0.118****
	EC Residential	(0.399)	**(7.532)****	(0.127)	**(7.181)****	0.163	**0.091****
	EC Service	(0.027)	**(3.216)****	(0.665)	**(6.044)****	0.097	**0.080****
	VA Agriculture	(2.474)	**(4.261)****	(2.474)	**(4.340)****	0.167	**0.053****
	VA Industry	(1.535)	**(3.773)****	(1.591)	**(3.804)****	0.162	**0.084****
	VA Residential	(1.882)	**(5.314)****	(1.832)	**(5.441)****	0.147	**(0.069)****
	VA Service	(1.951)	(2.515)	(0.999)	(2.631)	**0.094****	0.111
India	EC Agriculture	(2.124)	**(3.573)****	(2.251)	**(3.573)****	0.649	**0.203****
	EC Industry	(1.696)	**(3.677)****	1.0172	**(3.399)****	0.151	**(0.117)****
	EC Residential	(1.281)	**(2.986)****	(1.246)	**(2.986)****	0.643	**0.142****
	EC Service	(1.206)	**(6.904)****	(1.003)	**(6.969)****	0.174	**0.097****
	VA Agriculture	(2.517)	**(3.899)****	(1.491)	**(6.667)****	0.131	**0.115****
	VA Industry	(2.286)	(2.513)	(1.042)	**(5.281)****	0.111	**0.116****
	VA Residential	(0.498)	**(6.048)****	(1.343)	**(6.048)****	0.1840	**0.068****
	VA Service	(2.317)	**(5.429)****	(2.508)	**(5.421)****	0.1096	**0.082****
Indonesia	EC Agriculture	(1.746)	**(5.779)****	(1.697)	**(5.780)****	0.164	**(0.0561)****
	EC Industry	(2.207)	**(7.470)****	(2.207)	**(7.534)****	0.1607	**0.071****
	EC Residential	(1.034)	**(2.977)****	(1.077)	**(3.009)****	0.6493	**0.1275****
	EC Service	3.283	**(3.797)****	(9.9172)	**(4.153)****	0.171	0.152
	VA Agriculture	(2.135)	**(4.764)****	(2.205)	**(6.995)****	0.637	**0.384****
	VA Industry	(0.184)	**(6.927)****	(0.943)	**(8.805)****	**0.1865****	0.5000

	VA Residential	(2.075)	**(16.085)****	(2.279)	**(4.074)****	**0.086****	0.089
	VA Service	(1.095)	**(3.582)****	(1.373)	**(3.592)****	**0.142****	0.088
Malaysia	EC Agriculture	(2.769)	**(7.474)****	(2.891)	**(14.548)****	0.162	**0.1190****
	EC Industry	(1.712)	**(4.436)****	(1.712)	**(4.437)****	0.1664	**0.069****
	EC Residential	(2.138)	**(5.048)****	(2.129)	**(5.045)****	**0.142****	0.078
	EC Service	(0.510)	**(5.904)****	(0.220)	**(24.356)****	0.1798	0.481
	VA Agriculture	(2.130)	**(5.704)****	(2.042)	**(7.733)****	0.491	**0.4103****
	VA Industry	(1.546)	**(6.109)****	(1.528)	**(6.095)****	0.152	**0.083****
	VA Residential	(1.834)	**(4.253)****	(2.027)	**(4.148)****	0.6739	**0.092****
	VA Service	(3.153)	**(3.950)****	(3.153)	**(3.890)****	0.6800	**0.259****
Philippines	EC Agriculture	(1.043)	**(6.879)****	(0.692)	**(7.362)****	0.491	**0.3299****
	EC Industry	(2.641)	**(4.970)****	(2.818)	**(6.669)****	0.0783	**0.062****
	EC Residential	**(3.346)***	(0.924)	(0.099)	(2.202)	**0.1198***	0.1773
	EC Service	(1.452)	**(4.018)****	(1.626)	**(3.979)****	0.6642	**0.128****
	VA Agriculture	(1.656)	**(4.927)****	(1.789)	**(4.928)****	0.614	**0.094****
	VA Industry	(0.993)	**(4.825)****	(1.825)	**(7.152)****	**0.1348****	0.1051
	VA Residential	(0.908)	(3.049)	(0.976)	(2.993)	0.165	**0.087****
	VA Service	(2.609)	**(4.154)****	(2.516)	**(4.140)****	**0.186****	0.085
Thailand	EC Agriculture	(0.876)	**(4.406)****	(1.1305)	**(4.406)****	0.172	**0.099****
	EC Industry	(2.457)	**(5.179)****	(2.372)	**(5.034)****	0.156	**0.084****
	EC Residential	(0.428)	**(3.666)****	(1.217)	**(3.721)****	0.541	**0.182****
	EC Service	(1.996)	**(5.059)****	(1.999)	**(5.075)****	0.168	**0.090****
	VA Agriculture	(2.486)	**(5.083)****	(2.486)	**(5.084)****	**0.113****	0.111
	VA Industry	(0.898)	**(5.721)****	(1.027)	**(5.668)****	**0.120****	0.124
	VA Residential	(1.664)	**(3.378)****	(1.538)	**(3.378)****	0.695	**0.139****
	VA Service	1.416	**(3.455)****	3.264	**(3.322)****	0.683	**0.374****

*Significance at 10% level of significance
*Significance at 5% level of significance

The above table indicates stationarity properties of all variables under study. ADF, PP and KPSS unit root test indicate that certain variables exhibit mixed order of integration while most variables indicate stationarity at first difference.

4.2 LAG LENGTH SELECTION CRITERIA

Table 17 indicates the lag section for each sector of each country under study according to AIC, SC and HQ criteria.

Table 17: Results of Lag selection criteria for Objective 3

CHINA						
Agriculture						
Lag	Logl	LR stat	FPE	**AIC**	**SC**	**HQ**
0	-324.6917	NA	7.68e+08	26.13534	26.23285	26.16238
1	-266.3852	102.6195	9992880*	***21.79081****	***22.08334****	***21.87195****
2	-265.8282	0.891216	13275472	22.06625	22.55380	22.20148
3	-263.7764	2.954550	15824740	22.22211	22.90468	22.41143
4	-256.1610	9.747697*	12294583	21.93288	22.81047	22.17629
Industry						
0	-402.0131	NA	3.73e+11	32.32105	32.41856	32.34809
1	-320.1494	144.0801	7.37e+08	26.09195	26.38448	26.17309
2	-312.8640	11.65661	5.72e+08	25.82912	***26.31667****	25.96435
3	-311.6806	1.704147	7.31e+08	26.05445	26.73702	26.24376
4	-302.7803	11.39235*	5.12e+08*	25.66243*	26.54002	25.90583*
Residential						
0	-998.1565	NA	1.92e+32	80.01252	80.11003	80.03957
1	-923.1183	132.0672*	6.56e+29	74.32947	***74.62200****	74.41060
2	-918.3605	7.612543	6.23e+29	74.26884	74.75639	74.40407
3	-912.5013	8.437213	5.47e+29	74.12011	74.80268	74.30942
4	-906.5578	7.607709	4.86e+29*	73.96462*	74.84221	74.20803*
Service						
0	-971.7825	NA	2.33e+31	77.90260	78.00011	77.92964
1	-874.2418	171.6716	1.31e+28	70.41934	70.71187	70.50048
2	-865.5235	13.94921	9.09e+27*	70.04188	***70.52943****	***70.17711****
3	-864.8013	1.040089	1.21e+28	70.30410	70.98667	70.49342
4	-856.9675	10.02723*	9.20e+27	69.99740*	70.87499	70.24080
INDIA						
Agriculture						
0	-304.6759	NA	1.55e+08	24.53407	24.63158	24.56111
1	-227.8479	135.2173	457897.1	18.70783	19.00036	18.78897
2	-220.0903	12.41209*	341943.8*	***18.40723****	***18.89478****	***18.54245****
3	-217.9386	3.098458	404360.9	18.55509	19.23766	18.74440
4	-212.9565	6.377115	387824.7	18.47652	19.35411	18.71993
Industry						
0	-351.3192	NA	6.47e+09	28.26554	28.36305	28.29258
1	-270.1046	142.9378	13456022	22.08837	22.38090	22.16950
2	-268.8137	2.065449	16856906	22.30509	22.79265	22.44032
3	-256.8955	17.16222*	9125764.*	***21.67164****	***22.35421****	***21.86095****
4	-256.4397	0.583355	12571814	21.95518	22.83277	22.19858

Residential						
0	-962.6227	NA	1.12e+31	77.16982	77.26733	77.19686
1	-846.6689	204.0786	1.45e+27	68.21352	68.50605	68.29465
2	-838.8235	12.55272*	1.07e+27*	***67.90588****	***68.39343****	***68.04111****
3	-836.1374	3.868004	1.22e+27	68.01099	68.69356	68.20031
4	-834.9632	1.502918	1.58e+27	68.23706	69.11465	68.48046
Service						
0	-901.4665	NA	8.41e+28	72.27732	72.37483	72.30437
1	-793.6432	189.7690*	2.08e+25	63.97146	***64.26399****	64.05259
2	-788.2528	8.624676	1.88e+25*	63.86023*	64.34778	63.99545*
3	-787.9444	0.444133	2.58e+25	64.15555	64.83812	64.34487
4	-785.4749	3.160941	3.02e+25	64.27799	65.15558	64.52140
INDONESIA						
Agriculture						
0	18.83568	NA	0.000892	-1.346855	-1.249345	-1.319810
1	46.85177	49.30831*	0.000131*	***-3.268142****	***-2.975611****	***-3.187006****
2	47.44058	0.942103	0.000173	-2.995247	-2.507696	-2.860021
3	49.80934	3.411014	0.000201	-2.864748	-2.182177	-2.675431
4	51.01937	1.548828	0.000261	-2.641549	-1.763959	-2.398143
Industry						
0	38.05045	NA	0.000192	-2.884036	-2.786526	-2.856991
1	71.54056	58.94259	1.82e-05	-5.243244	***-4.950714****	-5.162109*
2	73.43630	3.033195	2.17e-05	-5.074904	-4.587354	-4.939678
3	80.72071	10.48955*	1.70e-05*	-5.337657*	-4.655086	-5.148341
4	82.61614	2.426156	2.09e-05	-5.169292	-4.291701	-4.925885
Residential						
0	11.39759	NA	0.001617	-0.751807	-0.654297	-0.724762
1	71.19508	105.2436*	1.87e-05*	***-5.215607****	***-4.923077****	***-5.134471****
2	71.78727	0.947498	2.47e-05	-4.942982	-4.455431	-4.807756
3	71.84560	0.083990	3.46e-05	-4.627648	-3.945077	-4.438332
4	74.27794	3.113404	4.07e-05	-4.502235	-3.624645	-4.258829
Service						
0	-2.418366	NA	0.004882	0.353469	0.450979	0.380514
1	86.06843	155.7368*	5.68e-06*	***-6.405474****	***-6.112944****	***-6.324339****
2	88.03340	3.143949	6.74e-06	-6.242672	-5.755122	-6.107446
3	93.96760	8.545248	5.89e-06	-6.397408	-5.714837	-6.208092
4	94.97537	1.289951	7.76e-06	-6.158030	-5.280439	-5.914624
MALAYSIA						
Agriculture						
0	-36.19985	NA	0.072826	3.055988	3.153498	3.083033
1	-13.71239	39.57791	0.016632	1.576992	***1.869522****	1.658127
2	-10.96003	4.403780	0.018536	1.676803	2.164353	1.812028
3	-7.016700	5.678398	0.018993	1.681336	2.363906	1.870652
4	2.333671	11.96847*	0.012844*	1.253306*	2.130897	1.496713*
Industry						
0	29.38042	NA	0.000384	-2.190434	-2.092924	-2.163389
1	79.35822	87.96093*	9.71e-06*	***-5.868658****	***-5.576128****	***-5.787522****
2	81.29574	3.100024	1.16e-05	-5.703659	-5.216109	-5.568433
3	83.33904	2.942351	1.38e-05	-5.547123	-4.864553	-5.357807

4	84.89376	1.990049	1.74e-05	-5.351501	-4.473911	-5.108095
Residential						
0	20.36230	NA	0.000789	-1.468984	-1.371474	-1.441939
1	87.37411	117.9408*	5.11e-06*	***-6.509929****	***-6.217398****	***-6.428793****
2	90.43362	4.895224	5.56e-06	-6.434690	-5.947140	-6.299464
3	93.80028	4.847992	5.97e-06	-6.384023	-5.701452	-6.194707
4	96.44664	3.387334	6.90e-06	-6.275731	-5.398141	-6.032325
Service						
0	0.480671	NA	0.003871	0.121546	0.219056	0.148591
1	77.29102	135.1862	1.15e-05	-5.703281	-5.410751	-5.622146
2	87.94452	17.04560*	6.79e-06*	***-6.235562****	***-5.748011****	***-6.100336****
3	89.23478	1.857972	8.60e-06	-6.018782	-5.336212	-5.829466
4	93.11151	4.962221	9.01e-06	-6.008921	-5.131331	-5.765515
PHILIPPINES						
Agriculture						
0	-14.94868	NA	0.013303	1.355895	1.453405	1.382940
1	29.25868	77.80496*	0.000535*	***-1.860694****	***-1.568164****	***-1.779559****
2	30.47067	1.939179	0.000674	-1.637653	-1.150103	-1.502428
3	32.61856	3.092974	0.000797	-1.489485	-0.806915	-1.300169
4	35.05136	3.113981	0.000937	-1.364109	-0.486518	-1.120703
Industry						
0	67.69543	NA	1.79e-05	-5.255634	-5.158124	-5.228589
1	93.80226	45.94803*	3.06e-06*	***-7.024181****	***-6.731651****	***-6.943046****
2	97.05450	5.203573	3.28e-06	-6.964360	-6.476809	-6.829134
3	100.4153	4.839582	3.52e-06	-6.913225	-6.230655	-6.723909
4	105.3272	6.287237	3.39e-06	-6.986178	-6.108587	-6.742771
Residential						
0	15.65197	NA	0.001150	-1.092158	-0.994648	-1.065113
1	143.5441	225.0901	5.72e-08	-11.00353	-10.71100	-10.92239
2	151.7098	13.06519*	4.13e-08*	***-11.33679****	***-10.84924****	***-11.20156****
3	154.3382	3.784854	4.70e-08	-11.22706	-10.54448	-11.03774
4	159.6292	6.772524	4.40e-08	-11.33034	-10.45275	-11.08693
Service						
0	12.29988	NA	0.001504	-0.823991	-0.726481	-0.796946
1	117.7331	185.5625*	4.51e-07*	***-8.938649****	***-8.646119****	***-8.857514****
2	120.7488	4.825161	4.92e-07	-8.859907	-8.372357	-8.724682
3	122.1382	2.000704	6.18e-07	-8.651058	-7.968487	-8.461742
4	124.9109	3.549084	7.08e-07	-8.552875	-7.675285	-8.309469
THAILAND						
Agriculture						
0	24.50501	NA	0.000566	-1.800401	-1.702891	-1.773356
1	59.22064	61.09950	4.86e-05	-4.257651	-3.965121	-4.176516
2	62.47008	5.199112	5.21e-05	-4.197607	-3.710056	-4.062381
3	66.92439	6.414200	5.12e-05	-4.233951	-3.551381	-4.044635
4	78.99738	15.45343*	2.79e-05*	***-4.879791****	***-4.002200****	***-4.636384****
Industry						
0	46.49381	NA	9.75e-05	-3.559504	-3.461994	-3.532459
1	102.5071	98.58340*	1.52e-06*	***-7.720568****	***-7.428038****	***-7.639433****
2	103.7467	1.983331	1.92e-06	-7.499735	-7.012184	-7.364509

3	104.5323	1.131223	2.53e-06	-7.242580	-6.560010	-7.053264
4	107.7661	4.139289	2.79e-06	-7.181286	-6.303695	-6.937880
Residential						
0	26.04016	NA	0.000501	-1.923213	-1.825703	-1.896168
1	87.55401	108.2644*	5.04e-06	-6.524321	***-6.231791****	***-6.443186****
2	91.89384	6.943724	4.95e-06	-6.551507	-6.063957	-6.416282
3	95.18549	4.739975	5.34e-06	-6.494839	-5.812269	-6.305523
4	101.5304	8.121501	4.59e-06*	-6.682433*	-5.804843	-6.439027
Service						
0	9.020764	NA	0.001955	-0.561661	-0.464151	-0.534616
1	78.21828	121.7876*	1.06e-05*	***-5.777463****	***-5.484932****	***-5.696327****
2	81.50303	5.255599	1.14e-05	-5.720243	-5.232692	-5.585017
3	83.30825	2.599516	1.38e-05	-5.544660	-4.862090	-5.355344
4	85.23314	2.463856	1.69e-05	-5.378651	-4.501061	-5.135245

*Significance at 10% level of significance
**Significance at 5% level of significance

For China lag 1 is selected for the agricultural and residential sector while lag 2 is selected for the industrial and service sector. In case of India lag 2 is chosen for the agricultural sector and residential sector. For the industrial sector, lag 3 and service sector lag 1. For Indonesia, lag 1 is selected for al four sectors while for Malaysia lag 4 is chosen for the agricultural sector, lag 2 for the service sector and lag 1 for the industrial and residential sector. For the Philippines, lag 1 is chosen for the agricultural, industrial and service sector while lag 2 for the residential sector. In case of Thailand, lag 4 is chosen for the agricultural sector while for the industrial, residential and service sector lag 1 is chosen.

4.3 ARDL BOUNDS TESTING APPROACH TO COINTEGRATION

Auto Regressive Distributed Lag (ARDL) can be applied to identify cointegrating relationships when variables have a mixed order of integration. Table 18 displays the results of ARDL bounds testing approach to cointegration.

Table 18: Results of ARDL bound testing approach to cointegration for sectoral energy consumption and economic growth

Country	Sector	F -value	Result
China	Agriculture	1.628155	Accept H0
	Industry	8.794203	**Reject H0**
	Service	1.753527	Accept H0
	Residential	2.494076	Accept H0
India	Agriculture	1.223768	Accept H0
	Industry	6.781303	**Reject H0**
	Service	0.161960	Accept H0
	Residential	7.225823	**Reject H0**
Indonesia	Agriculture	5.363867	**Reject H0**
	Industry	1.830521	Accept H0
	Service	0.136921	Accept H0
	Residential	0.426179	Accept H0
Malaysia	Agriculture	1.458065	Accept H0
	Industry	1.082209	Accept H0
	Service	2.270735	Accept H0
	Residential	0.031767	Accept H0
Philippines	Agriculture	0.197945	Accept H0
	Industry	1.038408	Accept H0
	Service	13.90534	**Reject H0**
	Residential	1.330623	Accept H0
Thailand	Agriculture	3.520900	**Reject H0**
	Industry	0.480164	Accept H0
	Service	1.056222	Accept H0
	Residential	2.132199	Accept H0

Null Hypothesis states that no long run cointegrating relationship exists while the alternate hypothesis states that there exists long run cointegrating relationship. The critical values proposed by **Pesaran et al. (2001)** is applicable for large sample size and cannot be applied for small sample sizes. Therefore, **P. K. Narayan (2005)** provides critical values for small sample sizes which are 2.496 - 3.346, 2.962 – 3.910, and 4.068 – 5.250 at 90%, 95%, and 99% resp. Since this study involves a small sample size we employ the same. In case of China, at 5% level of significance, there exists a long run cointegrating relationship between energy consumption and economic growth in the industrial sector and the same is with respect to India. Hypothesis H_{7b} and H_{7f} is rejected. However, in addition to the industrial sector, energy consumption in the residential sector also has a cointegrating relationship with economic growth for or India. Incase of Indonesia and Thailand there exists a cointegrating relationship between energy consumption and economic growth in the agricultural sector therefore we reject H_{7i} while for the Philippines, both variables are cointegrated in the agricultural sector and hypothesis H_{7s} and H_{7u} is rejected resp.

4.4 VECTOR ERROR CORRECTION MODEL (VECM)

China:

D(LVA_INDUSTRY) = C(1)*(LVA_INDUSTRY(-1) + 0.0912868772049 *LEC_INDUSTRY(-1) - 5.01453570916) + C(2)*D(LVA_INDUSTRY(-1)) + C(3)*D(LVA_INDUSTRY(-2)) + C(4)*D(LEC_INDUSTRY(-1)) +C(5)*D(LEC_INDUSTRY(-2)) + C(6)

India:

D(LVA_INDUSTRY) = C(1)*(LVA_INDUSTRY(-1) + 0.00397187461311*LEC_INDUSTRY(-1) - 3.3917027005) + C(2)*D(LVA_INDUSTRY(-1)) + C(3)*D(LVA_INDUSTRY(-2)) + C(4)*D(LVA_INDUSTRY(-3)) +C(5)*D(LEC_INDUSTRY(-1)) + C(6)*D(LEC_INDUSTRY(-2)) + C(7)*D(LEC_INDUSTRY(-3)) + C(8)

D(LVA_RESIDENTIAL) = C(1)*(LVA_RESIDENTIAL(-1) + 10.8359605052*LEC_RESIDENTIAL(-1) - 156.556059228) + C(2)*D(LVA_RESIDENTIAL(-1)) + C(3)*D(LVA_RESIDENTIAL(-2)) + C(4)*D(LEC_RESIDENTIAL(-1)) + C(5)*D(LEC_RESIDENTIAL(-2)) +C(6)

Indonesia:

D(LVA_AGRICUTURE) = C(1)*(LVA_AGRICUTURE(-1) +0.0697543152668*LEC_AGRICUTURE(-1) - 3.26657077145) +C(2)*D(LVA_AGRICUTURE(-1)) + C(3)*D(LEC_AGRICUTURE(-1))+ C(4)

Philippines:

D(LVA_SERVICE) = C(1)*(LVA_SERVICE(-1) - 2.3464335917 *LEC_SERVICE(-1) - 7.42196665554) + C(2)*D(LVA_SERVICE(-1))+ C(3)*D(LEC_SERVICE(-1)) + C(4)

Thailand:

D(LVA_AGRICUTURE) = C(1)*(LVA_AGRICUTURE(-1) +1.33200512035*LEC_AGRICUTURE(-1) - 12.9124803898) + C(2)*D(LVA_AGRICUTURE(-1)) + C(3)*D(LVA_AGRICUTURE(-2)) +C(4)*D(LVA_AGRICUTURE(-3)) + C(5)*D(LVA_AGRICUTURE(-4)) +C(6)*D(LEC_AGRICUTURE(-1)) + C(7)*D(LEC_AGRICUTURE(-2))+ C(8)*D(LEC_AGRICUTURE(-3)) + C(9)*D(LEC_AGRICUTURE(-4)) + C(10)

VECTOR ERROR CORRECTION MODEL (VECM)

VECM indicates how rapidly energy use corrects itself towards equilibrium after deviation in the previous period.

Table 19: Results of Vector Error Correction Model for sectoral energy consumption and economic growth

Country	Sector	Coefficient	Std. Error	t-Statistic	Prob.
China	Industry	(0.312687)	0.076832	(4.069726)	**0.0002****
India	Industry	(0.45294)	0.18251	(2.51102)	**0.01****
	Residential	0.004472	0.002017	2.217415	0.0323
Indonesia	Agriculture	(0.150312)	0.00406	(1.31779)	0.1941
Philippines	Service	(0.013227)	0.005413	(2.443658)	**0.01****
Thailand	Agriculture	(0.068860)	0.082883	(0.830818)	0.4131

** Significant at 5% level

Industrial energy consumption of China correct itself after a shock in the previous period by 31% while industrial energy consumption of India achieves equilibrium after a shock in the previous period to the extent of 45%. However, in the Philippines, energy consumption in the service sector achieves equilibrium after a shock in the previous period to the extent of 1%. For China we reject H_{8b}, For India we reject H_{8f} and for the Philippines we reject H_{8t}.

4.5 TODA YAMAMOTO CAUSALITY TEST

To check for causality between energy consumption and value added in each sector for the select countries, Toda Yamamoto causality test is applied which is considered to more effective than grangers causality test as the prerequisite for stationarity is not applicable.

Table 20: Results of Toda Yamamoto causality test on sectoral energy consumption and economic growth

	China	India	Indonesia	Malaysia	Philippines	Thailand
VA agriculture causes EC agriculture	***0.0913****	***0.0099*****	0.2071	0.4420	***0.0608****	***0.0001*****
EC agriculture causes VA agriculture	0.9508	0.3073	***0.0780****	0.6927	0.9504	***0.0567*****
VA industry causes EC industry	0.7816	***0.0063*****	0.6370	0.9509	***0.0157*****	0.9885
EC industry causes VA industry	***0.0443*****	0.3340	0.7622	0.1909	0.7772	0.5780
VA service causes EC service	0.111	***0.0258*****	0.2009	0.5948	***0.1000****	0.3234
EC service causes VA service	0.5698	***0.0016*****	0.2875	***0.0402*****	0.8558	0.1810
VA residential causes EC residential	0.3608	0.1598	0.6103	0.1195	0.9678	0.2252
EC residential causes VA residential	0.6943	0.6620	0.4651	0.5532	0.8719	0.8489

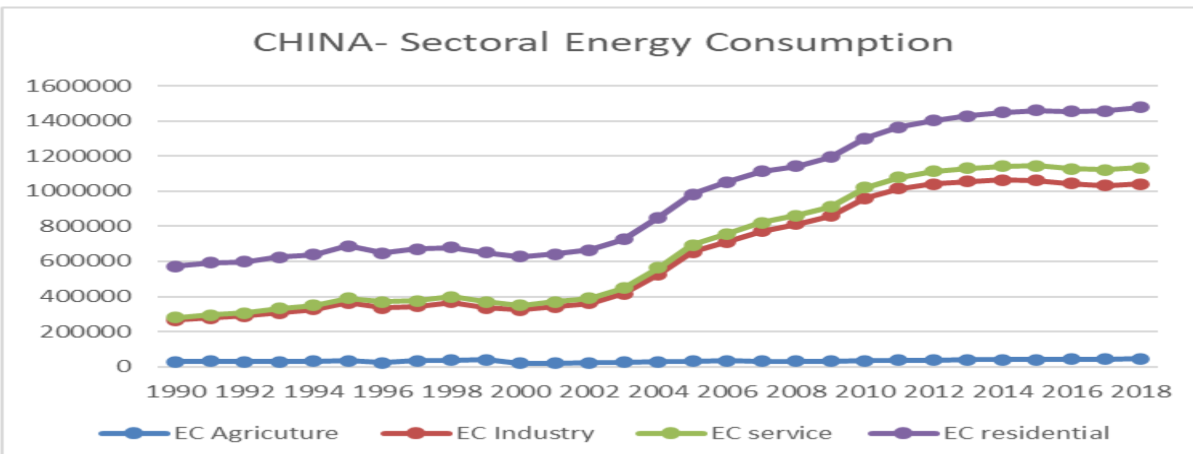
*Significance at 10% level of significance
**Significance at 5% level of significance

To check for causality between energy consumption and value added in each sector for the select countries, Toda Yamamoto causality test is applied. In China, India, Philippines and Thailand, agricultural growth causes its energy consumption. Agricultural energy consumption causes growth in Indonesia and Thailand. Industrial growth causes energy use in India and Philippines while the reverse is in case of China. There exists a bidirectional causality in the service sector for India. In the Philippines economic growth in the service sector causes energy use and the reverse in in case of Malaysia. Therefore, for China we reject H_{9b} and H_{9c}. For India, we reject H_{9k}, H_{9m}, H_{9p} and H_{9q}. For Indonesia we reject H_{9r} and Malaysia H_{9af}. For Philippines we reject H_{9ai}, H_{9ak} and H_{9ao}. For Thailand we reject H_{9ap} and H_{9aq}.

4.6 TREND ANAYSIS

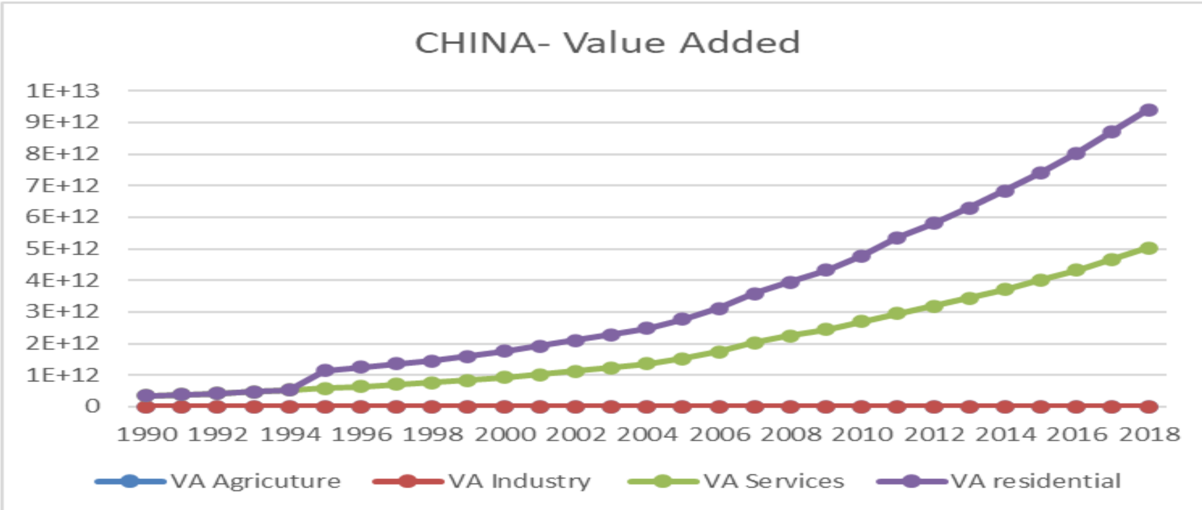
The Following graphs indicate the trend of sectoral energy consumption and sectoral value added.

Figure 49: Results of Trend analysis of sectoral energy consumption of China



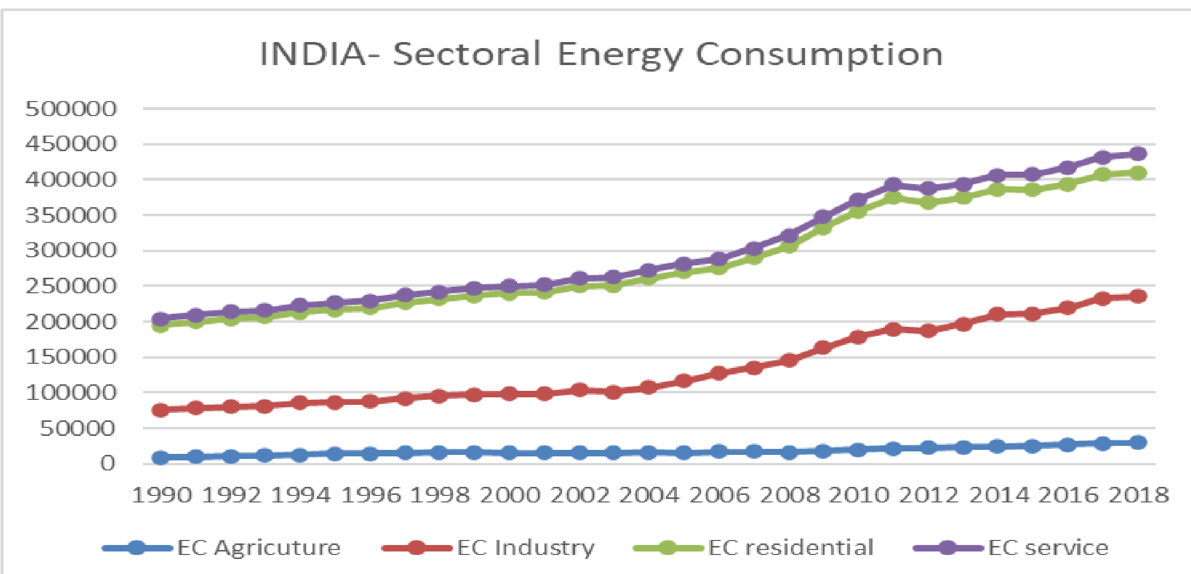
In figure 49, X axis represents the time period from 1990 to 2018 and Y axis represents the volume of energy consumption for each select sector. In case of China, the residential sector of the country consumes a higher quantum of energy compared to the agricultural sector, industrial and service sector.

Figure 50: Results of Trend analysis of sectoral value added for China



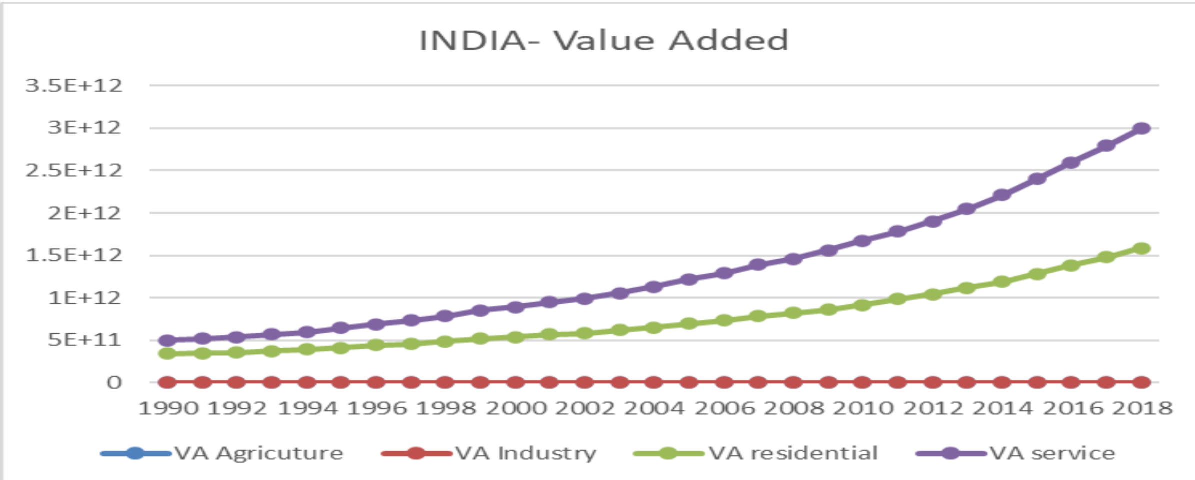
In the above figure 50, Y axis represents sectoral value added and X axis represents the time period from 1990 to 2018. With respect to the growth of the sectors of the Chinese economy, the residential sector has exhibited rapid growth followed by the service sector.

Figure 51: Results of Trend analysis of sectoral energy consumption of India



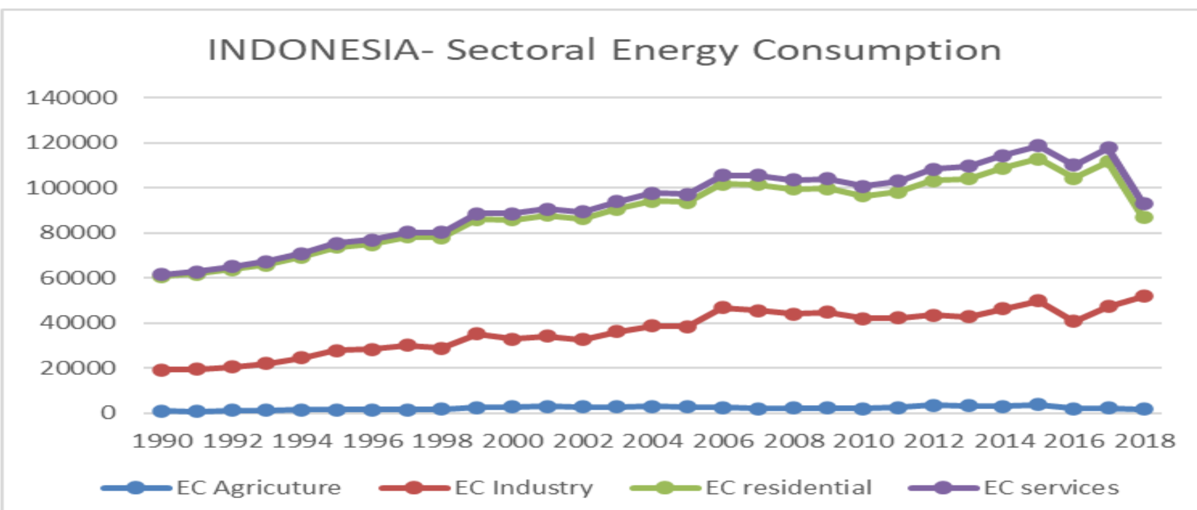
Sectoral energy consumption is represented by Y axis and X axis indicates the time period as exhibited in figure 51. In case of India, the energy consumption of the service sector surpasses that of the residential, industrial and agricultural sector.

Figure 52: Results of Trend analysis of sectoral value added for India



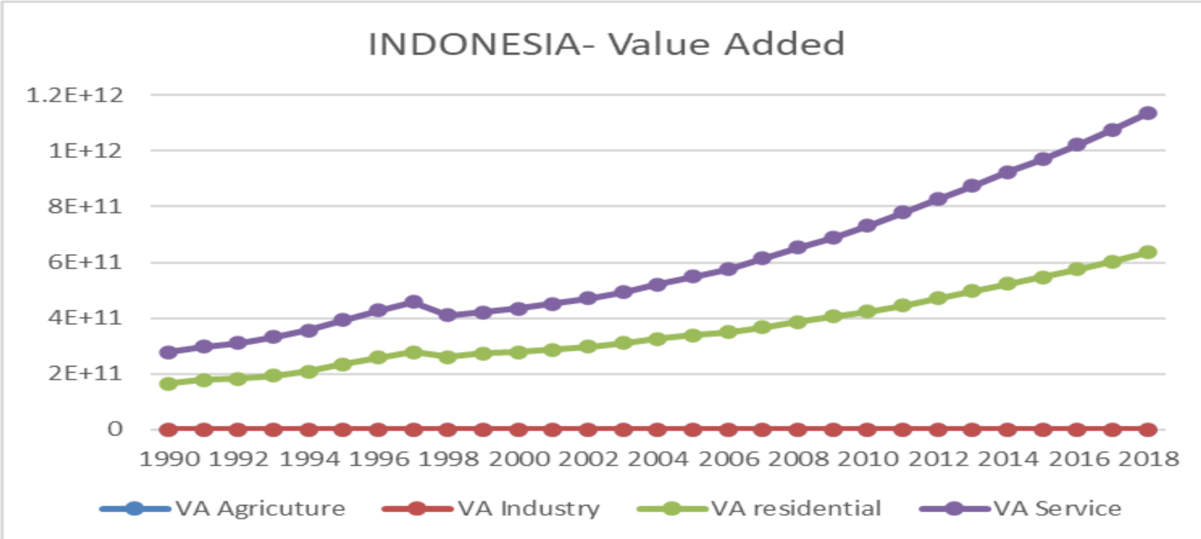
In figure 52, the X axis indicates sectoral value added while the Y axis represents the period of time from 1990 to 2018. The service sector is the most important sector which contributes to the economic growth of India. Since the year 1990 a sharp increase can be observed in the service sector till 2018. The residential sector is the second largest contributor towards the economic growth of India.

Figure 53: Results of Trend analysis of sectoral energy consumption for Indonesia



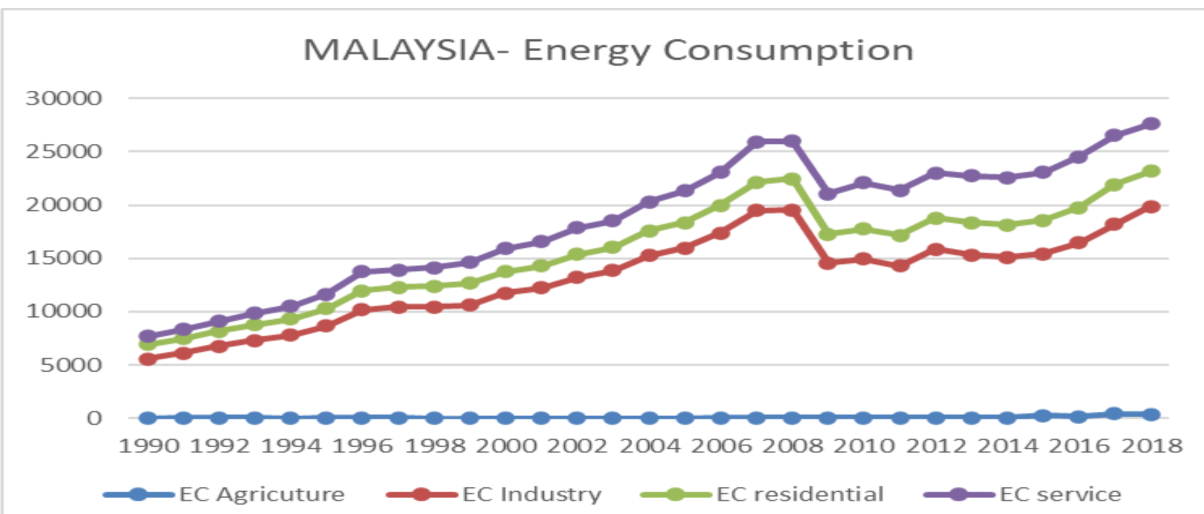
The service sector is a major consumer of energy followed by the residential sector for Indonesia. There was a steady increase in energy consumption since 1990 till 2017 followed by a decline as indicated in figure 53.

Figure 54: Results of Trend analysis of sectoral value added for Indonesia



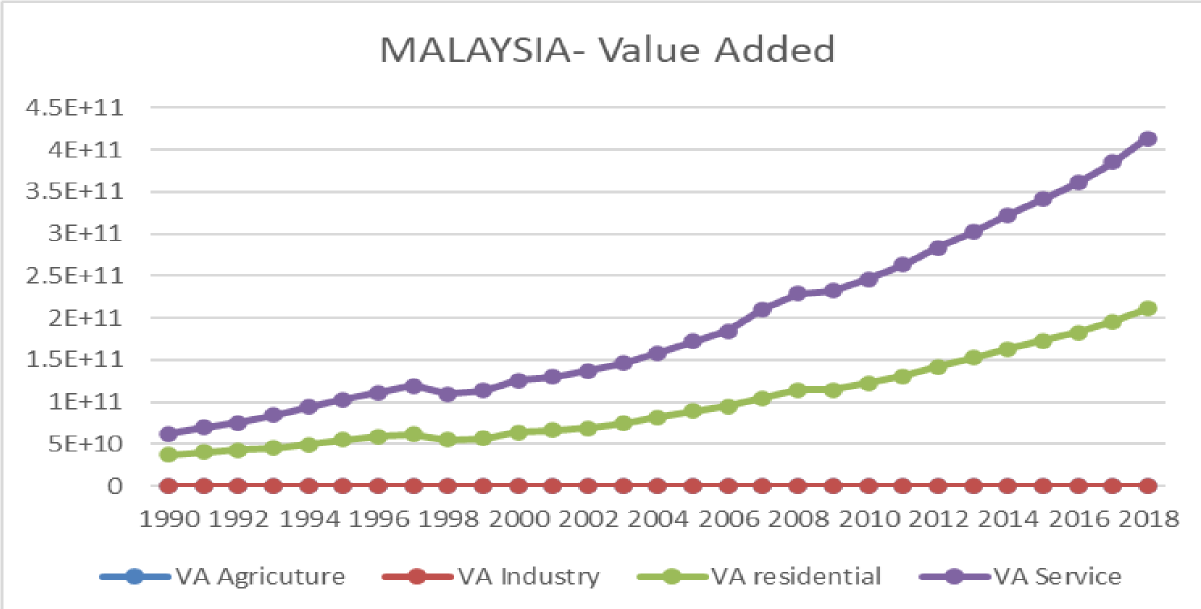
In figure 54 where the X axis represents years and Y axis represents sectoral value added, the service sector is a major contributor to the GDP of the country followed by the residential sector which is similar to India.

Figure 55: Results of Trend analysis of sectoral energy consumption for Malaysia



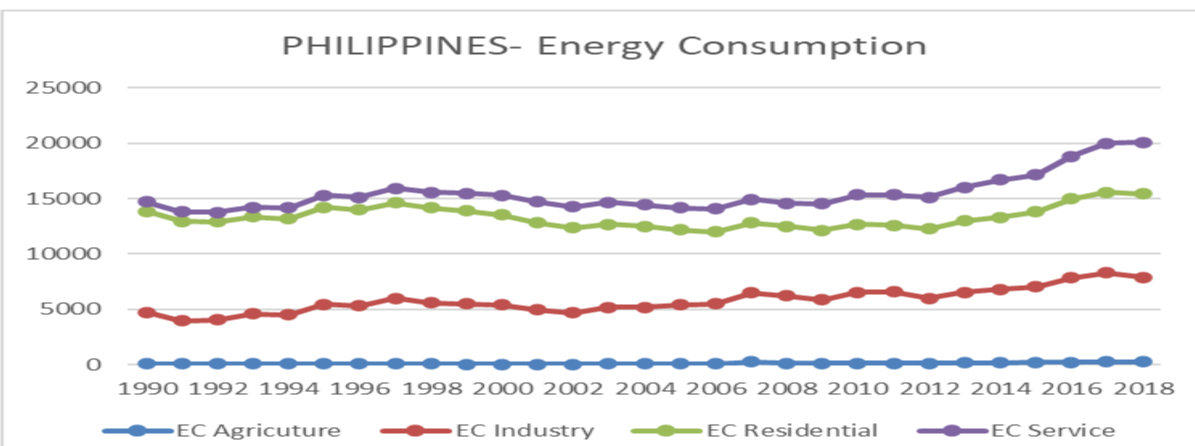
In the above figure 55, the energy consumption of the service sector is the highest followed by the service sector and industrial sector. After 2008, a decline in energy consumption is observed and after 2015 a mild a gradual increase is visible.

Figure 56: Results of Trend analysis of sectoral value added for Malaysia



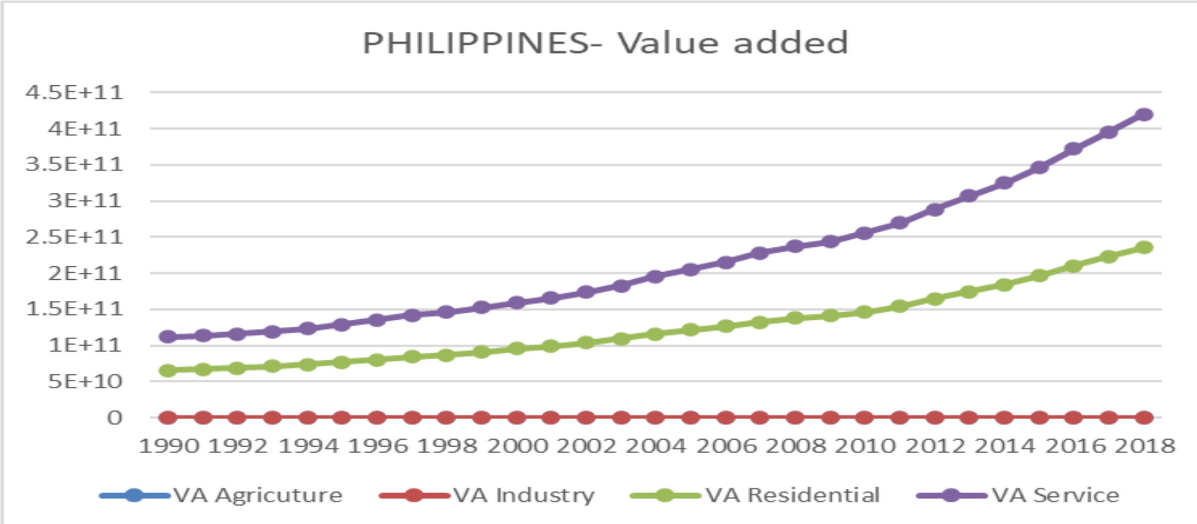
There has been a rapid increase in growth of the service sector i.e. the service sector is a major contributor to the overall GDP of Malaysia as indicated in figure 56 above.

Figure 57: Results of Trend analysis of sectoral energy consumption of Philippines



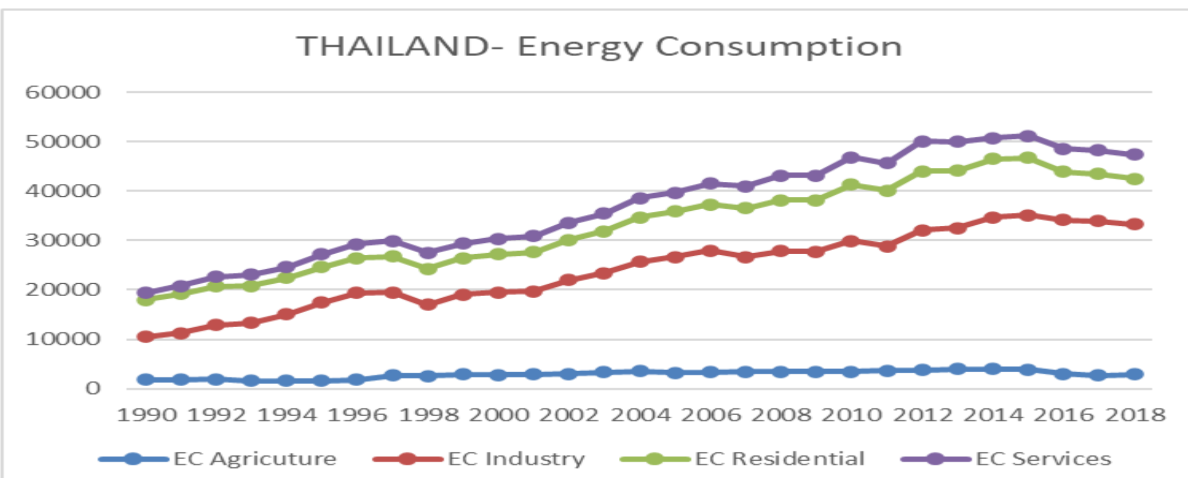
In figure 57, the service sector of Malaysia is the highest consumer of energy followed by the residential sector. Since 2012 there has been a steady increase in energy consumption which stabilized in 2017. Energy consumption by the agricultural sector remains minimum.

Figure 58: Results of Trend analysis of sectoral value added for Philippines



The growth of the service sector has exhibited a steady increasing trend since 1990 with the residential sector being the second highest consumer of energy consumption. In recent year the increasing trend has gained momentum upto 2018 as can be observe in the above figure 58.

Figure 59: Results of Trend analysis of sectoral energy consumption for Thailand



In the above figure 59, X axis indicates the time period from 1990 to 2018 and Y axis indicates sectoral energy consumption. The energy consumption of the service sector is the highest followed by the residential sector. From the above graph it can be observed that since 2015 there has been a mild decline in energy consumption.

Figure 60: Results of Trend analysis of sectoral value added for Thailand

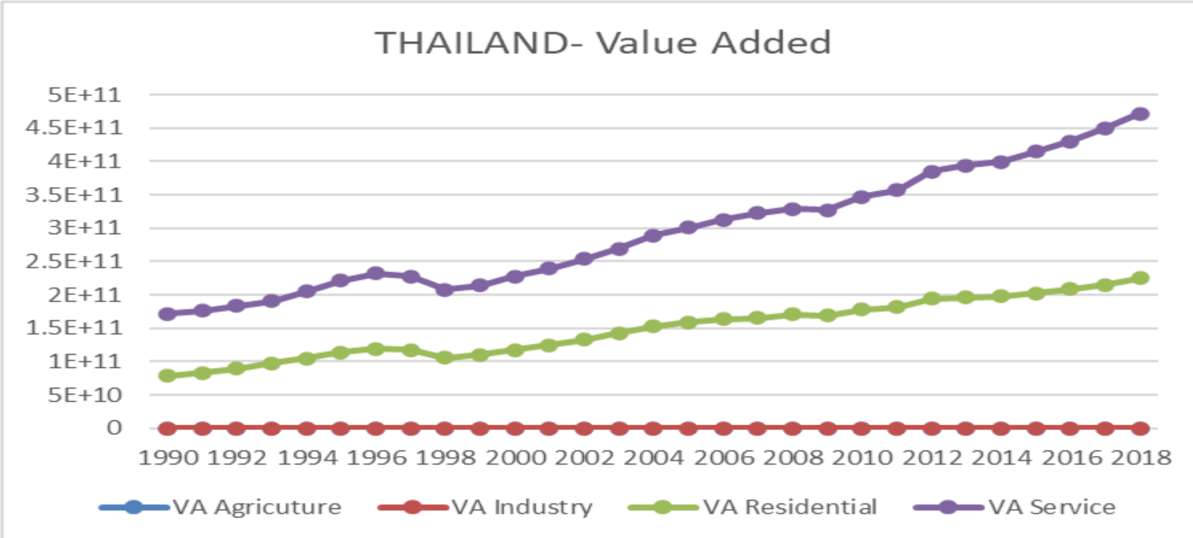
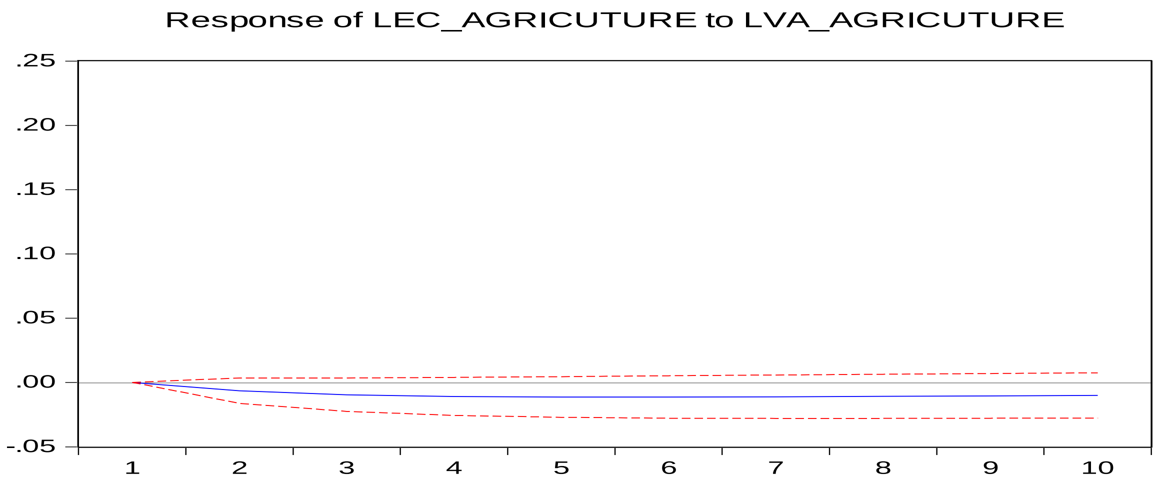


Figure 60 displays the trend in growth of the sectors of the economy of Thailand where the Y axis represents sectoral value added and Y axis time period in years. The service sector has distinctly grown since 1990 with a sharp increasing trend in recent years.

4.7 IMPULSE RESPONSE FUNCTION

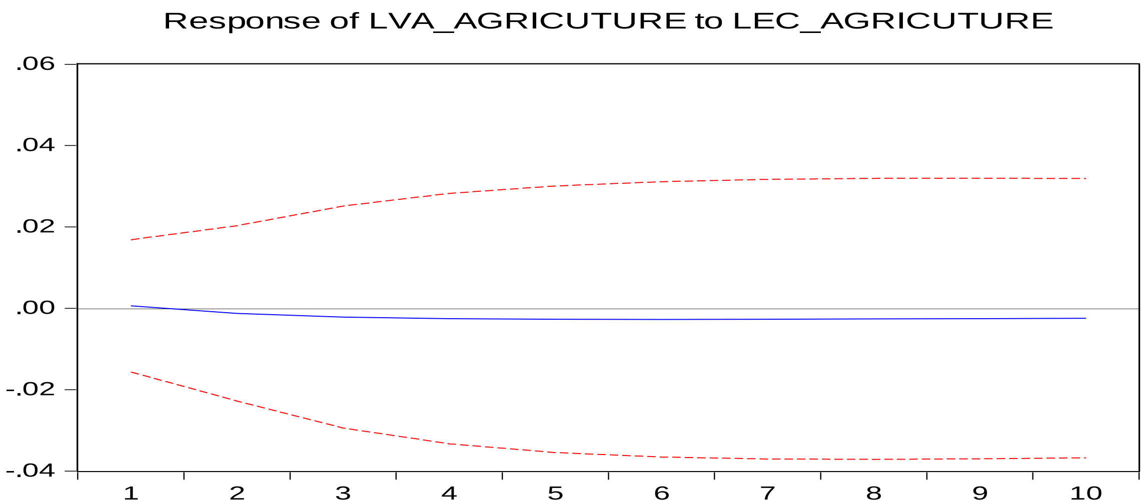
CHINA

Figure 61: Results of Impulse response function of agricultural energy consumption and value added for China



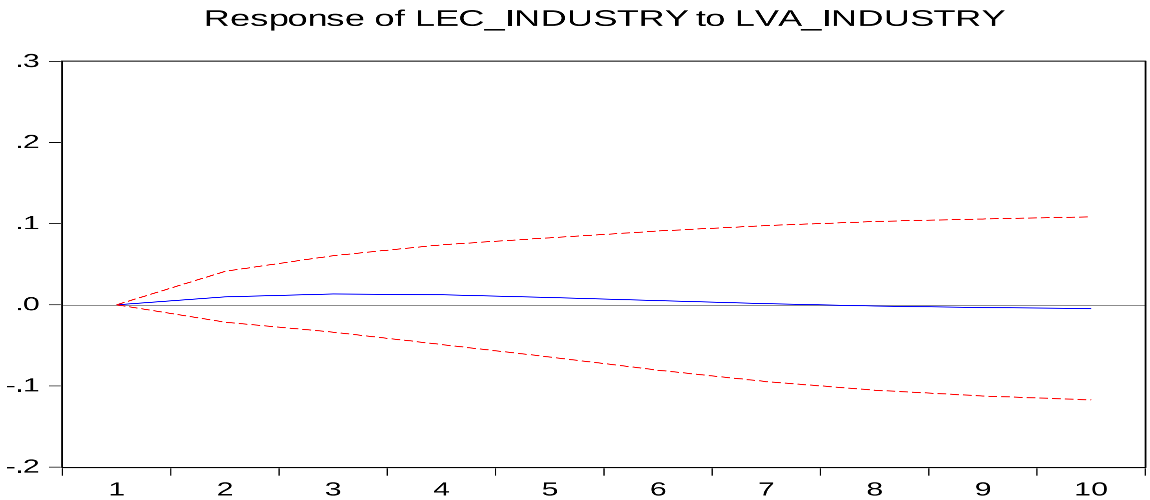
Over the ten year period, energy consumption has responded negatively to growth in the agricultural sector as observed in figure 61 however a mild increase in energy consumption can be observed after the seventh period.

Figure 62: Results of Impulse response function of agricultural value added and energy consumption for China



Similarly, growth in the agricultural sector has responded negatively to energy consumption as per figure 62.

Figure 63: Results of Impulse response function of Industrial energy consumption and value added for China



In the above figure 63, in the short run energy consumption responds positively to economic growth of the industrial sector however the impact of economic growth to energy consumption in the industrial sector is negative in the long run.

Figure 64: Results of Impulse response function of industrial value added and energy consumption for China

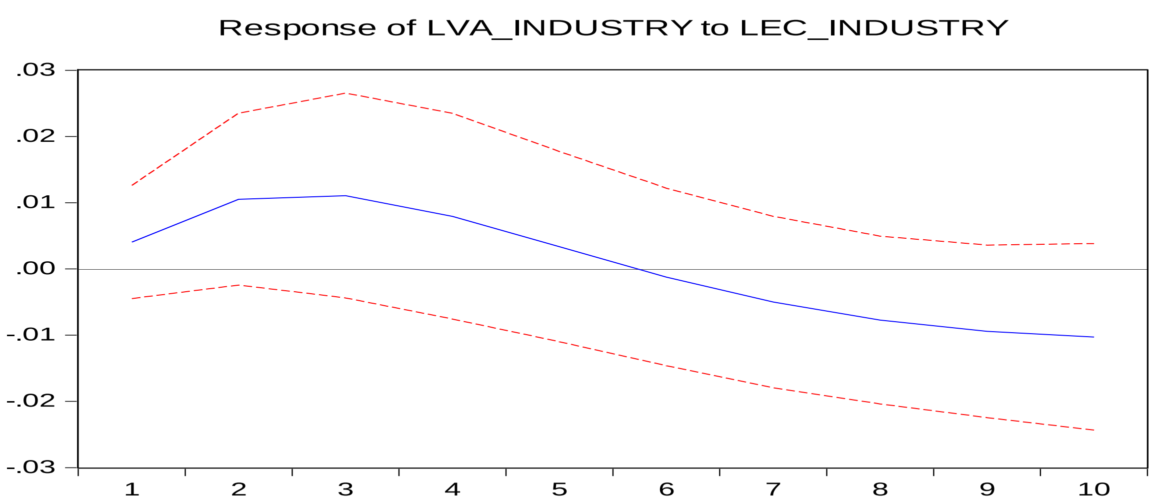
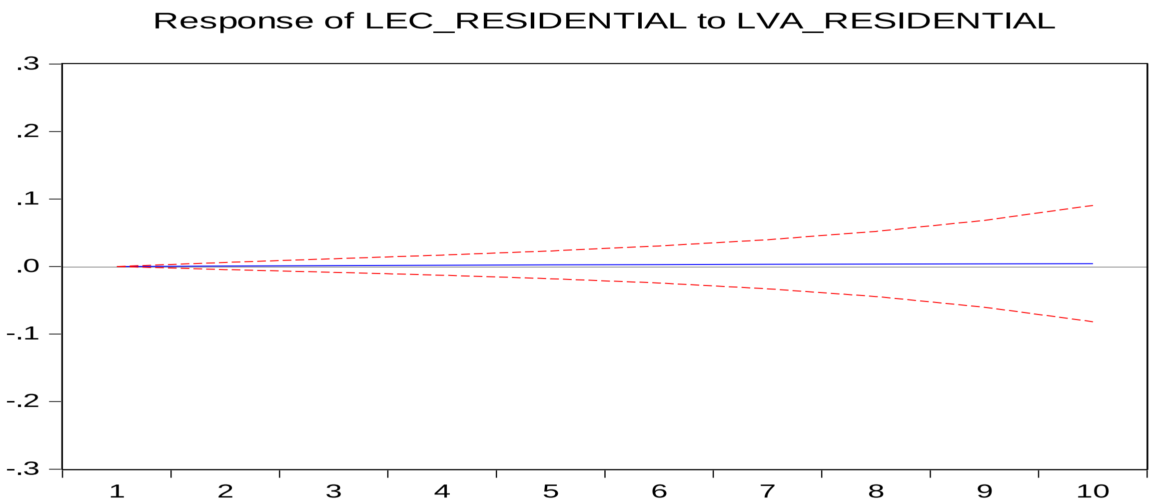


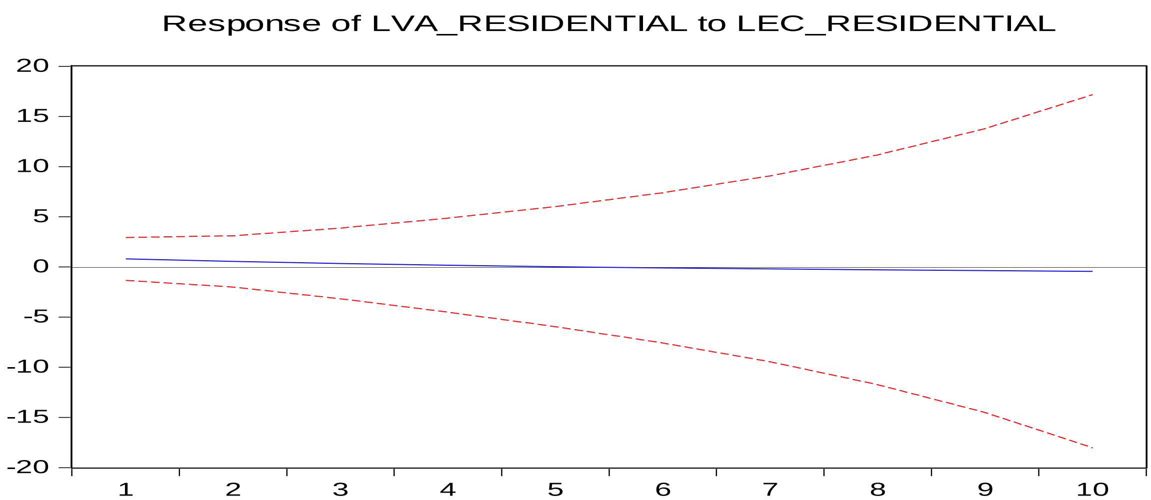
Figure 64 indicates a sharp increase in economic growth in response to energy consumption in the short run however after the third period a negative impact is observed in economic growth by energy consumption.

Figure 65: Results of Impulse response function of Residential energy consumption and value added for China



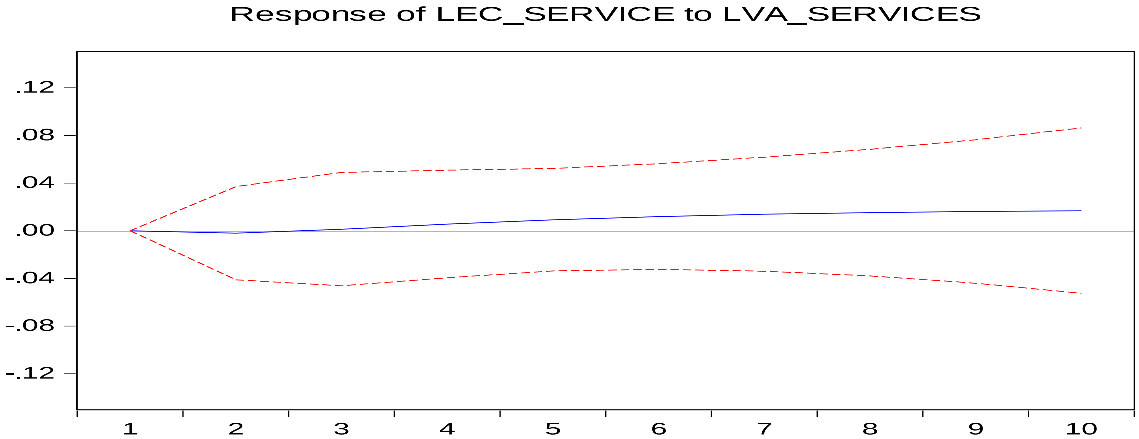
Energy consumption in the residential sector indicates a steady increase in response to economic growth of the sector as observed in figure 65.

Figure 66: Results of Impulse response function of residential value added and energy consumption for China



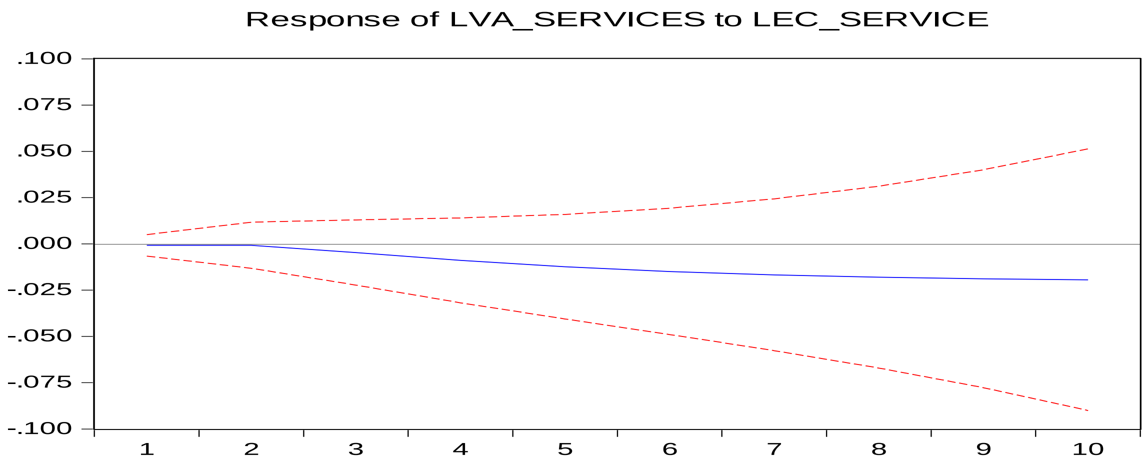
In figure 66, the response of growth in the residential sector to energy consumption exhibits a mild decline in the long run.

Figure 67: Results of Impulse response function of service energy consumption and value added for China



The above figure 67 indicates that energy consumption in the service sector declines in the short run as a response to economic growth however in the long run the impact of energy consumption to economic growth is positive in the service sector.

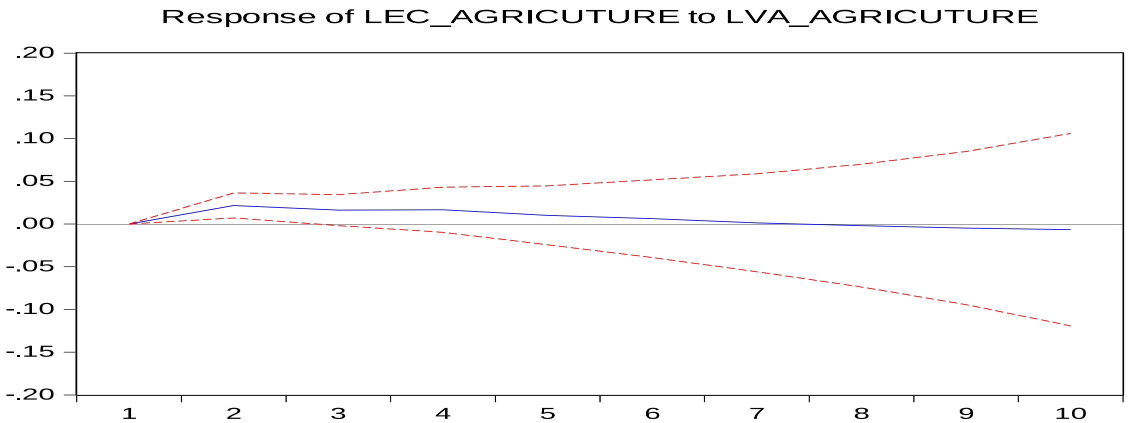
Figure 68: Results of Impulse response function of service value added and energy consumption for China



The impact of energy consumption on economic growth in the long run is negative for the service sector as displayed in figure 68.

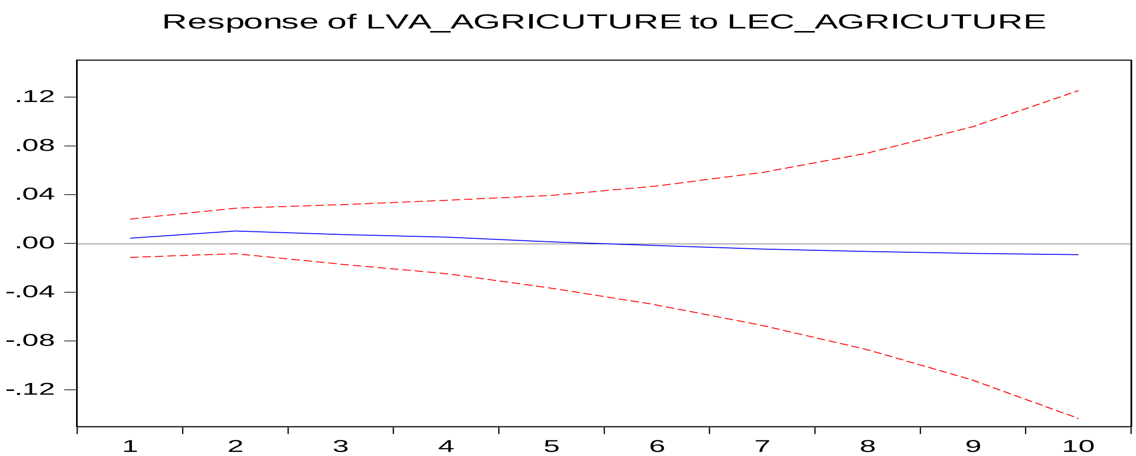
INDIA

Figure 69: Results of Impulse response function of agricultural energy consumption and value added for India



In figure 69, energy consumption indicates a sharp increase in the short run as a response to economic growth of the sector followed by a mild decline after the second period which then stabilizes after the third period and then steadily declines after the fourth period indicating that the impact of economic growth on energy consumption in the agricultural sector is negative.

Figure 70: Results of Impulse response function of agricultural value added and energy consumption for India



Similarly the impact of energy consumption on economic growth of India initially is positive in the short run but in the long run a declining trend is observed over the ten year period as indicated in figure 70.

Figure 71: Results of Impulse response function of industrial energy consumption and value added for India

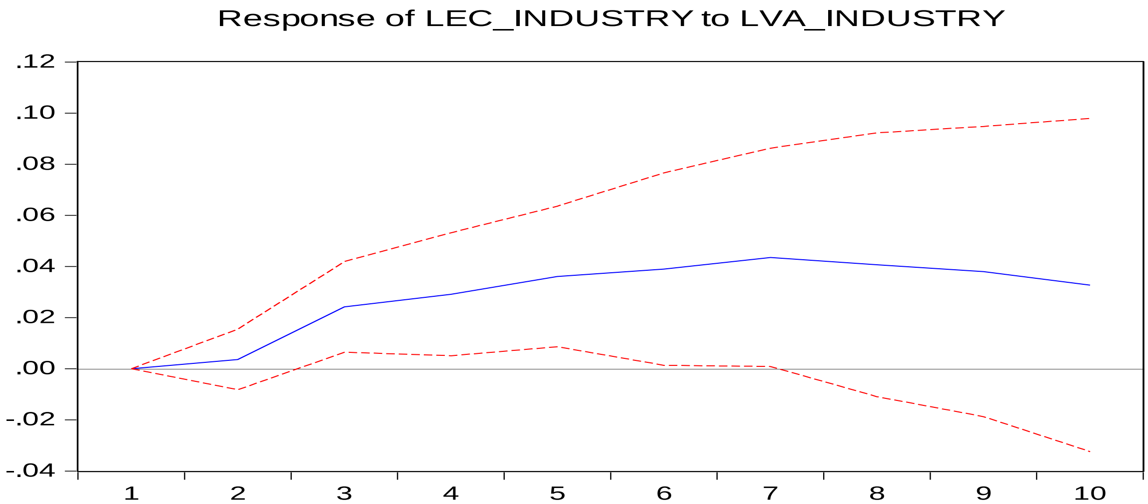
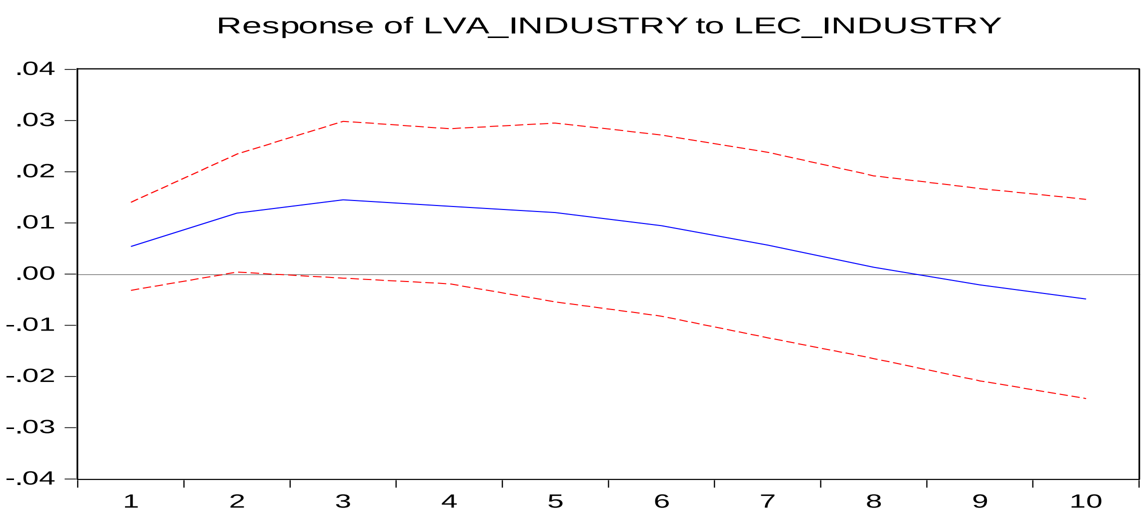


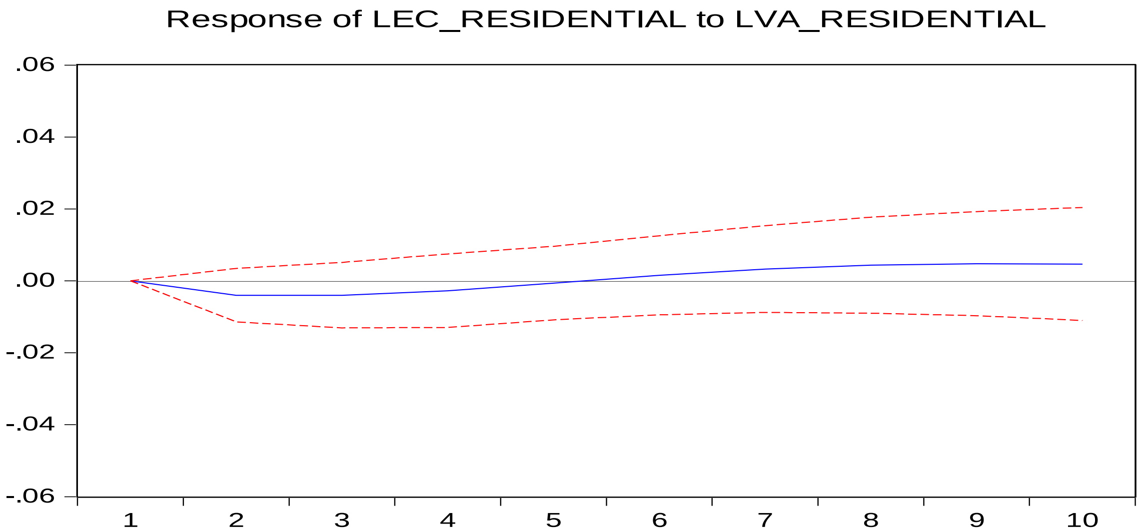
Figure 71 indicates that incase of the industrial sector, economic growth has a positive impact on energy consumption in the short and medium term upto the seventh period followed by a negative impact in the long run.

Figure 72: Results of Impulse response function of industrial value added and energy consumption for India



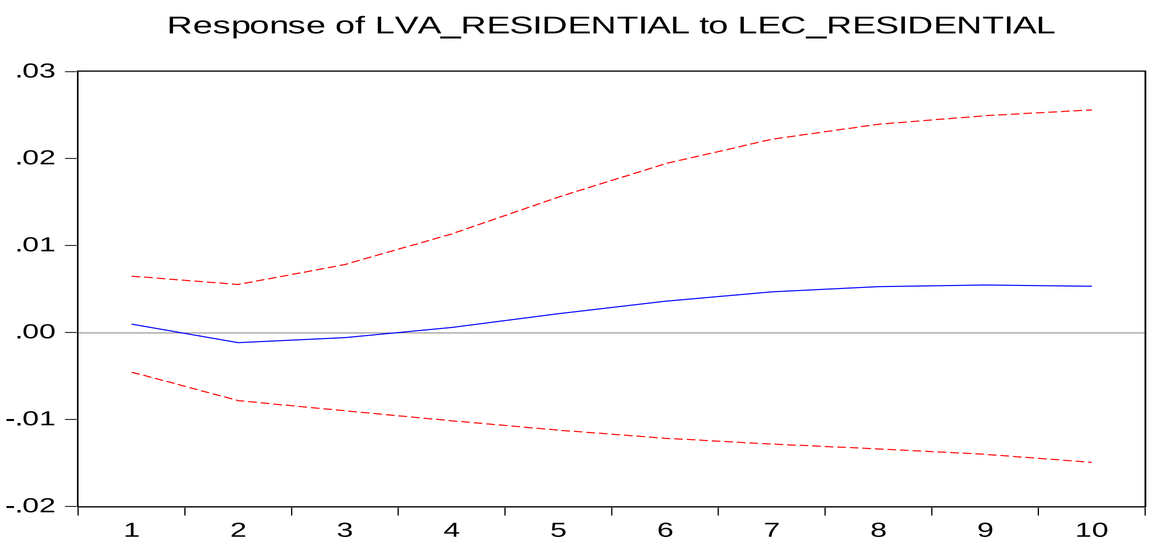
The response of economic growth to energy consumption in the industrial sector is positive in the short run followed by a negative response in the long run after the third period as per the above figure 72.

Figure 73: Results of Impulse response function of residential energy consumption and value added for India



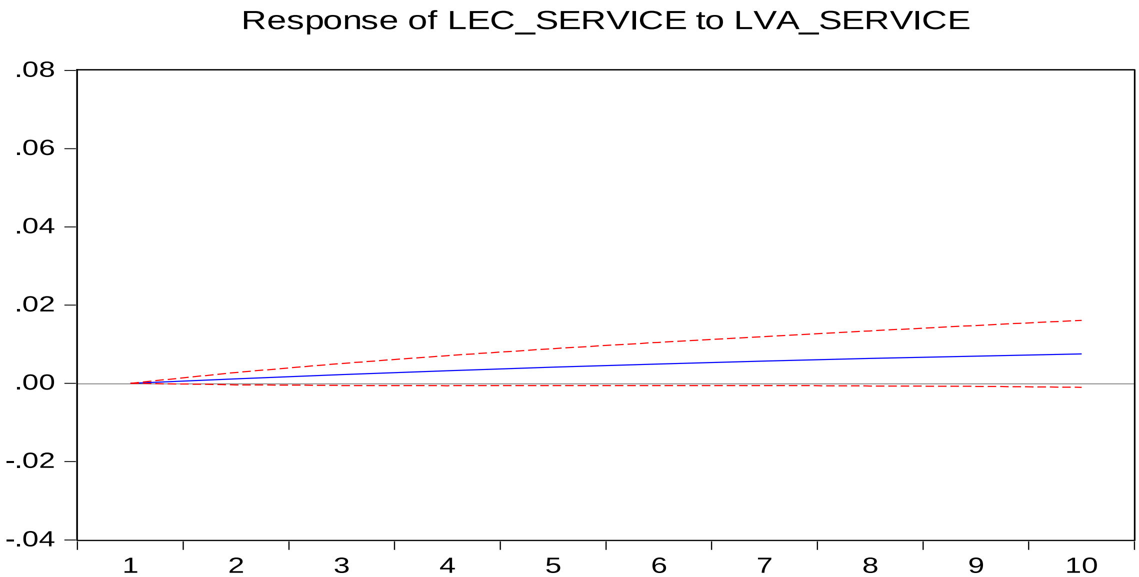
In figure 73, the impact of economic growth to energy consumption in the residential sector is negative in the short run. However after the second period an increase trend is observed indicating that economic growth has a positive impact on energy consumption in the long run.

Figure 74: Results of Impulse response function of residential value added and energy consumption for India



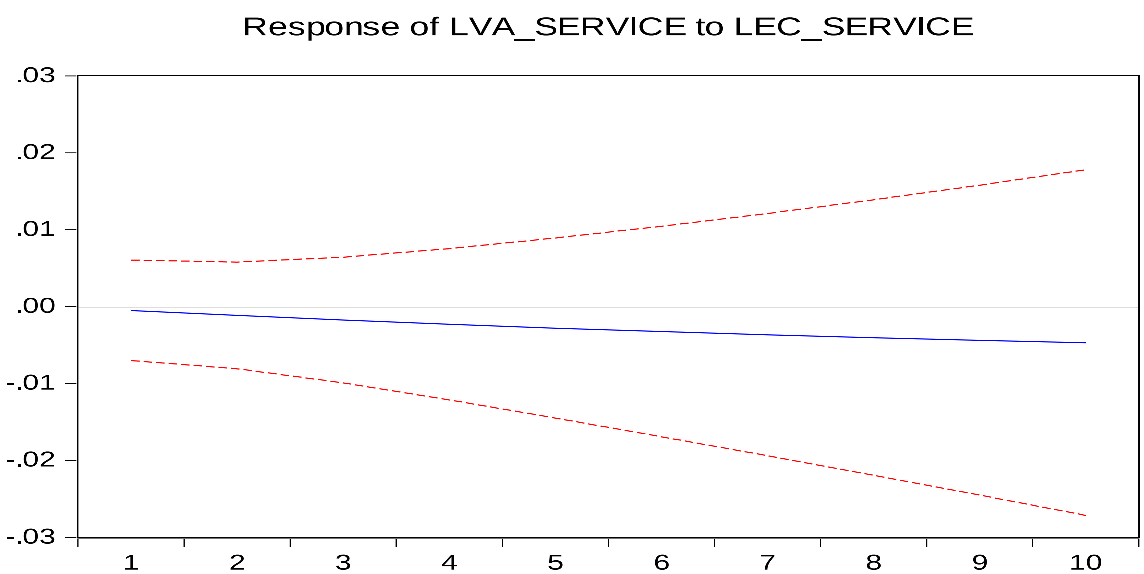
Similarly, energy consumption has a negative impact on economic growth in the short run however in the long run a positive impact can be observed in the above figure 74.

Figure 75: Results of Impulse response function of service energy consumption and value added for India



In the service sector of India, economic growth has a positive impact on energy consumption in the long run as indicated by a syeady increasing blue line in the above figure 75.

Figure 76: Results of Impulse response function of service value added and energy consumption for India



The impact of energy consumption on economic growth is negative in the long run in the service sector of India as indicated in figure 76.

INDONESIA

Figure 77: Results of Impulse response function of agricultural energy consumption and value added for Indonesia

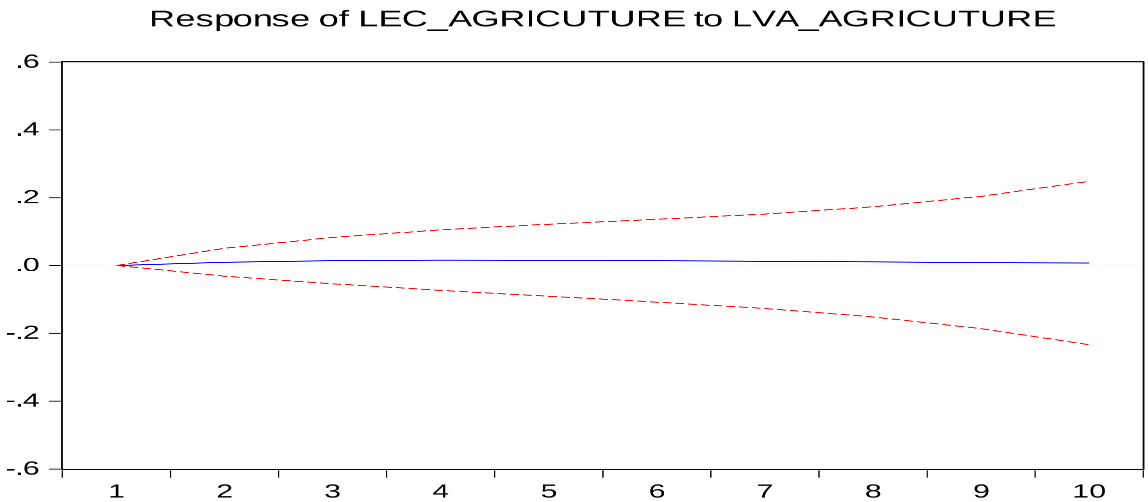
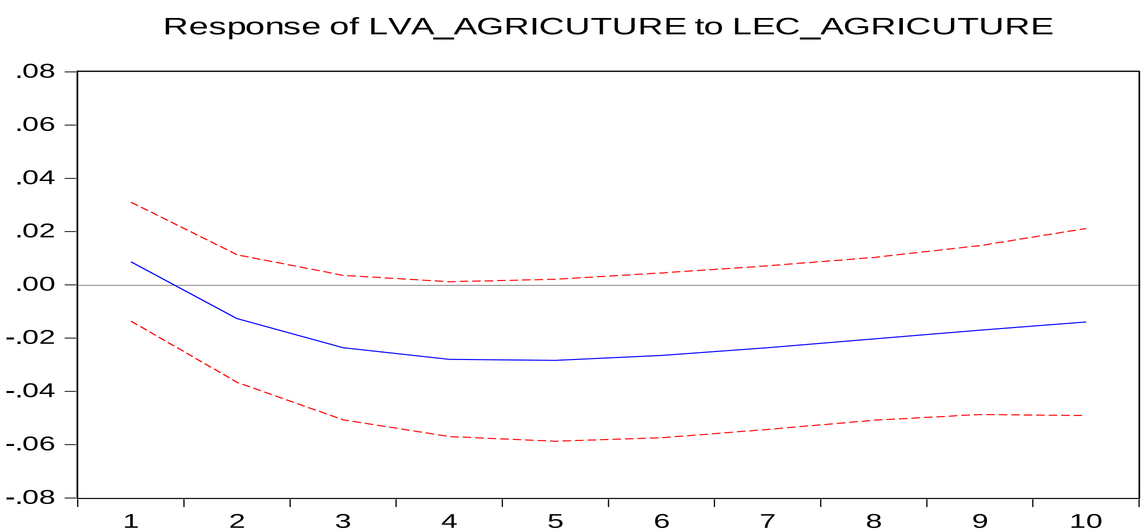


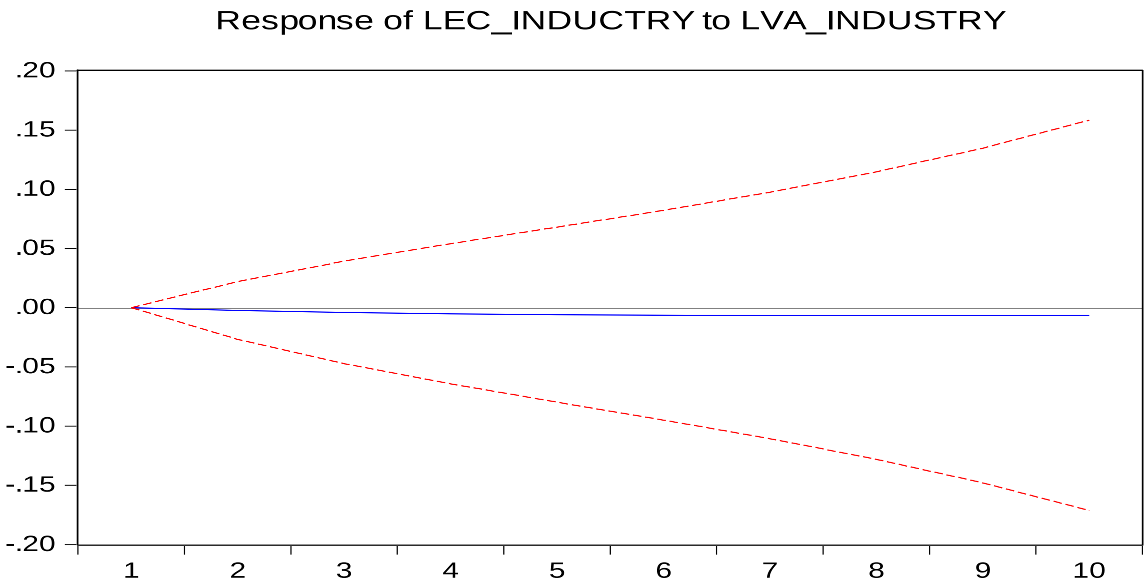
Figure 77 indicates that in the agricultural sector of Indonesia, economic growth of the sector has positive impact upto the fifth period followed by a mild decline in the long run.

Figure 78: Results of Impulse response function of agricultural value added and energy consumption for Indonesia



The response of economic growth to energy consumption is negative upto the fifth period however a positive impact is observed upto the tenth period as displayed in figure 78.

Figure 79: Results of Impulse response function of industrial energy consumption and value added for Indonesia



In figure 79, the energy consumption of the industrial sector responds negative to economic growth in the long run.

Figure 80: Results of Impulse response function of industrial value added and energy consumption for Indonesia

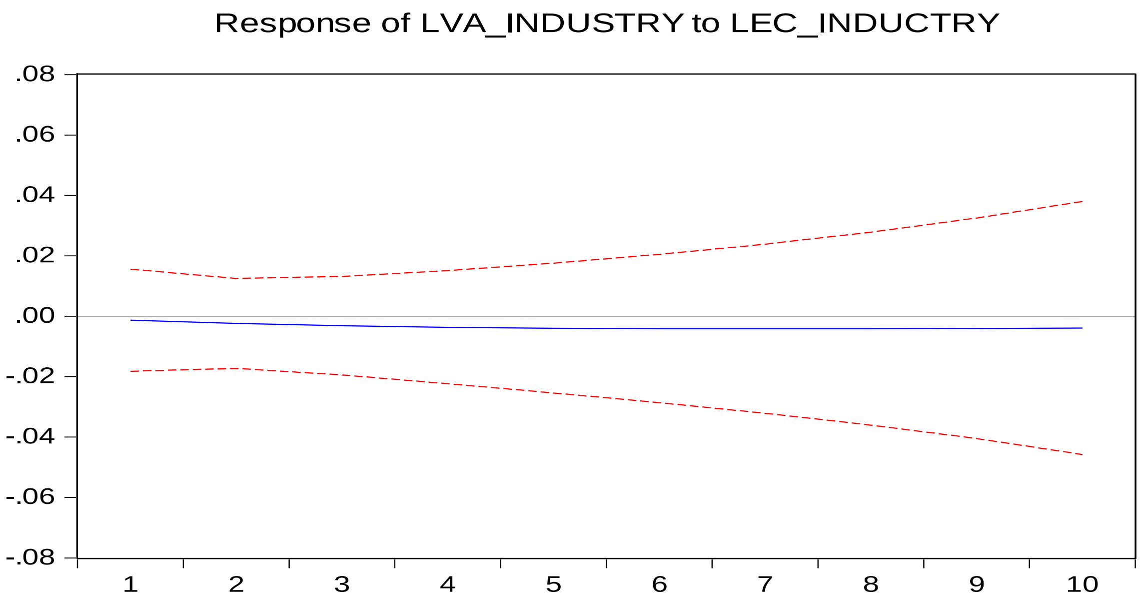
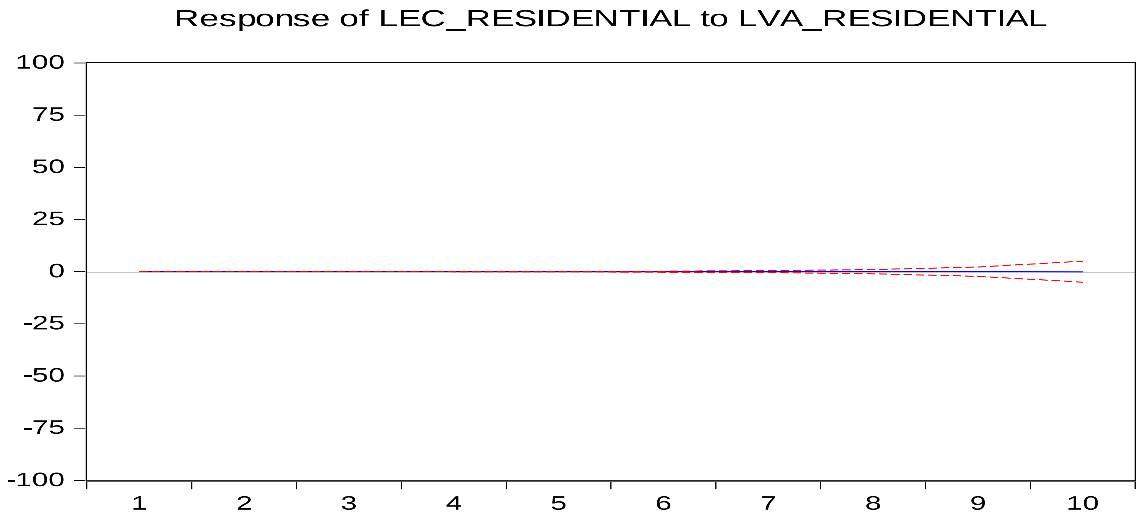


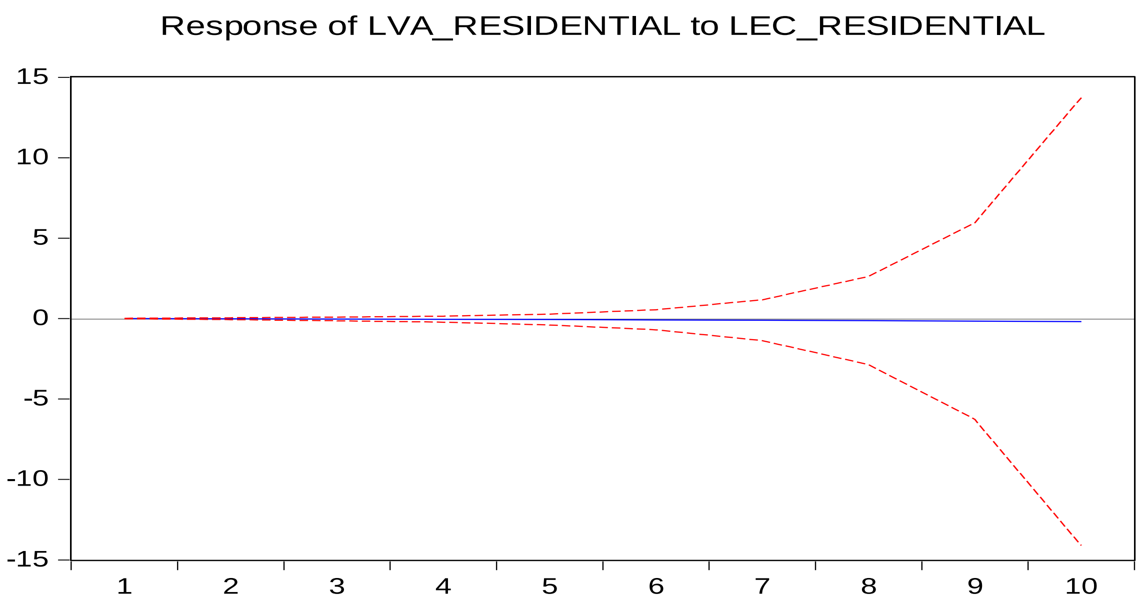
Figure 80 indicates that the growth of the industrial sector is negatively affected by energy consumption upto the ninth period followed by a mild increase.

Figure 81: Results of Impulse response function of residential energy consumption and value added for Indonesia



The energy consumption of the residential sector does not indicate a major impact by economic growth of the sector as indicated in figure 81.

Figure 82: Results of Impulse response function of residential value added and energy consumption for Indonesia



In the long run, economic growth of the residential sector exhibits a mild decrease as a response to energy consumption of the sector as observed in figure 82.

Figure 83: Results of Impulse response function of service energy consumption and value added for Indonesia

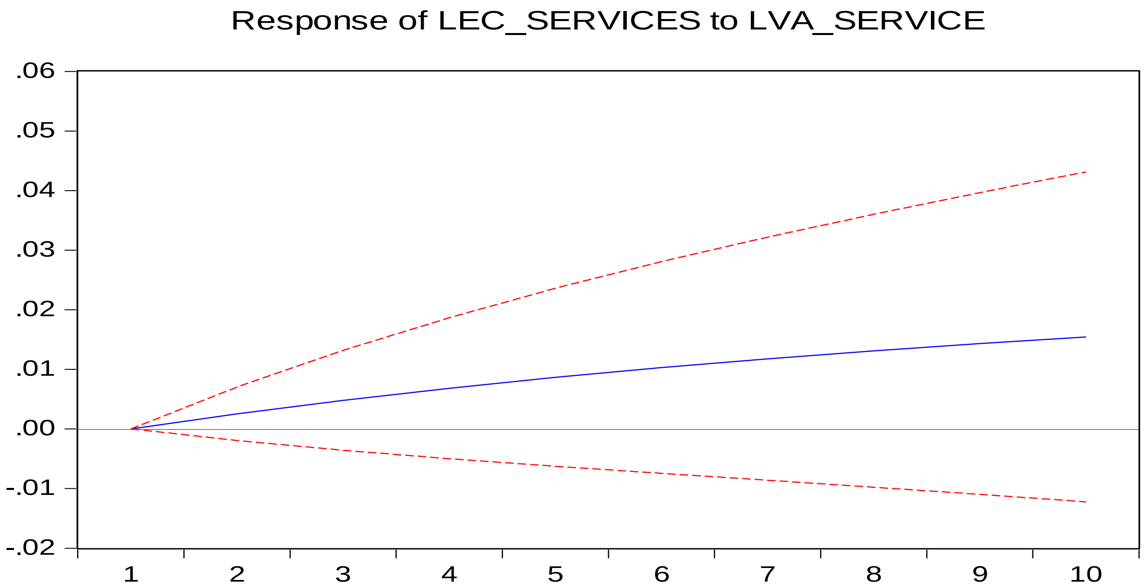
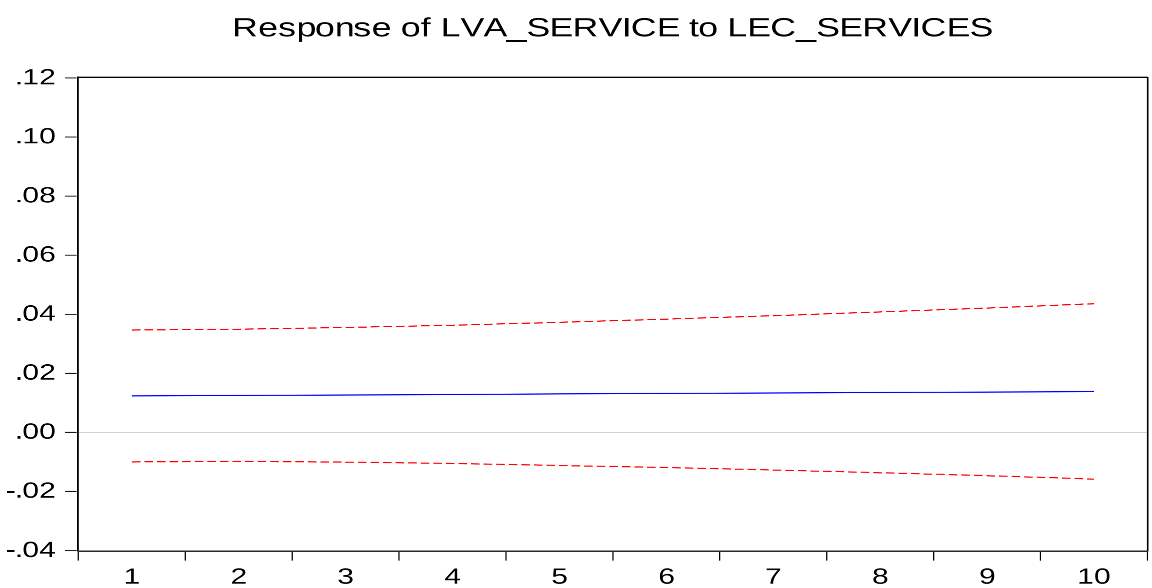


Figure 83 indicates that energy consumption of the service sector increases in the long run as a response to economic growth of the sector.

Figure 84: Results of Impulse response function of service value added and energy consumption for Indonesia



The economic growth of the service sector exhibits a mild steady increase in the long run as a response to energy consumption as per the above figure 84.

MALAYSIA

Figure 85: Results of Impulse response function of agricultural energy consumption and value added for Malaysia

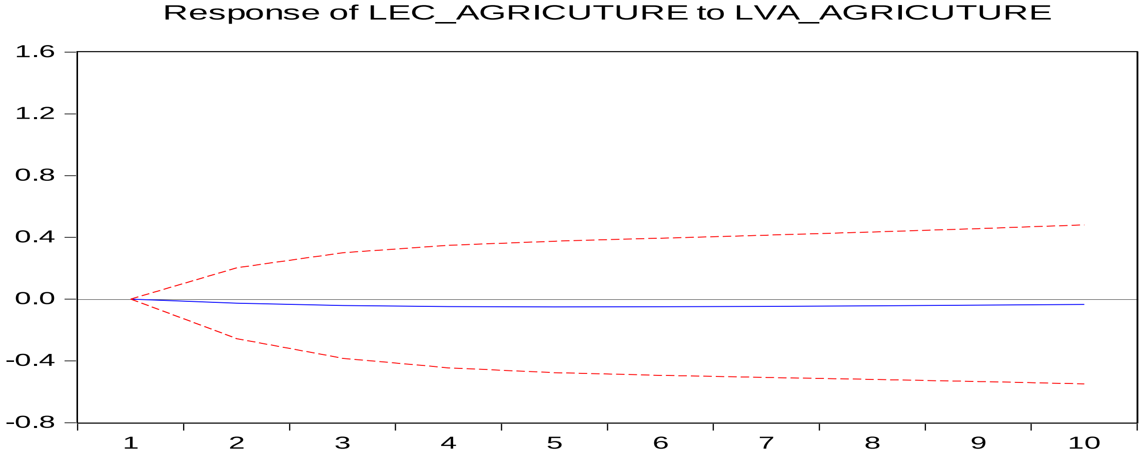
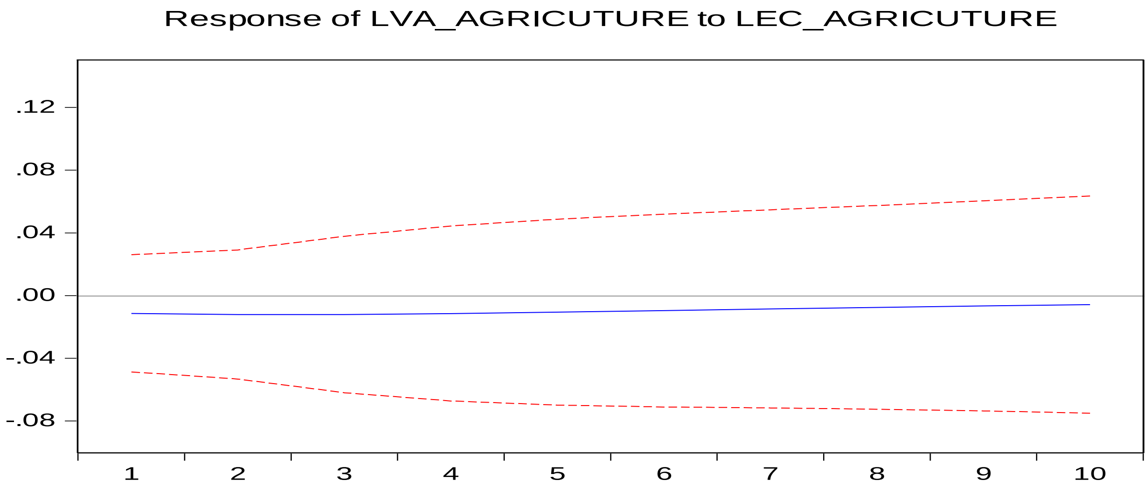


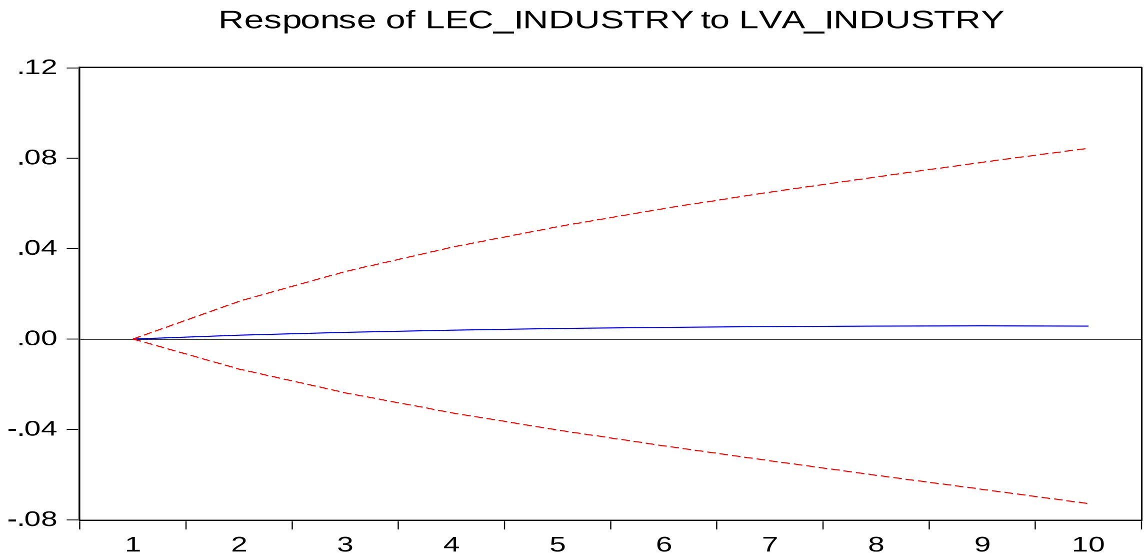
Figure 85 indicates that in the short run the response of energy consumption to economic growth of Malaysia is negative however after the seventh period a mild increase is observed which indicates that in the long run as the agricultural sector grows, consumption of energy increases.

Figure 86: Results of Impulse response function of agricultural value added and energy consumption for Malaysia



Economic growth of Malaysia increases in the long run as a response to energy consumption by the sector as per figure 86. Therefore, energy consumption has a positive impact on agricultural economic growth.

Figure 87: Results of Impulse response function of industrial energy consumption and value added for Malaysia



In the long run there exists a positive impact of economic growth on energy consumption in the industrial sector as indicated in figure 87.

Figure 88: Results of Impulse response function of industrial value added and energy consumption for Malaysia

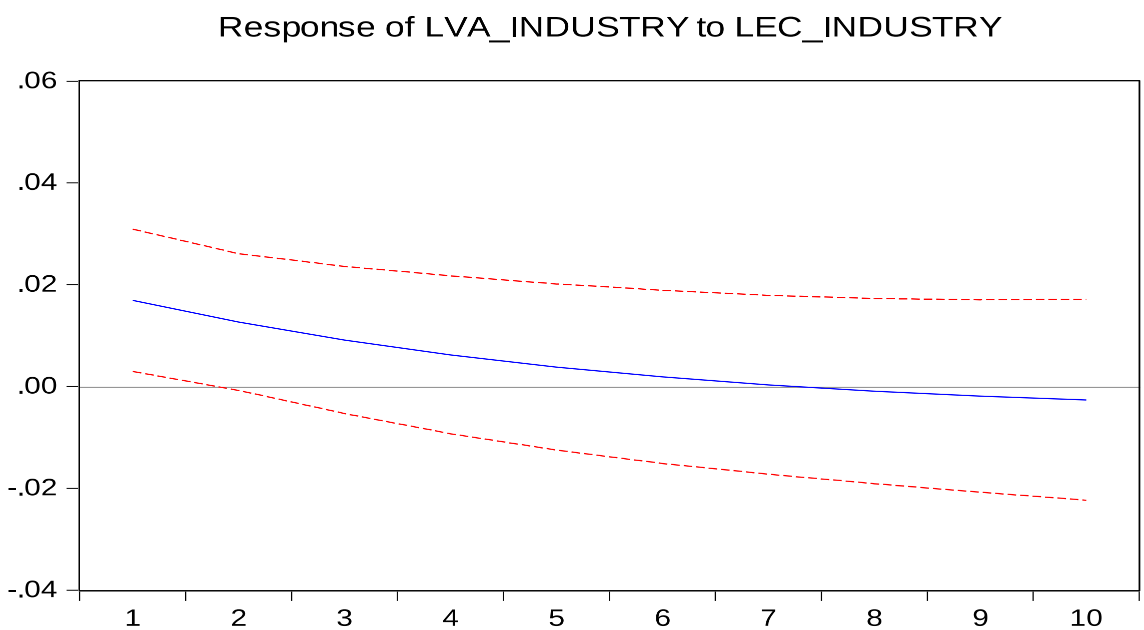
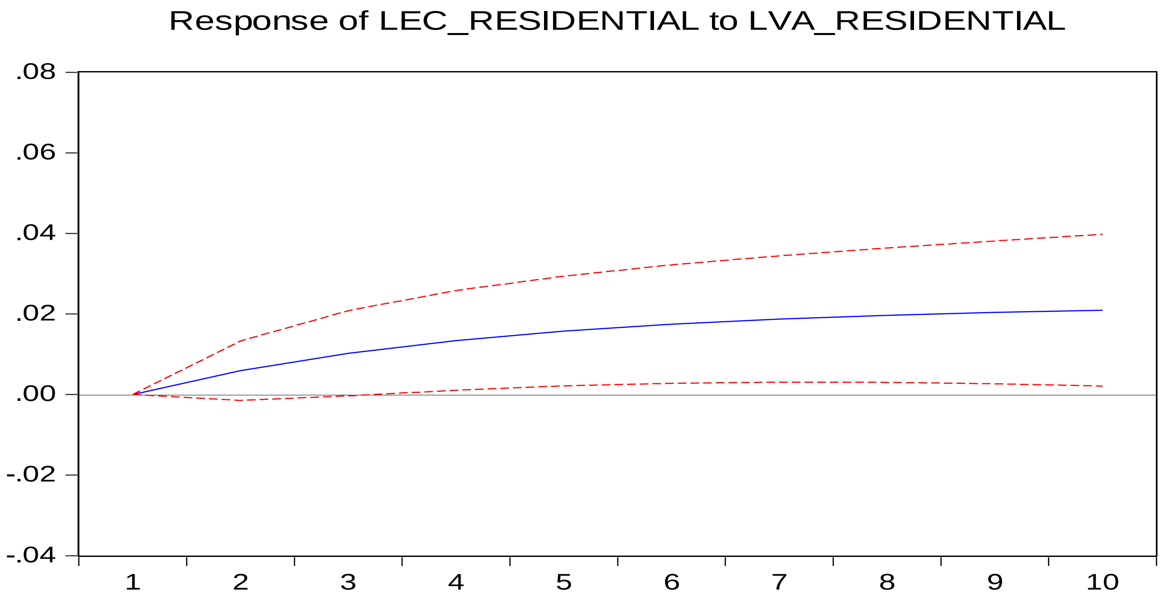


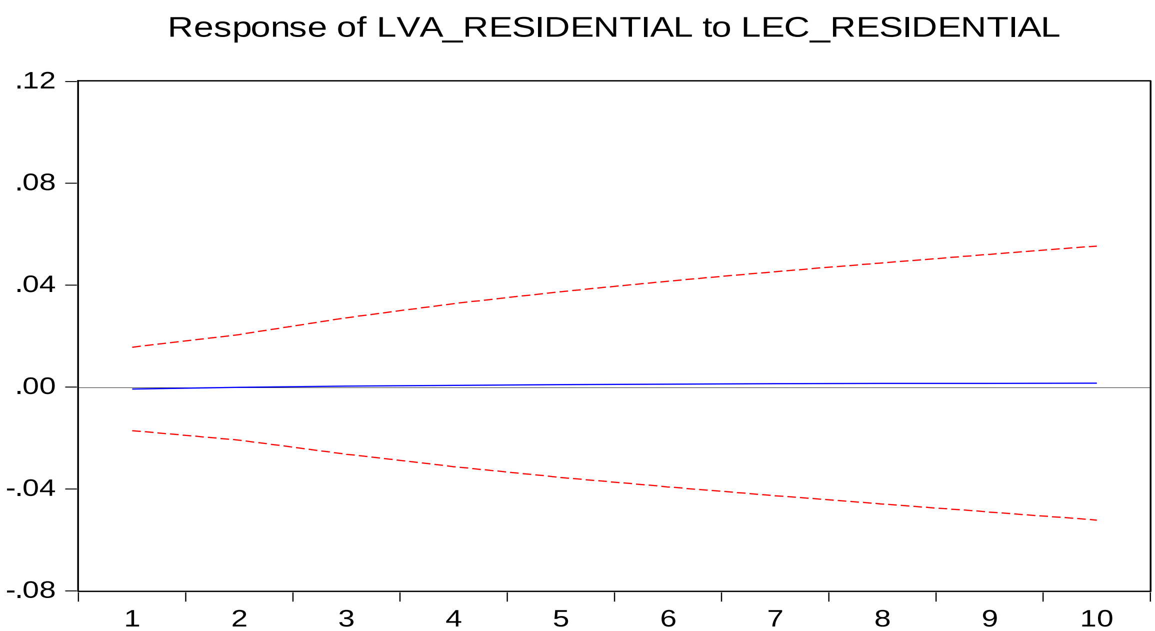
Figure 88 indicates that in the short run, industrial economic growth responds negatively to energy consumption.

Figure 89: Results of Impulse response function of residential energy consumption and value added for Malaysia



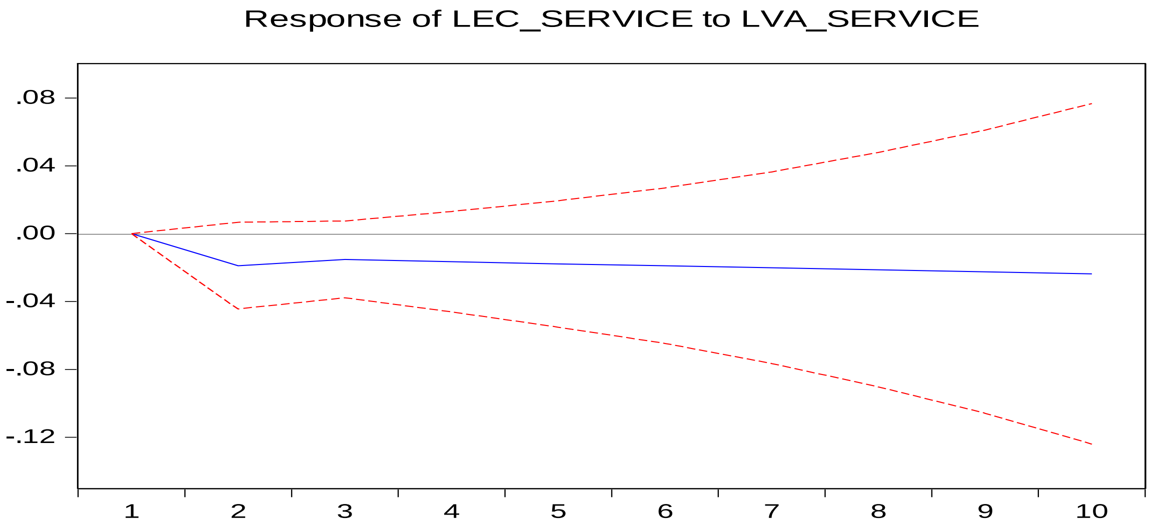
In the above figure 89, energy consumption of the Malaysian residential sector responds positively to economic growth of the sector in the long run.

Figure 90: Results of Impulse response function of residential value added and energy consumption for Malaysia



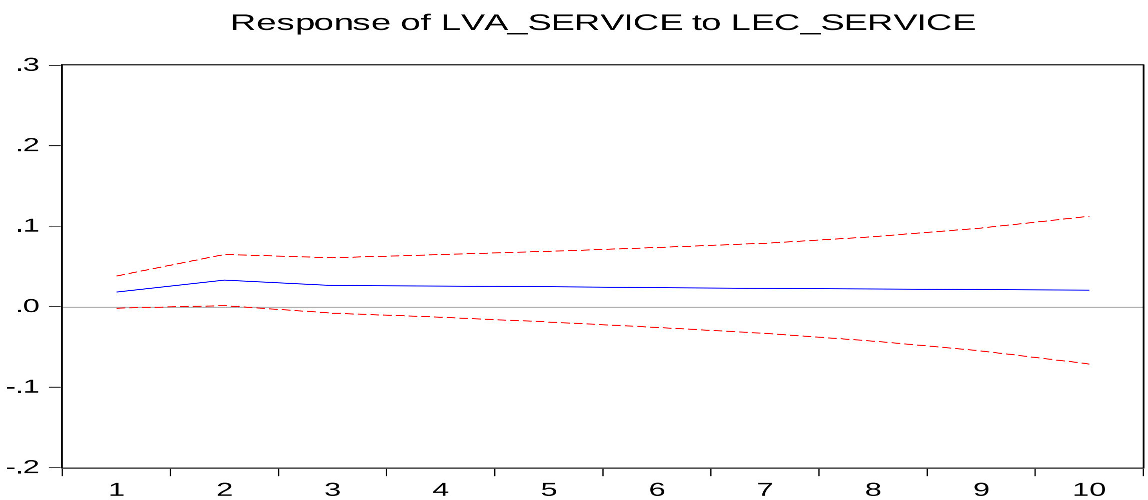
The impact of energy consumption on economic growth in the long run is positive at a steady rate for the residential sector of Malaysia as indicated in figure 90.

Figure 91: Results of Impulse response function of service energy consumption and value added for Malaysia



In figure 91 in the short run, growth in the service sector has a negative impact on energy consumption upto the second period after which a mild recovery is observed till the third period and a gradual decreasing trend in energy consumption in the long run as a response to growth exists.

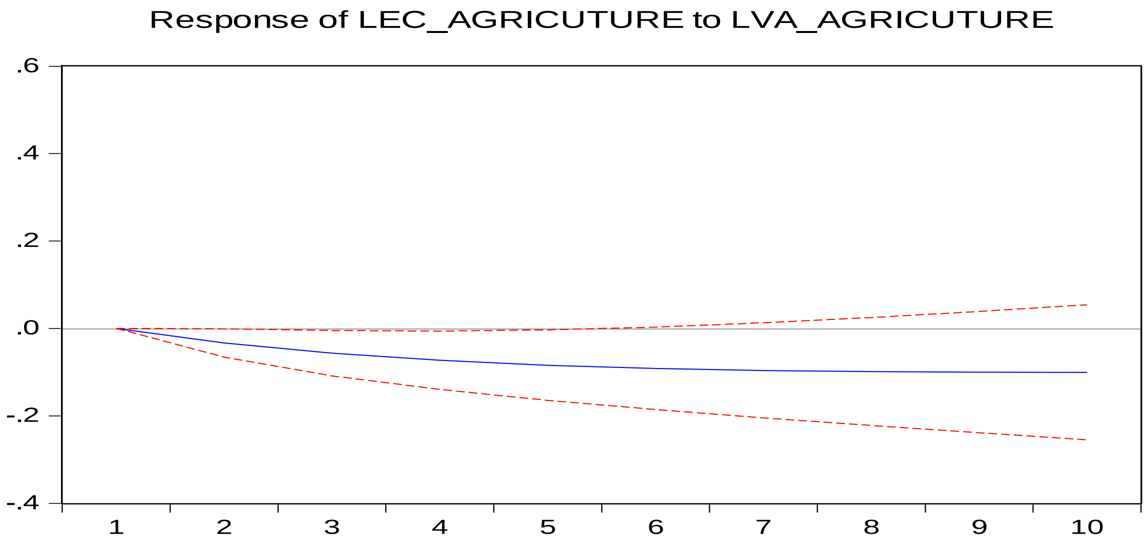
Figure 92: Results of Impulse response function of service value added and energy consumption for Malaysia



The response of economic growth to energy consumption for the service sector in the short run is positive while in the long run a mild decreasing trend is visible as indicated in figure 92.

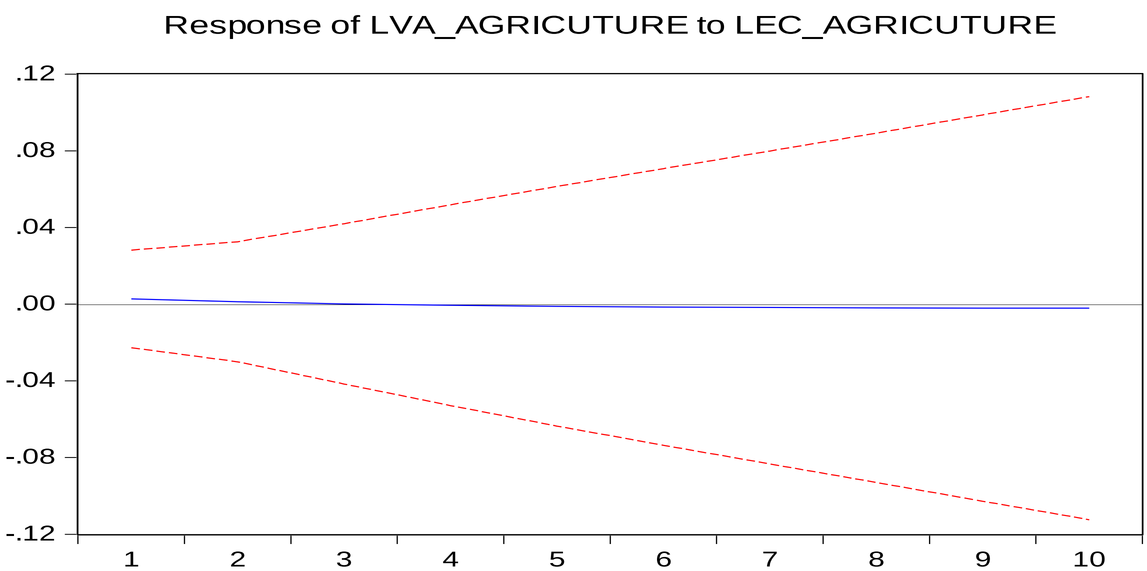
PHILIPPINES

Figure 93: Results of Impulse response function of agricultural energy consumption and value added for Philippines



In figure 93, energy consumption in the agricultural sector is negatively affected by growth of the sector in the long run i.e. throughout the ten year period.

Figure 94: Results of Impulse response function of agricultural value added and energy consumption for Philippines



Energy consumption in the agricultural sector in the Philippines has a mild negative impact on economic growth as displayed in figure 94.

Figure 95: Results of Impulse response function of industrial energy consumption and value added for Philippines

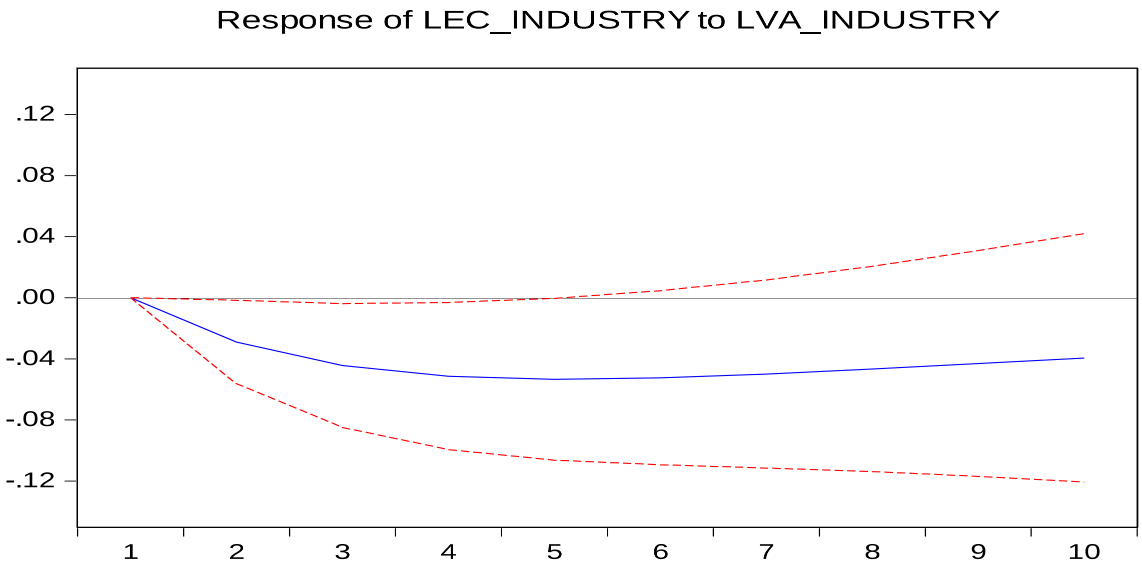
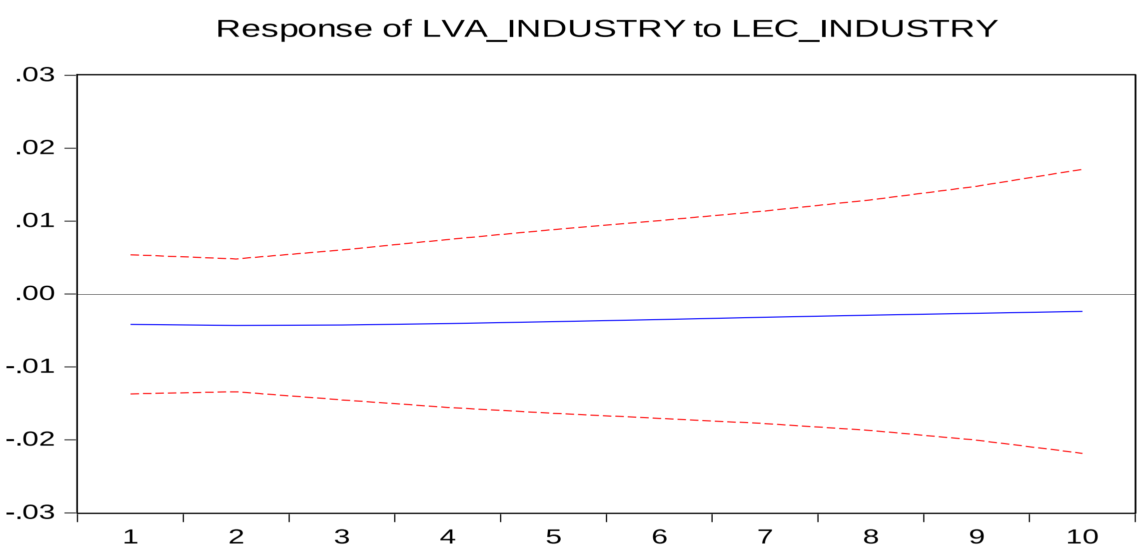


Figure 95 indicates that in the short run, economic growth of the industrial sector has a negative impact on energy consumption. However, after the fifth period, a positive response is observed by energy consumption to economic growth of the industrial sector.

Figure 96: Results of Impulse response function of industrial value added and energy consumption for Philippines



The response of industrial economic growth to energy consumption is positive in the long run as indicated in figure 96.

Figure 97: Results of Impulse response function of residential energy consumption and value added for Philippines

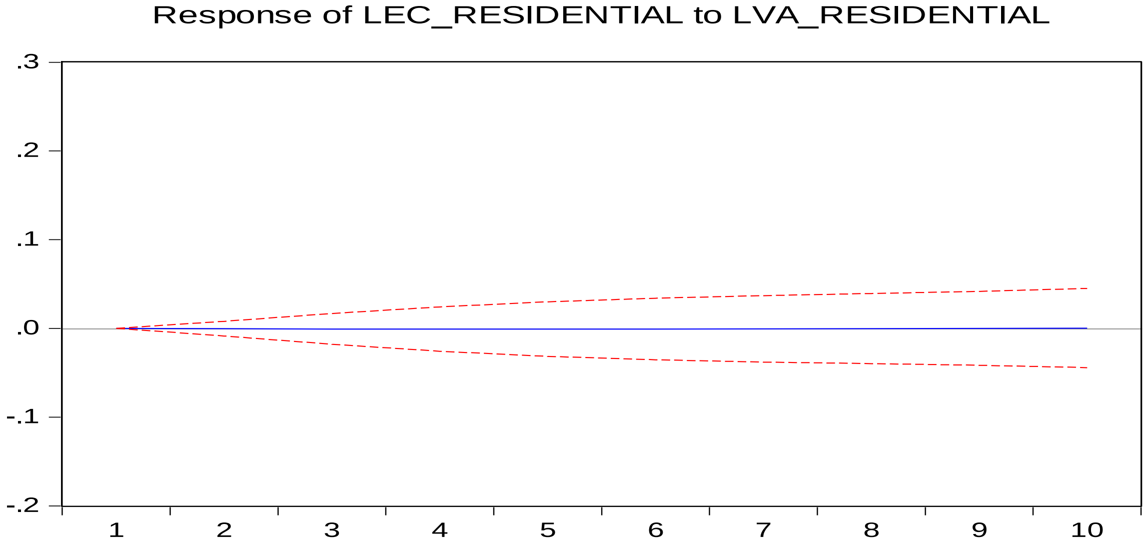


Figure 97 indicates that the response of energy consumption to economic growth in the residential sector is consistent throughout the period.

Figure 98: Results of Impulse response function of residential value added and energy consumption for Philippines

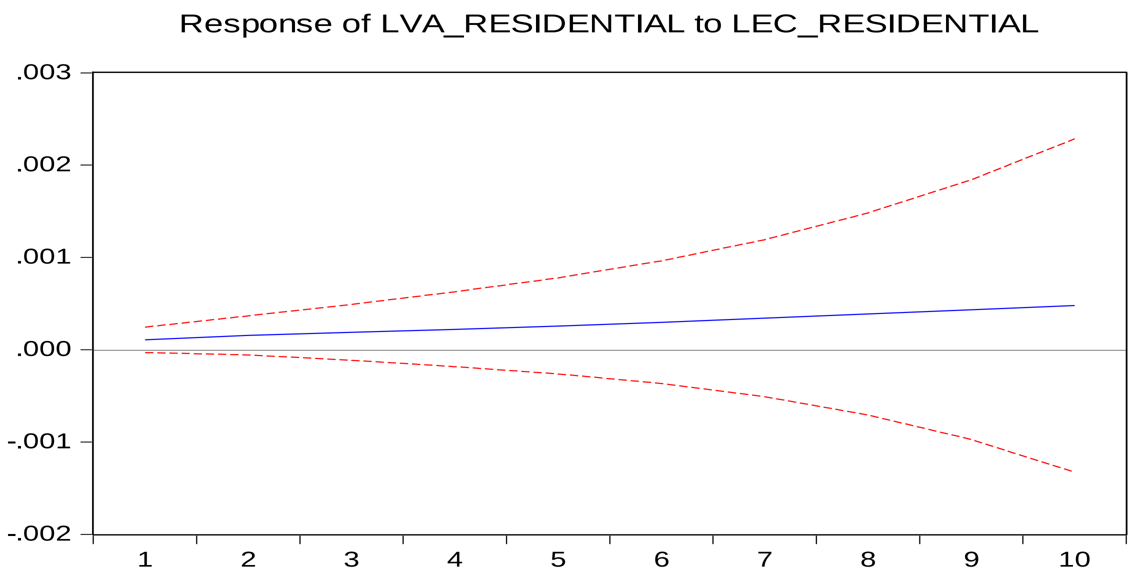
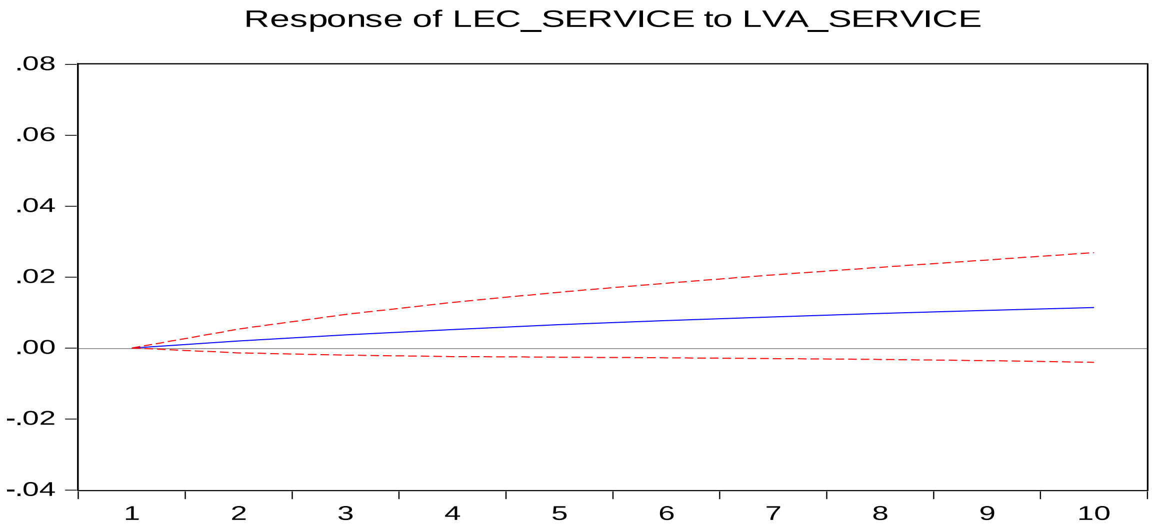


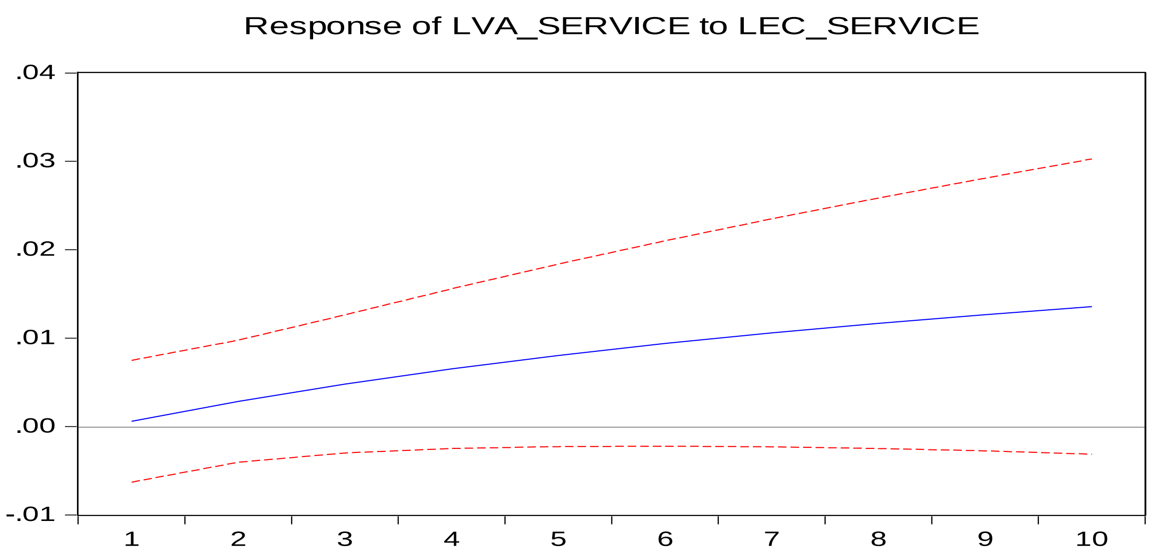
Figure 98 indicates that energy consumption of the residential sector has a positive impact on economic growth in the long run.

Figure 99: Results of Impulse response function of service energy consumption and value added for Philippines



In case of the service sector of the Philippines, economic growth has a positive impact on energy consumption throughout the ten-year period as per the above figure 99.

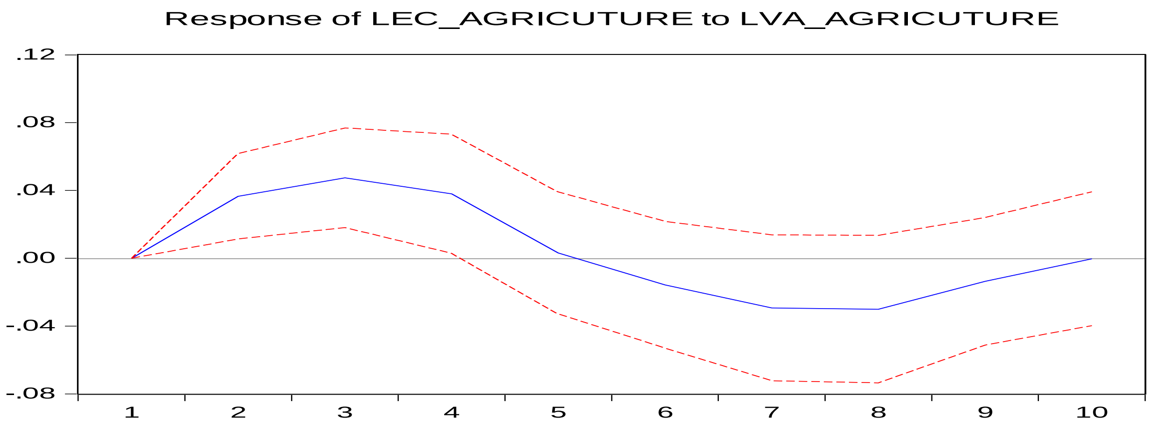
Figure 100: Results of Impulse response function of service value added and energy consumption for Philippines



In figure 100 energy consumption has a positive impact on economic growth of the service sector which can be observed by an increasing trend in the above graph.

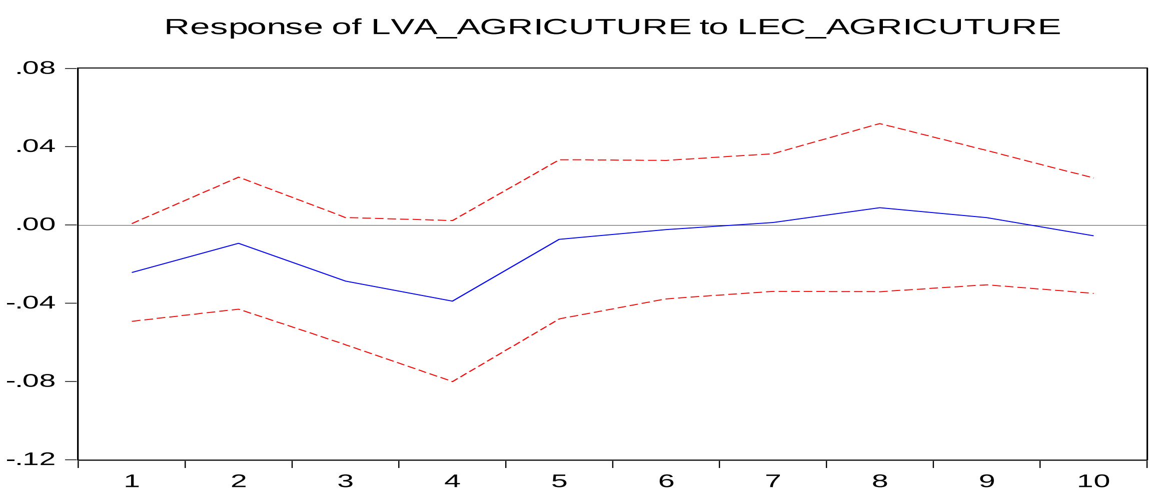
THAILAND

Figure 101: Results of Impulse response function of agricultural energy consumption and value added for Thailand



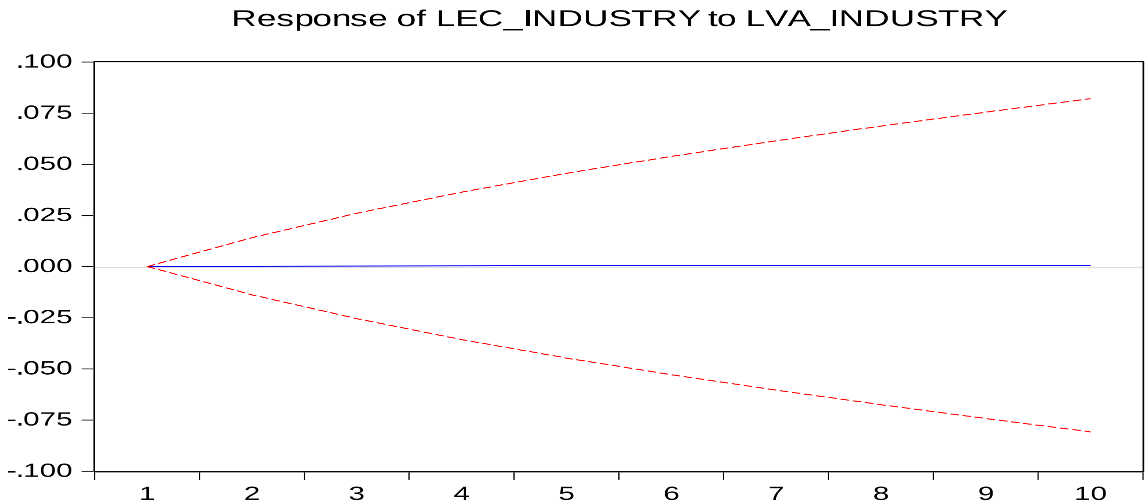
For Thailand, in the short run upto the third period growth in the agricultural sector has positive impact on energy consumption after which a decline is observed indicating a negative impact till the eighth period followed by a recovery. Therefore, economic growth has a positive impact on economic growth in the long run as indicated in figure 101.

Figure 102: Results of Impulse response function of agricultural value added and energy consumption for Thailand



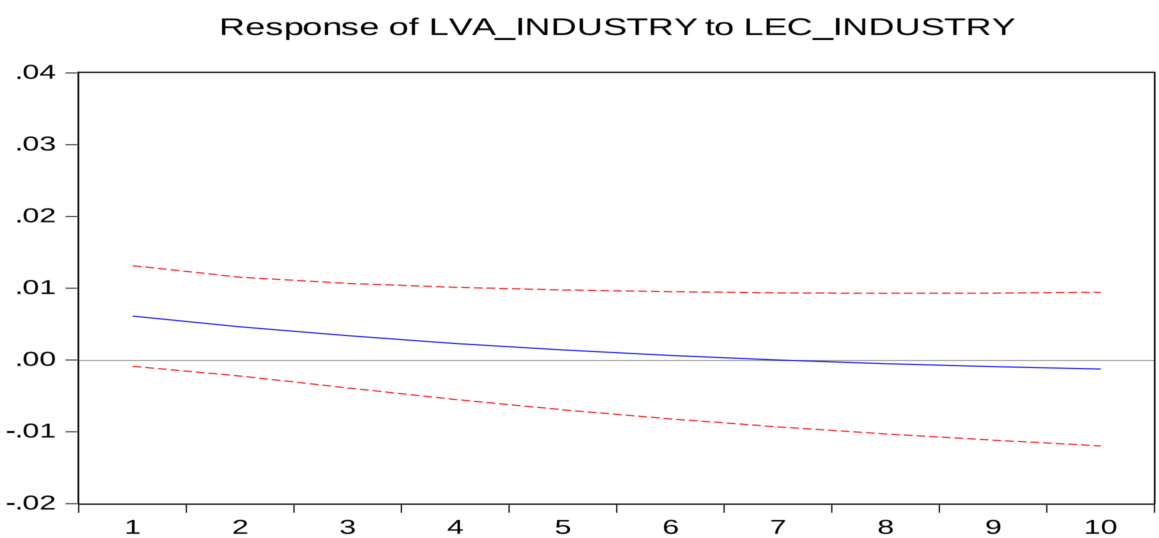
In figure 102, in the short run energy consumption has a positive impact on economic growth till the second period followed by a negative impact till the fourth period. Upto the eighth period appositive impact by energy consumption is observed followed by a negative impact. Therefore, the impact is volatile.

Figure 103: Results of Impulse response function of industrial energy consumption and value added for Thailand



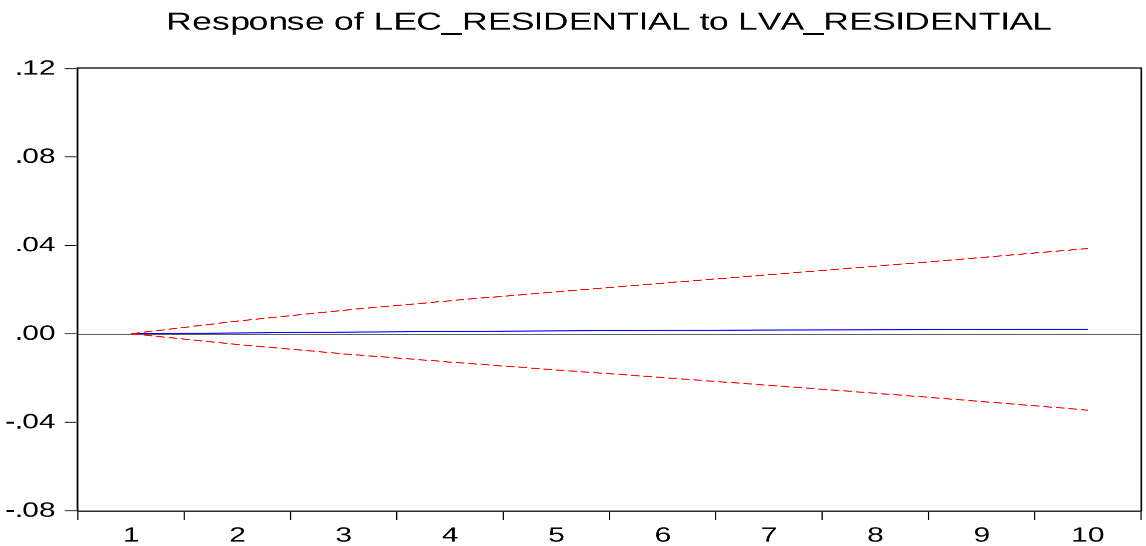
The response of energy consumption to economic growth of the industrial sector is consistent in the long run as indicated in figure 103.

Figure 104: Results of Impulse response function of industrial value added and energy consumption for Thailand



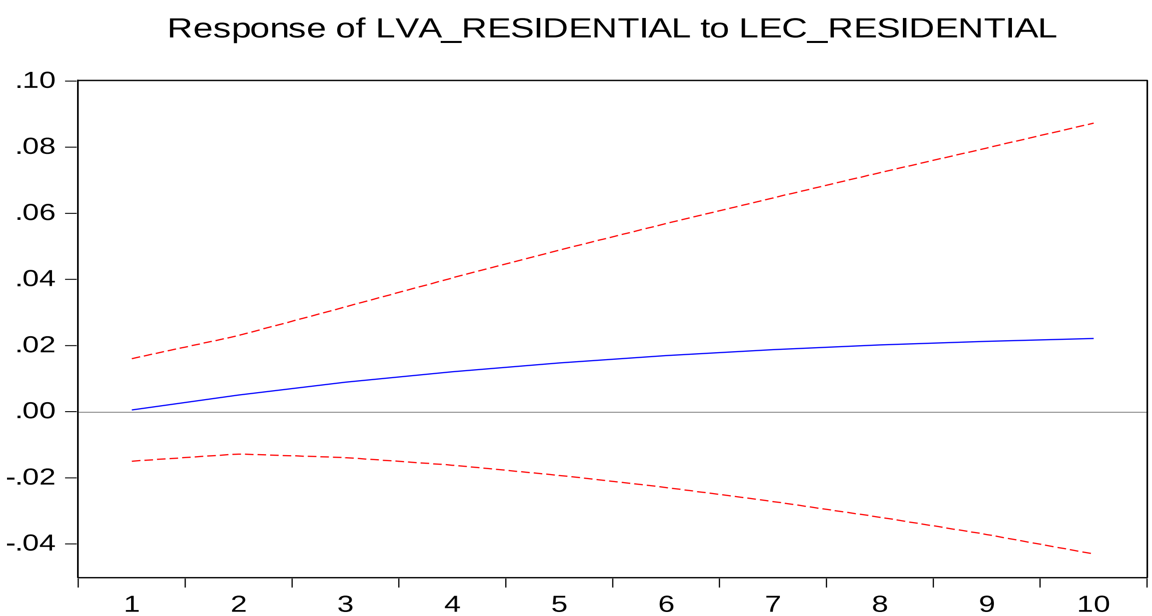
Energy consumption of the industrial sector has a negative impact on its growth in the long run as observed in figure 104.

Figure 105: Results of Impulse response function of residential energy consumption and value added for Thailand



In figure 105, residential energy consumption responds positively to economic growth in the long run.

Figure 106: Results of Impulse response function of residential value added and energy consumption for Thailand



Similarly, economic growth of the residential sector is positively affected by energy consumption of the sector in the long run as indicated in figure 106.

Figure 107: Results of Impulse response function of service energy consumption and value added for Thailand

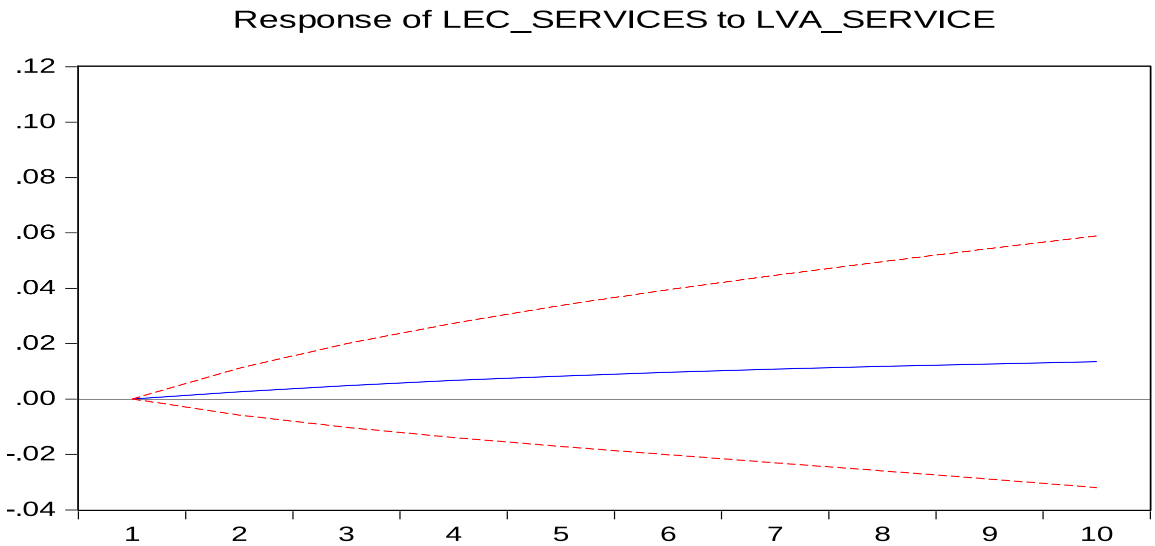


Figure 107 indicates that in the long run, energy consumption by the service sector responds positive to growth of the sector.

Figure 108: Results of Impulse response function of service value added and energy consumption for Thailand

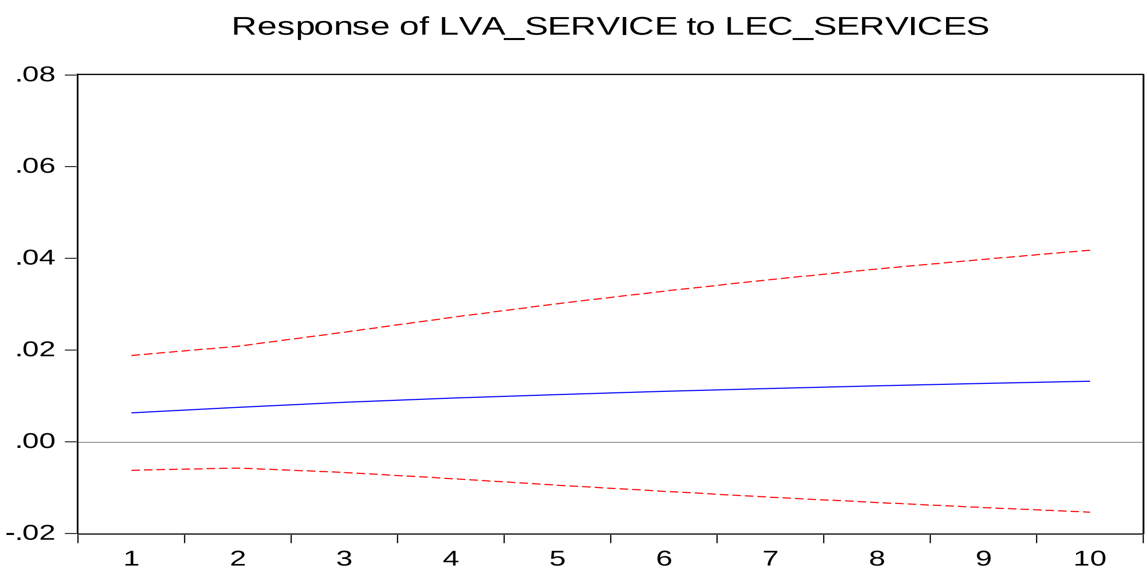
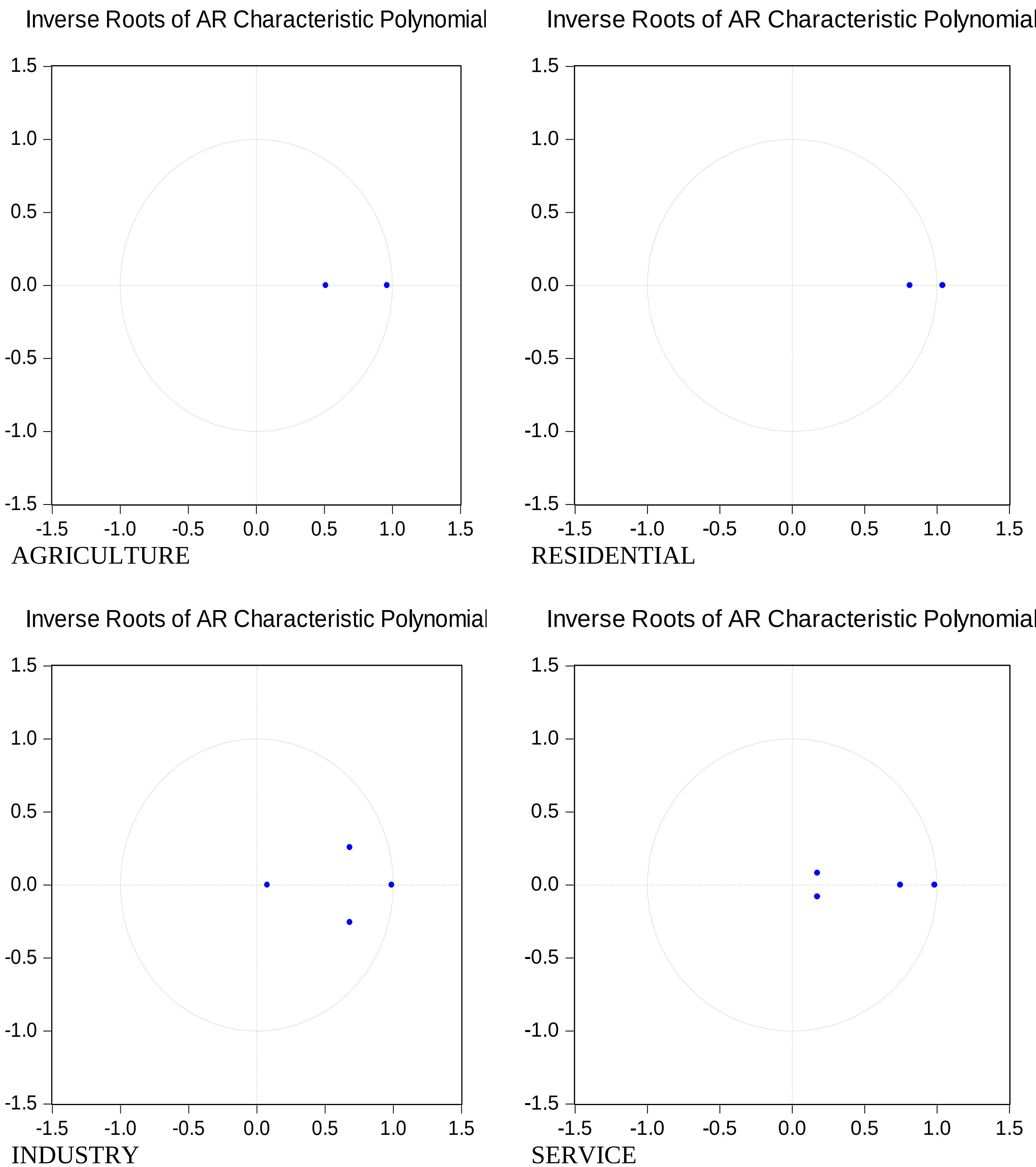


Figure 108 suggests that economic growth increases in the long run with growth of the residential sector.

4.8 STABILITY TEST

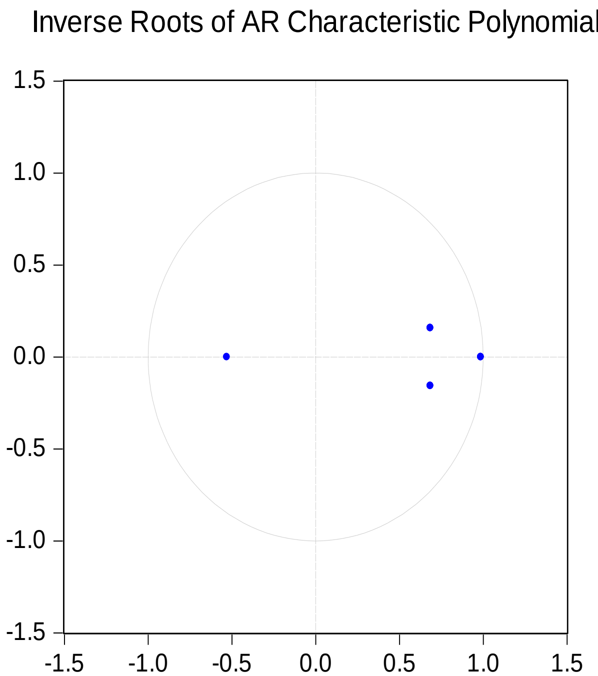
<u>CHINA</u>

Figure 109: Results of stability test for China

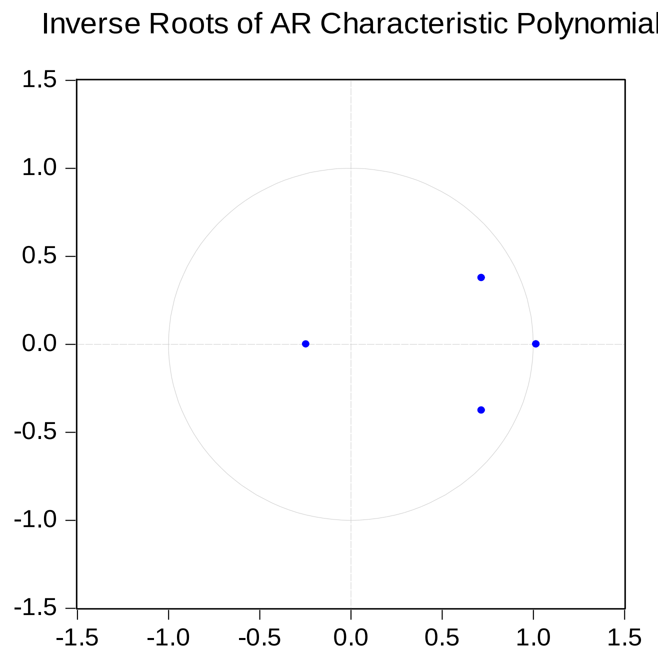


INDIA

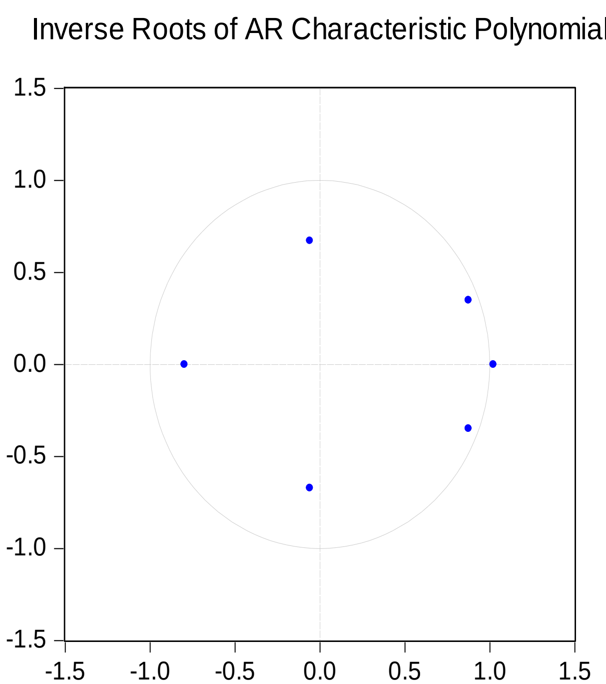
Figure 110: Results of stability test for India



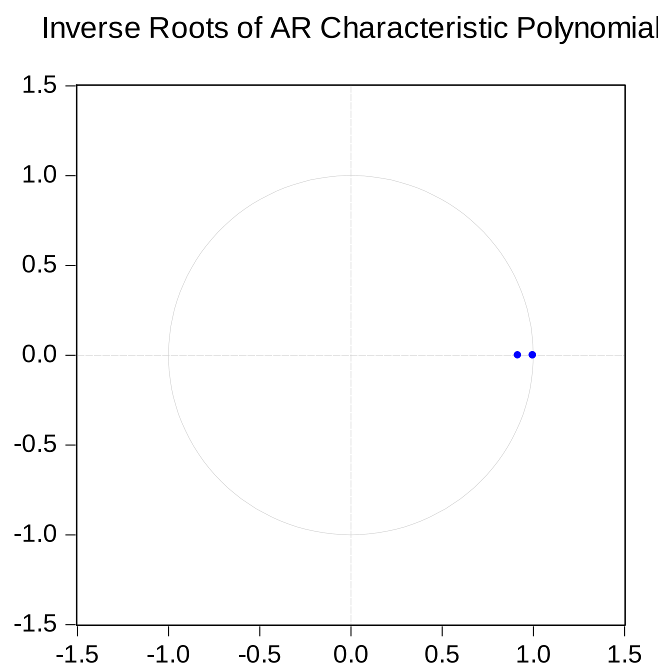
AGRICULTURE



RESIDENTIAL



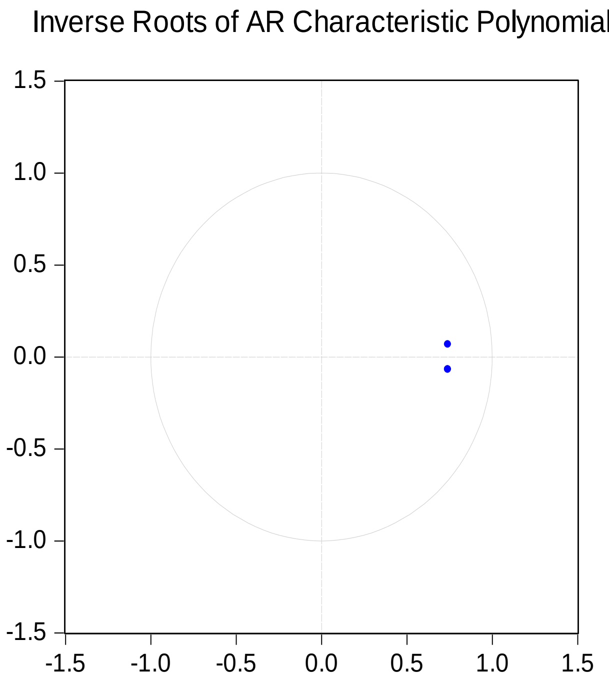
INDUSTRY



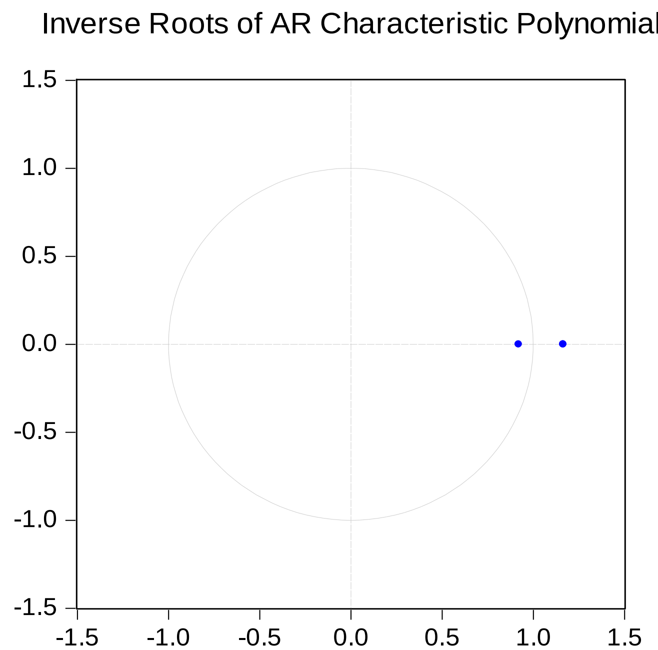
SERVICE

INDONESIA

Figure 111: Results of stability test for Indonesia



AGRICULTURE



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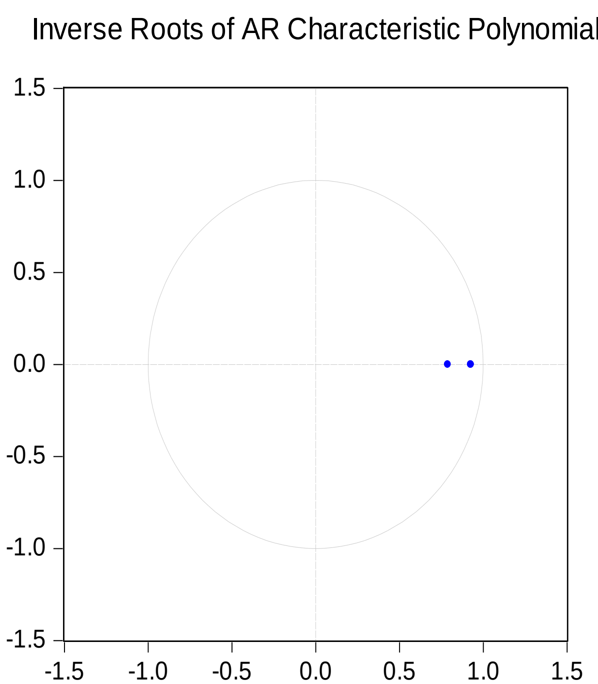
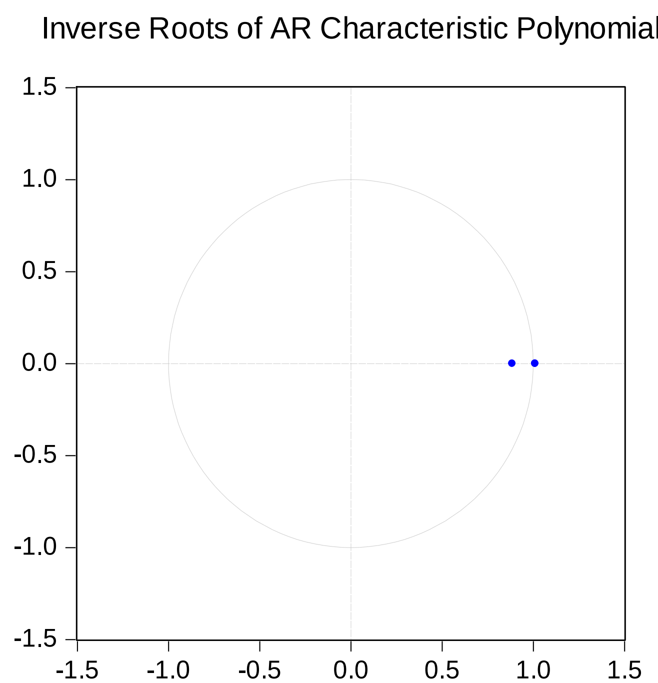


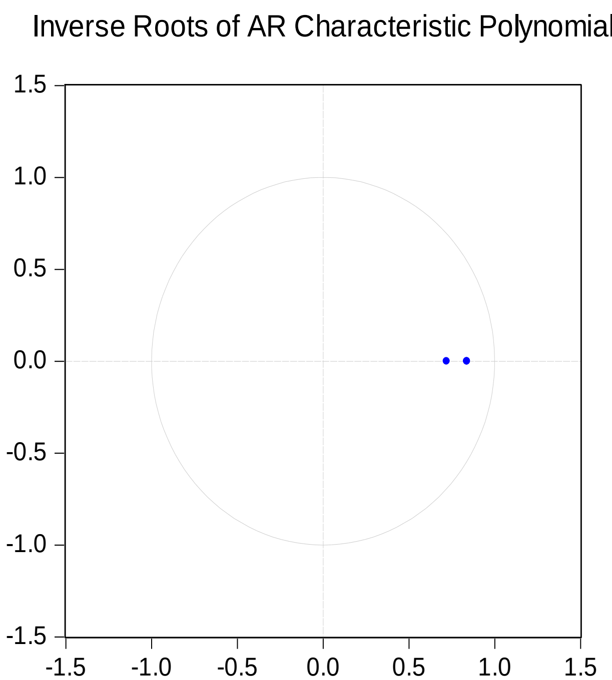
INDUSTRY



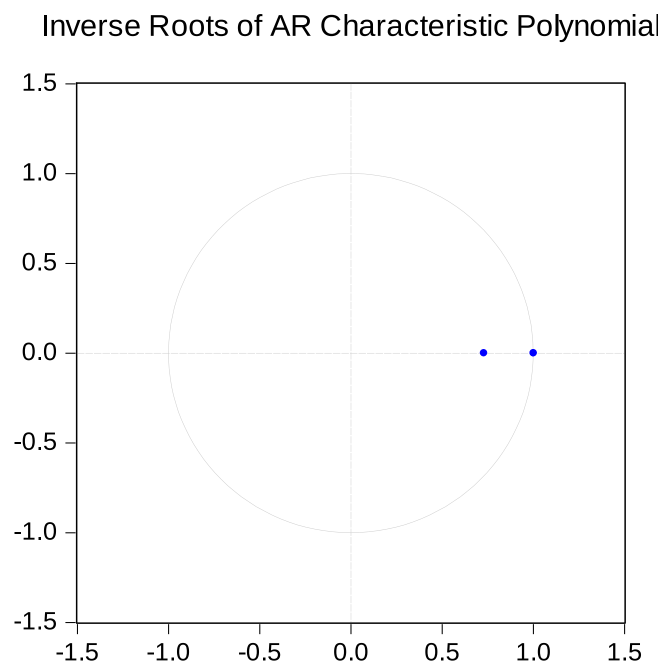
SERVICE

MALAYSIA

Figure 112: Results of stability test for Malaysia



AGRICULTURE



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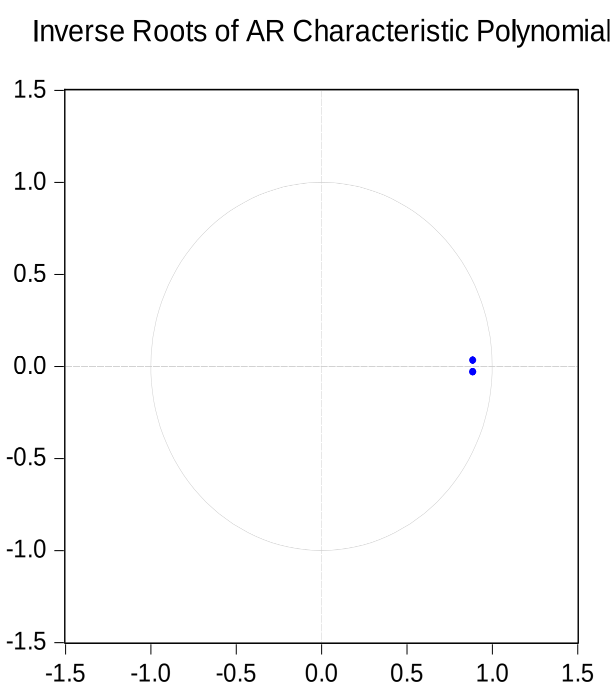
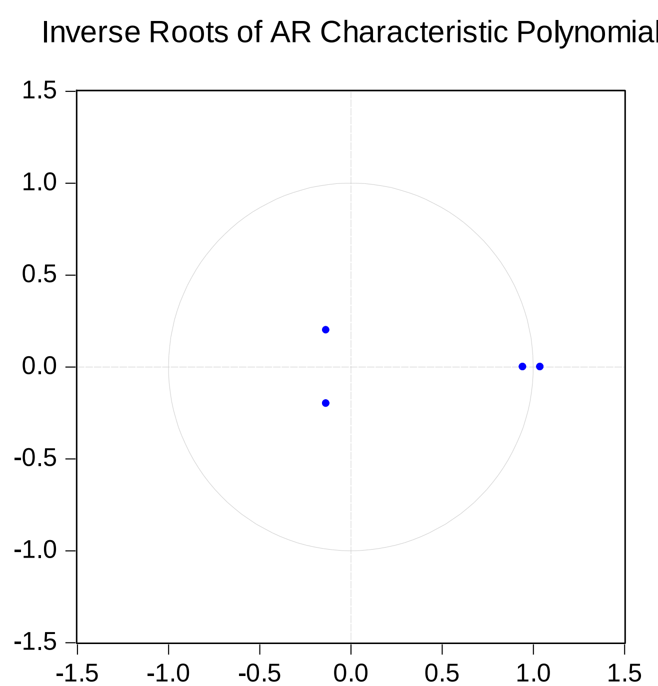


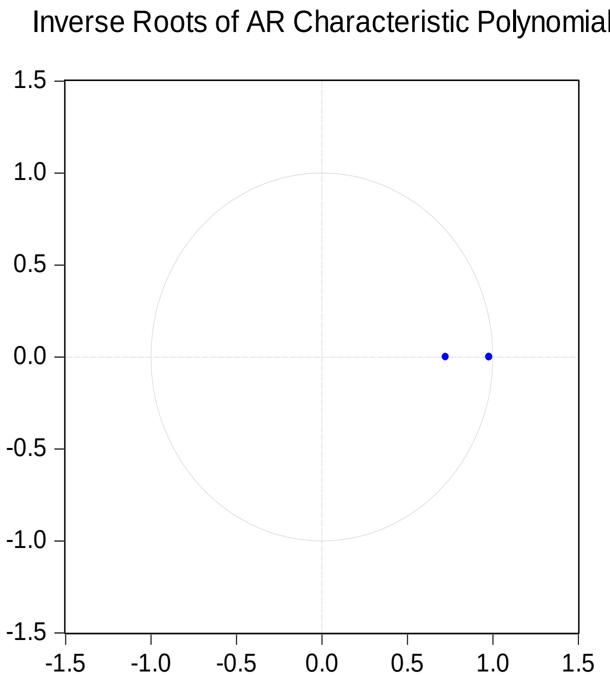
INDUSTRY



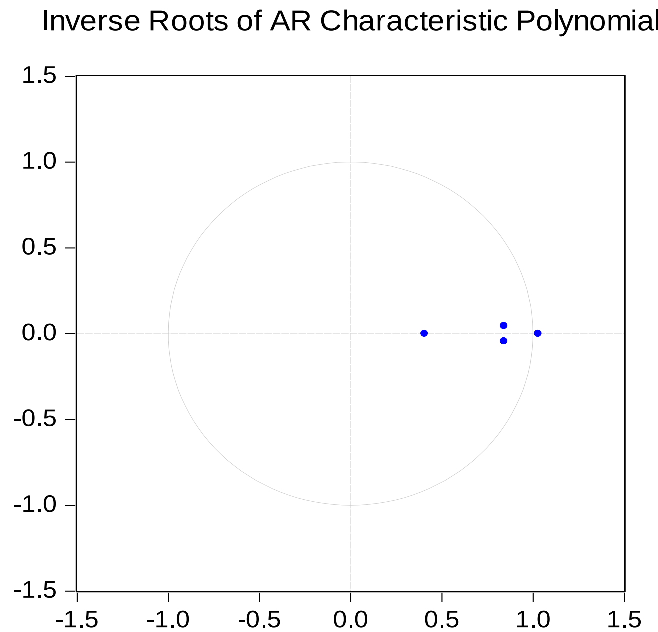
SERVICE

PHILIPPINES

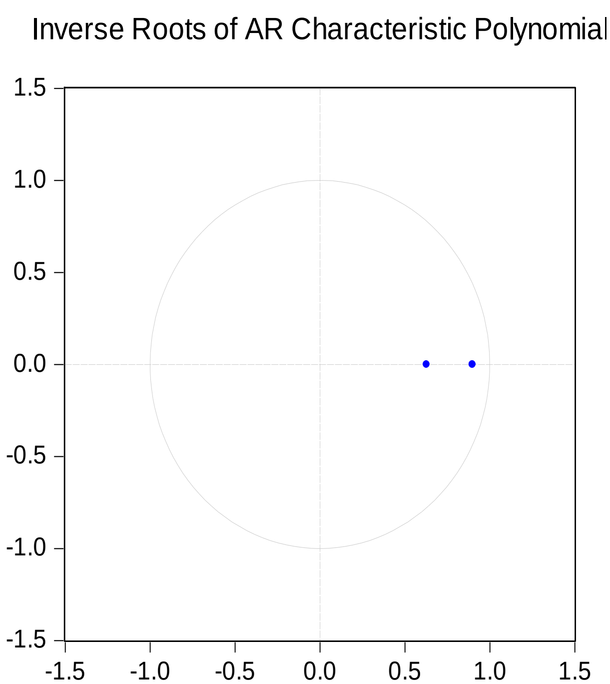
Figure 113: Results of stability test for Philippines



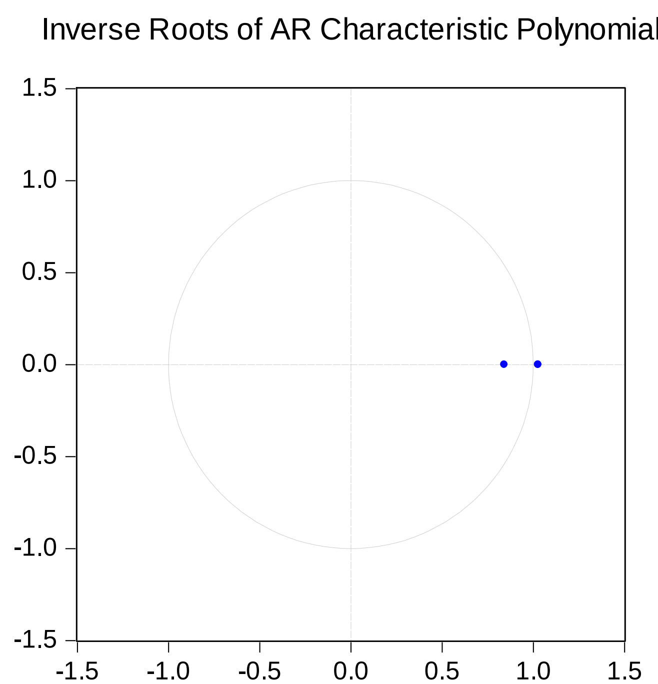
AGRICULTURE



RESIDENTIAL



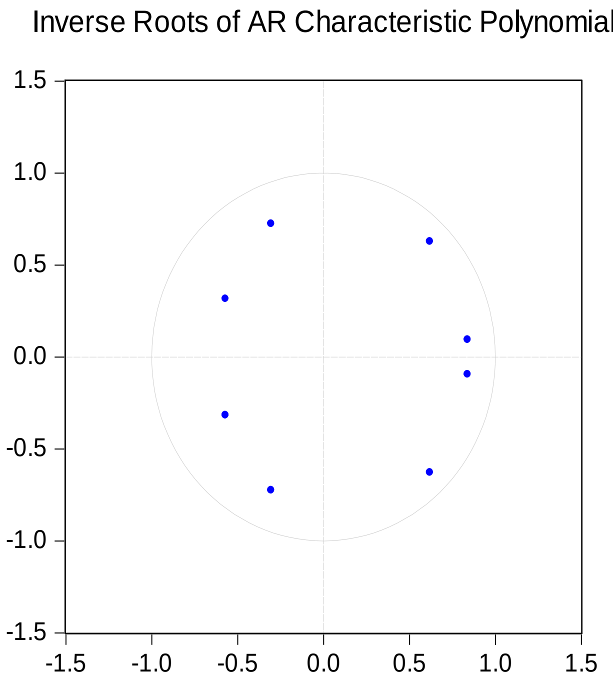
INDUSTRY



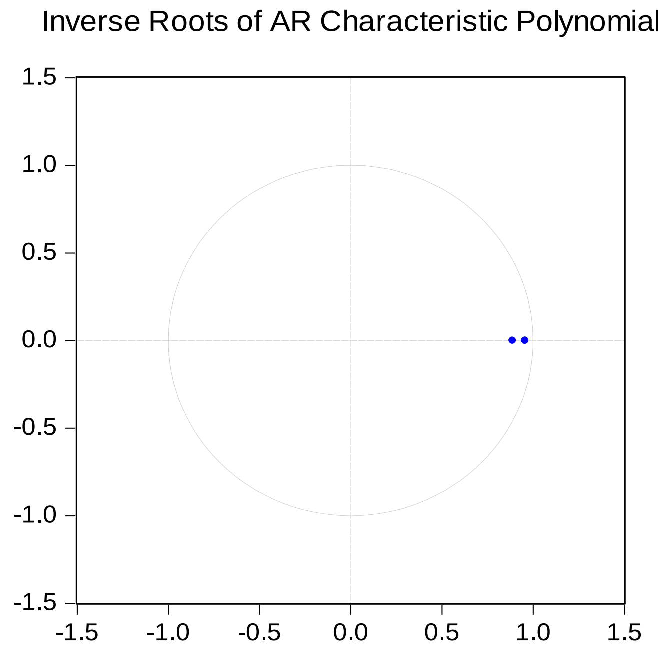
SERVICE

THAILAND

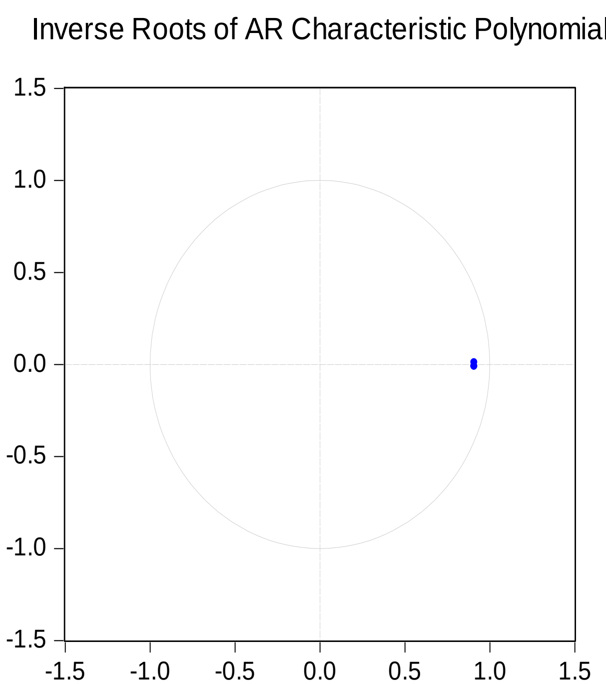
Figure 114: Results of stability test for Thailand



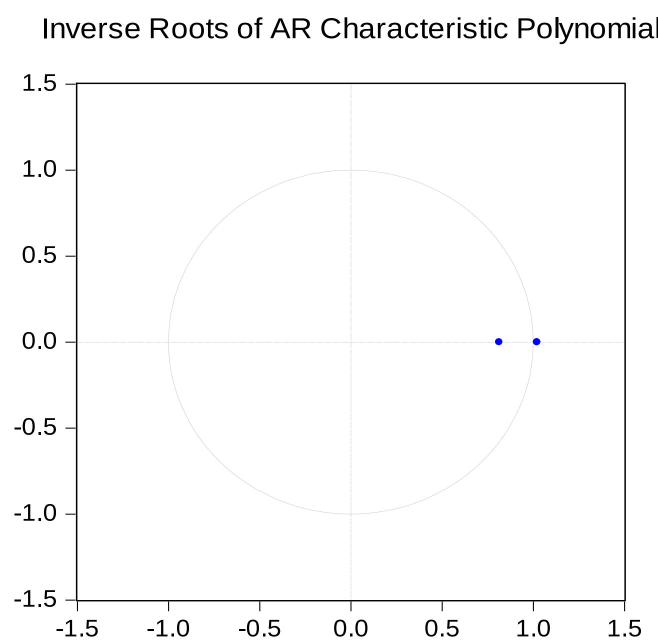
AGRICULTURE



RESIDENTIAL



INDUSTRY



SERVICE

The stability tests as indicated in figure 109, 110, 111, 112, 113 and 114 suggests that the model is stable since the roots lie within the circle.

CHAPTER 5

RENEWABLE ENERGY CONSUMPTION, CARBON EMISSIONS AND ECONOMIC GROWTH

The consumption of conventional energy to fuel economic activities does not lead to the long term sustainability of an economy. This is mainly due to the fact that conventional energy is exhaustible and not replenishable. Therefore, an economy highly dependent on non-renewable energy will jeopardize the future growth and development of the country. In addition, the consumption of unclean energy has detrimental effect on the environment. Over the years, countries have overused conventional energy leading to major global issues such as climate change, environmental pollution, loss of flora and fauna, decreasing life expectancy due to health problems etc.

It is evident that the solution to these major global issue lies in countries making efforts towards finding possibilities of employing renewable energy and replacing the need to consume conventional energy. This chapter focuses on the relationship between renewable energy consumption and economic growth while also considering how carbon emissions relate to renewable energy consumption and economic growth for China, India, Indonesia, Malaysia, Philippines and Thailand. Renewable energy consumption refers to the input equivalent i.e. the amount of fuel that would be required by thermal power stations to generate the reported electricity output measured in exajoules. Carbon emissions reflect those emitted through consumption of oil, gas and coal for combustion related activities and economic growth refers to the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products.

Stationarity tests such as ADF test PP test and KPSS test are applied to understand whether variables have a unit root. ARDL bound test and Johansen's cointegration test is applied to understand cointegrating relationship among variables, Regression is employed to identify the impact and Toda Yamamoto causality test is applied to identify causal relationship between variables.

5.1 UNIT ROOT TESTS

Unit root tests are employed to identify the stationarity properties of variables i.e. whether a variable is stationary at levels or first difference on the basis of which further analysis can be conducted to achieve objectives.

Table 21: Results of stationarity tests for Objective 4

Country	Variable	ADF unit root		PP unit root		KPSS unit root	
		Level	1st difference	Level	1st difference	Level	1st Difference
China	Renewable Energy Consumption	-4.705519** (0.0058)	-6.230249 (0.0001)	2.596975 (0.2841)	-6.129976** (0.0001)	0.065973** (0.146000)	0.081687 (0.146000)
	GDP	-2.255074 (0.1927)	-2.483165 (0.3331)	-2.506707** (0.1000)	-2.718367 (0.2372)	0.120676** (0.146000)	0.092890 (0.146000)
	CO_2 emissions	-2.606337 (0.2804)	-1.923945 (0.6155)	-1.222684 (0.8867)	-1.923945 (0.6155)	0.100975** (0.146000)	0.117457 (0.146000)
India	Renewable Energy Consumption	-3.764488** (0.0336)	-8.584368 (0.0000)	-4.167562** (0.0138)	-8.584368 (0.0000)	0.167987 (0.146000)	0.103834 ** (0.146000)
	GDP	-3.850407** (0.0279)	-5.001912 (0.0021)	-3.814302** (0.0302)	-8.389134 (0.0000)	0.185301 (0.146000)	0.166016** (0.146000)
	CO_2 emissions	-2.232591 (0.4539)	-2.041508 (0.5534)	-1.693030 (0.7285)	-4.980387** (0.0022)	0.121998** (0.146000)	0.113502 (0.146000)
Indonesia	Renewable Energy Consumption	-1.602500 (0.7671)	-5.347511** (0.0009)	-1.704549 (0.7233)	-5.349198** (0.0009)	0.115692** (0.146000)	0.121228 (0.146000)
	GDP	-1.745035 (0.7027)	-2.794271* (0.0729)	-1.648042 (0.7481)	-3.743872** (0.0357)	0.131161** (0.146000)	0.080721 (0.146000)
	CO_2 emissions	-2.228761 (0.4570)	-4.464227** (0.0086)	-2.077538 (0.5361)	-5.622957** (0.0005)	0.185827 (0.146000)	0.281052** (0.463000)
Malaysia	Renewable Energy Consumption	-2.988730 (0.1603)	-3.424810* (0.0884)	-2.988730 (0.1603)	-4.218083** (0.0192)	0.108759** (0.146000)	0.144759 (0.146000)
	GDP	-3.310049* (0.0946)	-5.281369 (0.0027)	-3.310049* (0.0946)	-6.433088 (0.0003)	0.078014** (0.146000)	0.126938 (0.146000)
	CO_2 emissions	-0.969654 (0.9248)	-6.215274** (0.0005)	-0.686101 (0.9593)	-6.221278** (0.0005)	0.169837 (0.146000)	0.064091** (0.146000)
Philippines	Renewable Energy Consumption	-48.75989** (0.0000)	-4.619029 (0.0033)	-30.33534** (0.0000)	-4.555342 (0.0039)	0.157940 (0.146000)	0.154796 (0.146000)
	GDP	-1.105718 (0.9144)	-6.299273** (0.0000)	-0.424764 (0.9833)	-3.659205** (0.0369)	0.208377 (0.146000)	0.058421** (0.146000)
	CO_2	-1.675827	-4.863930**	-1.970211	-4.875987**	0.066246**	0.091612

	emissions	(0.7444)	**(0.0017)**	(0.6002)	**(0.0016)**	**(0.146000)**	(0.146000)
Thailand	Renewable Energy Consumption	-2.412512 (0.3647)	**-7.617356**** **(0.0000)**	-2.668635 (0.2552)	**-7.129751**** **(0.0000)**	0.147284 (0.146000)	**0.140565**** **(0.146000)**
	GDP	-3.336691 (0.0791)	**-3.572551**** **(0.0490)**	**-3.865543**** **(0.0257)**	-3.515032 (0.0552)	**0.124595**** **(0.146000)**	0.121094 (0.146000)
	CO2 emissions	**-3.266062**** **(0.0902)**	-2.395126 (0.3736)	-3.139159 (0.1148)	**-3.831123**** **(0.0281)**	0.176340 (0.146000)	**0.120852**** **(0.146000)**

*10% significance level
**5% significance level

The above table 21 indicates statonarity properties of all variables under study. ADF, PP and KPSS unit root test indicate that certain variables exhibit mixed order of integration while most variables indicate stationarity at first difference.

5.2 LAG SELECTION CRITERIA

Lag selection criteria aids in identifying the number of lags to be considered when applying econometric techniques when analysing data. Table 22 displays the results of lag selection criteria according to AIC, SC and HQ criteria for three pairs of variables viz. renewable energy consumption and GDP, Renewable energy consumption and carbon emissions and carbon emissions and GDP for each of the Newly Industrialised Countries. The least lags is considered to be desirable.

Table 22: Results of Lag selection criteria for objective 4

CHINA						
REC & GDP						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	-27.95148	NA	0.041598	2.495956	2.594128	2.522001
1	78.79044	186.7984	7.98e-06	-6.065870	-5.771357	-5.987736
2	97.01378	28.85362	2.46e-06	-7.251149	-6.760293	-7.120924
3	106.8974	14.00173*	1.54e-06	-7.741446	-7.054248	-7.559132
4	113.4781	8.225872	1.30e-06*	***-7.95650****	***-7.07296****	***-7.72210****
5	114.5750	1.188320	1.77e-06	-7.714580	-6.634698	-7.428087
6	116.2316	1.518553	2.41e-06	-7.519297	-6.243072	-7.180714
REC & CO2 emissions						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	-38.22343	NA	0.097910	3.351953	3.450124	3.377997
1	49.39279	153.3284	9.24e-05	-3.616066	-3.321552	-3.537931
2	73.15540	37.62414*	1.80e-05	-5.262950	***-4.77209****	***-5.13273****
3	74.86488	2.421756	2.23e-05	-5.072073	-4.384875	-4.889759

4	81.93477	8.837371	1.80e-05*	-5.327898	-4.444357	-5.093494
5	82.81408	0.952582	2.50e-05	-5.067840	-3.987957	-4.781347
6	90.92443	7.434488	1.99e-05	-5.41037*	-4.134144	-5.071786
CO2 emissions & GDP						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	-3.011364	NA	0.005205	0.417614	0.515785	0.443659
1	122.1283	218.9944	2.15e-07	-9.677356	-9.382842	-9.599221
2	136.1817	22.25125*	9.41e-08*	***-10.5151****	***-10.0243****	***-10.3849****
3	139.4231	4.591935	1.03e-07	-10.45192	-9.764723	-10.26961
4	143.6902	5.333974	1.05e-07	-10.47419	-9.590646	-10.23978
5	146.4486	2.988247	1.24e-07	-10.37072	-9.290835	-10.08422
6	147.5582	1.017128	1.77e-07	-10.12985	-8.853626	-9.791268
INDIA						
REC & GDP						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	-5.067889	NA	0.006179	0.588991	0.687162	0.615036
1	89.70456	165.8518*	3.21e-06*	***-6.97538****	***-6.68087****	***-6.89725****
2	91.05498	2.138179	4.05e-06	-6.754582	-6.263726	-6.624358
3	93.24157	3.097664	4.81e-06	-6.603464	-5.916266	-6.421150
4	94.45437	1.516001	6.33e-06	-6.371198	-5.487657	-6.136794
5	98.66869	4.565509	6.67e-06	-6.389057	-5.309175	-6.102564
6	103.0237	3.992116	7.25e-06	-6.418644	-5.142419	-6.080061
REC & CO2 emissions						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	-11.64299	NA	0.010212	1.091439	1.188949	1.118484
1	76.09466	154.4182*	1.26e-05*	***-5.60757****	***-5.31504****	***-5.52644****
2	78.35098	3.610113	1.46e-05	-5.468078	-4.980528	-5.332852
3	80.35828	2.890511	1.75e-05	-5.308662	-4.626092	-5.119346
4	82.83651	3.172144	2.05e-05	-5.186921	-4.309330	-4.943515
5	85.84757	3.372389	2.36e-05	-5.107806	-4.035195	-4.810309
6	88.95725	2.985286	2.79e-05	-5.036580	-3.768949	-4.684993
CO2 emissions & GDP						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	35.72824	NA	0.000231	-2.698259	-2.600749	-2.671214
1	114.3034	138.2923*	5.93e-07*	***-8.66427****	***-8.37174****	***-8.58314****
2	118.0821	6.045912	6.09e-07	-8.646570	-8.159019	-8.511344
3	121.3604	4.720741	6.58e-07	-8.588833	-7.906263	-8.399517
4	122.0181	0.841824	8.92e-07	-8.321447	-7.443856	-8.078041
5	122.5913	0.641977	1.25e-06	-8.047302	-6.974692	-7.749806
6	127.4300	4.645193	1.28e-06	-8.114402	-6.846771	-7.762815
INDONESIA						
REC & GDP						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	-8.844165	NA	0.008163	0.867533	0.965043	0.894578
1	63.34073	127.0454	3.50e-05	-4.587259	***-4.29473****	-4.506123
2	66.86641	5.641091	3.66e-05	-4.549313	-4.061763	-4.414087

3	69.50089	3.793647	4.17e-05	-4.440071	-3.757501	-4.250755
4	74.22578	6.047856	4.08e-05	-4.498062	-3.620472	-4.254656
5	87.62086	15.00249*	2.05e-05*	-5.24967*	-4.177058	-4.95217*
6	88.11425	0.473657	2.98e-05	-4.969140	-3.701509	-4.617553
REC & CO2 emissions						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	-5.771713	NA	0.006384	0.621737	0.719247	0.648782
1	53.56468	104.4321	7.65e-05	-3.805175	***-3.51264****	-3.724039
2	57.12562	5.697495	7.99e-05	-3.770049	-3.282499	-3.634824
3	58.27203	1.650833	0.000102	-3.541762	-2.859192	-3.352446
4	62.16120	4.978139	0.000107	-3.532896	-2.655305	-3.289490
5	67.94110	6.473489	9.88e-05	-3.675288	-2.602677	-3.377791
6	84.60067	15.99319*	3.95e-05*	-4.68805*	-3.420423	-4.33647*
CO2 emissions & GDP						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	13.66947	NA	0.001348	-0.933558	-0.836047	-0.906512
1	85.73658	126.8381*	5.83e-06*	***-6.37893****	***-6.08640****	***-6.29779****
2	87.99709	3.616811	6.76e-06	-6.239767	-5.752217	-6.104542
3	88.76350	1.103627	8.93e-06	-5.981080	-5.298509	-5.791764
4	90.20433	1.844264	1.14e-05	-5.776346	-4.898756	-5.532940
5	90.96021	0.846582	1.57e-05	-5.516817	-4.444206	-5.219320
6	95.86059	4.704367	1.61e-05	-5.588847	-4.321216	-5.237260
MALAYSIA						
REC & GDP						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	11.25841	NA	0.000998	-1.234455	-1.140048	-1.235461
1	45.67575	55.06773	1.75e-05	-5.290099	-5.006879	-5.293116
2	46.46087	1.046839	2.80e-05	-4.861450	-4.389416	-4.866478
3	57.71654	12.00605*	1.18e-05	-5.828872	-5.168025	-5.835912
4	64.31029	5.274995	1.04e-05*	-6.174705	-5.325044	-6.183755
5	70.23370	3.159156	1.24e-05	-6.431160	-5.392687	-6.442222
6	77.34507	1.896364	2.23e-05	***-6.84601****	***-5.61872****	***-6.85908****
REC & CO2 emissions						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	14.33671	NA	0.000662	-1.644895	-1.550488	-1.645900
1	42.85530	45.62974*	2.54e-05	-4.914040	-4.630820	-4.917057
2	44.35153	1.994978	3.71e-05	-4.580204	-4.108171	-4.585233
3	53.02600	9.252764	2.20e-05	-5.203467	-4.542620	-5.210506
4	57.17523	3.319384	2.68e-05	-5.223364	-4.373704	-5.232415
5	62.81295	3.006784	3.34e-05	-5.441727	-4.403253	-5.452789
6	78.92961	4.297777	1.81e-05*	***-7.05728****	***-5.83000****	***-7.07036****
CO2 emissions & GDP						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	34.02979	NA	4.79e-05	-4.270639	-4.176232	-4.271645
1	65.92504	51.03239	1.17e-06	-7.990005	-7.706785	-7.993022

2	69.39164	4.622144	1.31e-06	-7.918886	-7.446853	-7.923914
3	72.08382	2.871655	1.74e-06	-7.744510	-7.083663	-7.751549
4	77.37410	4.232219	1.81e-06	-7.916546	-7.066886	-7.925597
5	87.02358	5.146393	1.32e-06	-8.669811	-7.631337	-8.680873
6	136.5305	13.20186*	8.34e-09*	***-14.7374****	***-13.5101****	***-14.7505****
PHILIPPINES						
REC & GDP						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	-2.632516	NA	0.004375	0.243817	0.330005	0.274482
1	116.3461	219.1712	1.03e-05	-5.807691	***-5.54913****	-5.715695
2	123.3563	12.17549	8.82e-06	-5.966119	-5.535175	-5.812792
3	129.7764	10.47502*	7.81e-06*	-6.09350*	-5.490175	-5.87884*
4	130.0310	0.388531	9.60e-06	-5.896368	-5.120669	-5.620380
5	132.9514	4.150043	1.03e-05	-5.839547	-4.891471	-5.502229
6	138.2651	6.991768	9.86e-06	-5.908691	-4.788238	-5.510042
REC & CO2 emissions						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	0.815826	NA	0.003649	0.062325	0.148514	0.092990
1	104.4670	190.9364	1.93e-05	-5.182473	***-4.92391****	-5.090477
2	109.8119	9.283241	1.80e-05	-5.253257	-4.822313	-5.09993*
3	112.9273	5.083044	1.89e-05	-5.206700	-4.603379	-4.992043
4	115.6081	4.091696	2.05e-05	-5.137267	-4.361568	-4.861279
5	121.7027	8.660761	1.87e-05	-5.247509	-4.299433	-4.910191
6	129.1685	9.823411*	1.59e-05*	-5.42992*	-4.309466	-5.031271
CO2 emissions & GDP						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	-3.998469	NA	0.004701	0.315709	0.401898	0.346374
1	132.6787	251.7738*	4.36e-06*	***-6.66730****	***-6.40874****	***-6.57531****
2	135.4089	4.741923	4.68e-06	-6.600469	-6.169525	-6.447143
3	139.1584	6.117640	4.76e-06	-6.587286	-5.983965	-6.372629
4	141.4395	3.481620	5.27e-06	-6.496816	-5.721117	-6.220828
5	144.7621	4.721600	5.54e-06	-6.461163	-5.513087	-6.123845
6	149.4551	6.174965	5.47e-06	-6.497636	-5.377182	-6.098987
THAILAND						
REC & GDP						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	-27.32741	NA	0.027851	2.094815	2.189972	2.123905
1	46.90765	132.5626	0.000185	-2.921975	***-2.63653****	-2.834703
2	50.51493	5.926242	0.000191	-2.893924	-2.418136	-2.748471
3	52.25797	2.614565	0.000228	-2.732712	-2.066610	-2.529078
4	61.45403	12.48036*	0.000161	-3.103859	-2.247442	-2.842044
5	66.05015	5.581001	0.000161	-3.146439	-2.099707	-2.826443
6	71.89005	6.257037	0.000151*	-3.27786*	-2.040814	-2.89968*
REC & CO2 emissions						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	-10.25685	NA	0.008228	0.875489	0.970647	0.904580

1	53.12372	113.1796	0.000119	-3.365980	-3.080507	-3.278708
2	57.59454	7.344927	0.000115	-3.399610	-2.923823	-3.254157
3	62.18123	6.880035	0.000112	-3.441517	-2.775414	-3.237882
4	76.04314	18.81259	5.69e-05	-4.145939	-3.289521	-3.884123
5	90.94855	18.09942*	2.72e-05	-4.924896	-3.878164	-4.604900
6	99.64937	9.322310	2.08e-05*	***-5.26067****	***-4.02362****	***-4.88249****
CO2 emissions & GDP						
Lag	LogL	LR	FPE	**AIC**	**SC**	**HQ**
0	39.77468	NA	0.000231	-2.698191	-2.603034	-2.669101
1	120.0423	143.3351*	9.96e-07*	***-8.14588****	***-7.86041****	***-8.05861****
2	122.4502	3.955791	1.12e-06	-8.032158	-7.556371	-7.886705
3	125.6726	4.833579	1.20e-06	-7.976614	-7.310512	-7.772980
4	125.8365	0.222445	1.62e-06	-7.702608	-6.846191	-7.440793
5	131.5189	6.900069	1.50e-06	-7.822780	-6.776048	-7.502783
6	132.1461	0.671960	2.04e-06	-7.581863	-6.344816	-7.203685

*Lag selection

For China lag 4 is selected for renewable energy consumption and GDP and lag 2 is selected for renewable energy consumption and carbon emissions as well as carbon emissions and GDP. In case of India, Indonesia and Philippines, lag 1 is selected for all three pairs of variables. For Malaysia, lag 6 is selected and for Thailand lag 1 is selected for renewable energy consumption and GDP as well as for carbon emissions and GDP while for renewable energy consumption and carbon emissions lag 6 is selected.

5.3 China

5.3.1 ARDL Bound testing approach to cointegration

Table 23: Results of ARDL bound test for China

Critical value bounds					
90% level		***95% level***		**99% level**	
2.496	3.346	2.962	3.910	4.068	5.250

Variable	F -value	Result
REC & GDP	8.039088	**Reject H0**
REC & CO2 emissions	10.91670	**Reject H0**

5.3.2 Linear regression

Table 24: Results of regression analysis for China

Dependent Variable: CO2 EMISSIONS
Independent Variable: GDP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP	**0.619218**	0.022950	26.98128	**0.0000**
C	-9.317416	0.663488	-14.04309	0.0000
R-squared	**0.961690**			
Adjusted R-squared	0.960369			

In case of China a cointegrating relationship exists between renewable energy consumption and GDP as well as between renewable energy consumption and CO2 emissions since the F value which is 8.039088 and 10.91670 resp. lies above the upper critical value of 3.910 at 5% level of significance as indicated in table 23. Regression was applied to find out if GDP has an impact on CO2 emissions of China. Table 24 indicates that GDP has a significant impact on CO2 emissions where a percent change in GDP in lead to 0.62% increase in CO2 emissions. This indicates that the country is relying on conventional energy to fuel its economic activities. R square is 96% which implies that 96% of variation in carbon emissions can be explained by the independent variable i.e. GDP. Therefore we reject H_{14a}, H_{14b} and H_{14c}.

5.4 India

5.4.1 ARDL Bound testing approach to cointegration

Table 25: Results of ARDL bound test for India

Critical value bounds					
90% level		***95% level***		**99% level**	
2.496	3.346	2.962	3.910	4.068	5.250

Variable	F -value	Result
REC & CO2 emissions	11.84479	**Reject H0**
CO2 emissions and GDP	1.956863	**Accept H0**

5.4.2 Linear regression

Table 26: Results of Regression analysis for India

Dependent Variable: GDP

Independent Variable: REC

Variable	Coefficient	Std. Error	t-Statistic	Prob.
REC	**0.259098**	0.011293	22.94341	**0.0000**
C	28.47132	0.037578	757.6644	0.0000
R-squared	**0.949495**			
Adjusted R-squared	0.947691			

Table 25 indicates the results ARDL bound testing approach to cointegration for India. ARDL bound testing approach indicates that there exists a cointegrating relationship between Renewable energy consumption and Carbon emissions as the F-value (12.30624) is higher than the upper critical value of 3.910 while in case of carbon emissions and GDP there is no cointegrating relationship. Since GDP and renewable energy consumption are stationery at levels, simple linear regression is applied to understand if renewable energy consumption has an impact on GDP. Table 26 displays results which indicate that Renewable energy has an impact on GDP of India. A percent change in renewable energy consumption leads to 0.25% increase in GDP of the country. R square indicates that 95% of variation in the GDP can be explained by renewable energy consumption. We reject H_{15a} and H_{15c}. Therefore, the country should focus on non-conventional sources of energy which will promote sustainable growth and development.

5.5 Indonesia

5.5.1 Johansen's Cointegration test

Table 27: Results of Johansen's cointegration test for Indonesia

Variables	Hypothesised no. of cointegrating equations	**Eigen value**	**Trace statistic**	**Critical value @ 5% (p value)**	**Max Eigen statistic**	**Critical value @ 5% (p value)**
REC & GDP	None	0.167356	5.473364	15.49471 (0.7567)	5.311315	14.26460 (0.7021)
	At most 1	0.005572	0.162048	3.841466 (0.6873)	0.162048	3.841466 (0.6873)
REC & CO2 emissions	None	0.212871	7.597183	15.49471 (0.5094)	6.941516	14.26460 (0.4961)
	At most 1	0.022356	0.655666	3.841466 (0.4181)	0.655666	3.841466 (0.4181)
CO2 emissions & GDP	None	0.161820	5.289224	15.49471 (0.7774)	4.942624	14.26460 (0.7491)
	At most 1	0.012302	0.346599	3.841466 (0.5560)	0.346599	3.841466 (0.5560)

In case of Indonesia, all 3 pairs of variables do not have a cointegrating relationship according to Johansens Cointegration test as indicated in table 27. Therefore, we accept H_{16a}, H_{16b} and H_{16c}.

5.6 Malaysia

5.6.1 ARDL Bound testing approach to cointegration

Table 28: Results of ARDL bound test for Malaysia

Critical value bounds					
90% level		***95% level***		**99% level**	
2.496	3.346	2.962	3.910	4.068	5.250

Variable	F -value	Result
REC & GDP	1.820156	**Accept H0**
CO2 emissions and GDP	19.31400	**Reject H0**

5.6.2 Johansen Cointegration test

Table 29: Results of Johansen Cointegration test for Malaysia

Variables	Hypothesised no. of cointegrating equations	**Eigen value**	**Trace statistic**	**Critical value @ 5% (p value)**	**Max Eigen statistic**	**Critical value @ 5% (p value)**
REC & CO2 emissions	None	0.642304	24.96645	15.49471 (0.0014)	19.53334	14.26460 (0.0067)
	At most 1	0.248702	5.433107	3.841466 (0.0198)	5.433107	3.841466 (0.0198)

Carbon emissions and GDP have a long run cointegrating relationship since the F value i.e. 19.31400 resp. is above the upper limit of 3.910 at 5% level of significance as indicated in table 28. In table 29 which includes the results of Johansen's cointegration test, renewable energy consumption and carbon emissions are cointegrated in the long run. Therefore, we reject H_{17b} and H_{17c}.

5.7 Philippines

5.7.1 ARDL Bound testing approach to cointegration

Table 30: Results of ARDL Bound test for Philippines

Critical value bounds					
90% level		***95% level***		**99% level**	
2.496	3.346	2.962	3.910	4.068	5.250

Variable	F -value	Result
REC & GDP	1.032537	**Accept H0**
REC & CO2 emissions	33.14469	**Reject H0**

5.7.2 Johansen Cointegration test

Table 31: Results of Johansen Cointegration test for Philippines

Variables	Hypothesised no. of cointegrating equations	**Eigen value**	**Trace statistic**	**Critical value @ 5% (p value)**	**Max Eigen statistic**	**Critical value @ 5% (p value)**
CO2 emissions & GDP	None	0.062821	2.745590	15.49471 (0.9772)	2.725004	14.26460 (0.9634)
	At most 1	0.000490	0.020586	3.841466 (0.8858)	0.020586	3.841466 (0.8858)

Table 30 displays the results of ARDL Bound testing approach to cointegration for Philippines. There exists a long run cointegrating relationship between renewable energy consumption and carbon emissions as the f-value (33.14469) is higher than the upper critical value of 3.910 thus we reject H_{18b} however a cointegrating relationship does not exists between renewable energy consumption and GDP. Carbon emissions and GDP do not have a long run cointegrating relationship according to Johansens cointegration test as indicated in table 31.

5.8 Thailand

5.8.1 ARDL Bound testing approach to cointegration

Table 32: Results of ARDL bound test for Thailand

Critical value bounds					
90% level		***95% level***		**99% level**	
2.496	3.346	2.962	3.910	4.068	5.250

Variable	F -value	Result
REC & GDP	2.881305	**Accept H0**
CO2 emissions & GDP	6.535314	**Reject H0**

5.8.2 Johansen's Cointegration test

Table 33: Results of Johansen's Cointegration test for Thailand

Variables	Hypothesised no. of cointegrating equations	**Eigen value**	**Trace statistic**	**Critical value @ 5% (p value)**	**Max Eigen statistic**	**Critical value @ 5% (p value)**
REC & CO2 emissions	None	0.669749	33.95038	15.49471 (0.0000)	29.91337	14.26460 (0.0001)
	At most 1	0.138878	4.037008	3.841466 (0.0445)	4.037008	3.841466 (0.0445)

Cointegration test results included in table 32 indicates that there exists a cointegrating relationship between CO2 emissions and GDP since the f-value of 6.535314 is higher than the upper critical value of 3.910. Hypothesis H_{19b} is rejected. However, no cointegration exists between renewable energy consumption and GDP as results are inconclusive. Since Renewable energy consumption and CO2 emissions are stationery at first difference, Johansen's cointegration test is applied and results indicate that there exists a cointegrating relationship between the variables as per table 33.

5.9 TODA YAMAMOTO CAUSALITY TEST

Table 34: Results of Toda Yamamoto causality test renewable energy consumption, Carbon emissions and GDP

	China	India	Indonesia	Malaysia	Philippines	Thailand
REC causes GDP	0.2439	0.9433	0.7163	***0.0005****	0.9355	0.9036
GDP causes REC	***0.0001****	***0.0105****	0.5664	*0.6359*	0.9700	0.6371
REC causes CO2 emissions	0.2674	***0.0034****	0.8169	***0.0023****	0.7020	0.2179
CO2 emissions causes REC	0.4532	0.3762	***0.0895****	0.7126	0.2506	***0.0005****
CO2 emissions causes GDP	***0.0116****	***0.0068****	0.2678	***0.0026****	0.8553	0.2213
GDP causes CO2 emissions	0.7792	0.1795	0.9420	0.5397	0.5363	0.1536

*Indicates significance at 10%
**Indicates significance at 5%

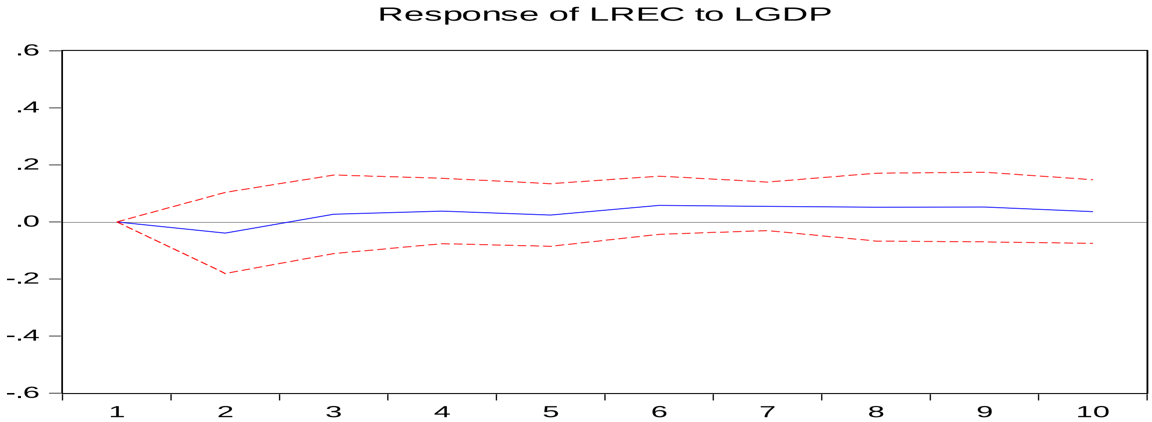
Table 34 displays the results of Toda Yamamoto causality test which indicates that economic growth leads to renewable energy consumption and carbon emissions causes GDP in case of China. Therefore, H_{20b} and H_{20e} is rejected. Similarly, in case of India. GDP causes renewable energy consumption and Renewable energy consumption causes CO2 emissions. Therefore, we reject H_{20h} and H_{20i}. In addition, renewable energy consumption causes CO2 emissions for Indonesia. For Malaysia and Thailand, carbon emissions encourages renewable energy consumption therefore we reject H_{20u} and H_{20ah}.

For Malaysia, Renewable energy consumption causes GDP and CO2 emissions and carbon emissions causes economic growth. Hypothesis H_{20s} and H_{20w} is rejected. No causality exists in case of Philippines.

5.10 IMPULSE RESPONSE FUNCTION

CHINA

Figure 115: Results of Impulse response function of renewable energy consumption and GDP for China



In case of the response of renewable energy consumption to economic growth of China, upto the second period renewable energy consumption indicates a negative effect after which renewable energy consumption responds positively and exhibits volatility to indicate that GDP has a negative impact on renewable energy consumption as indicated in figure 115.

Figure 116: Results of Impulse response function of GDP and renewable energy consumption for China

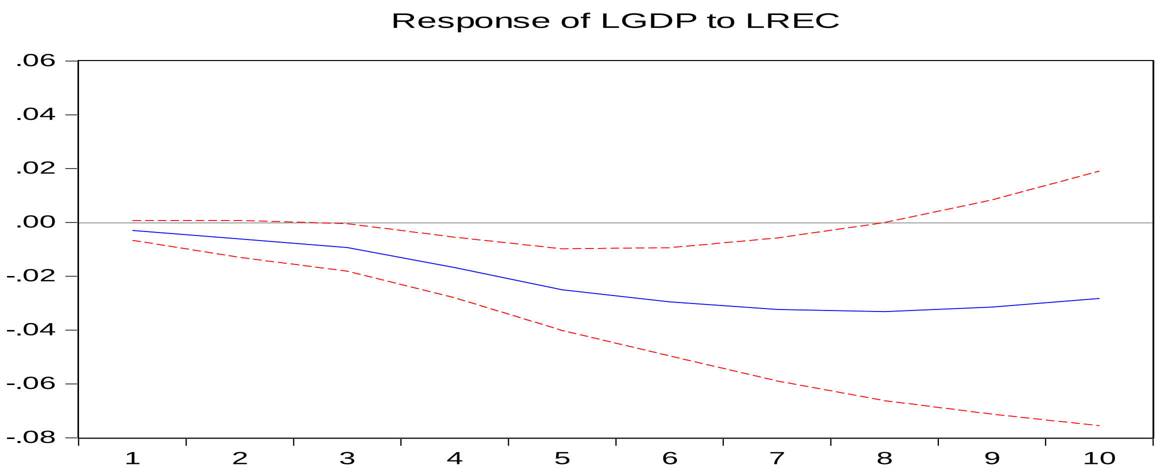
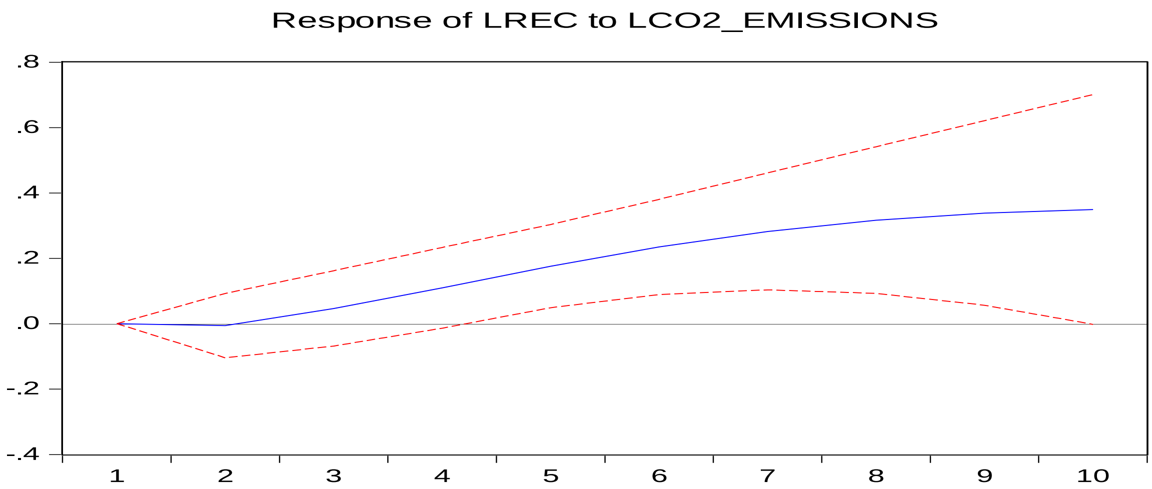


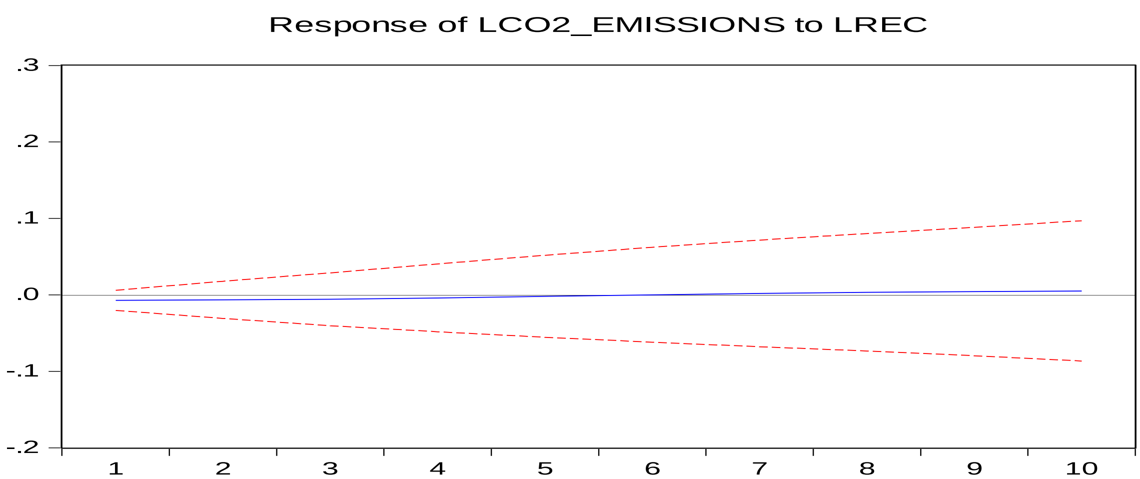
Figure 116 indicates that in the short run renewable energy consumption has negative impact on economic growth however in the long run renewable energy consumption has a positive impact on economic growth.

Figure 117: Results of Impulse response function of renewable energy consumption and carbon emissions for China



Carbon emissions has a positive impact on renewable energy consumption in the long run as per figure 117 where the blue line shows an upward trend.

Figure 118: Results of Impulse response function of carbon emissions and renewable energy consumption for China



The response of carbon emissions to renewable energy consumption is positive in the long run with a gradual increase in carbon emissions till the tenth period as indicates in figure 118.

Figure 119: Results of Impulse response function of carbon emissions and GDP for China

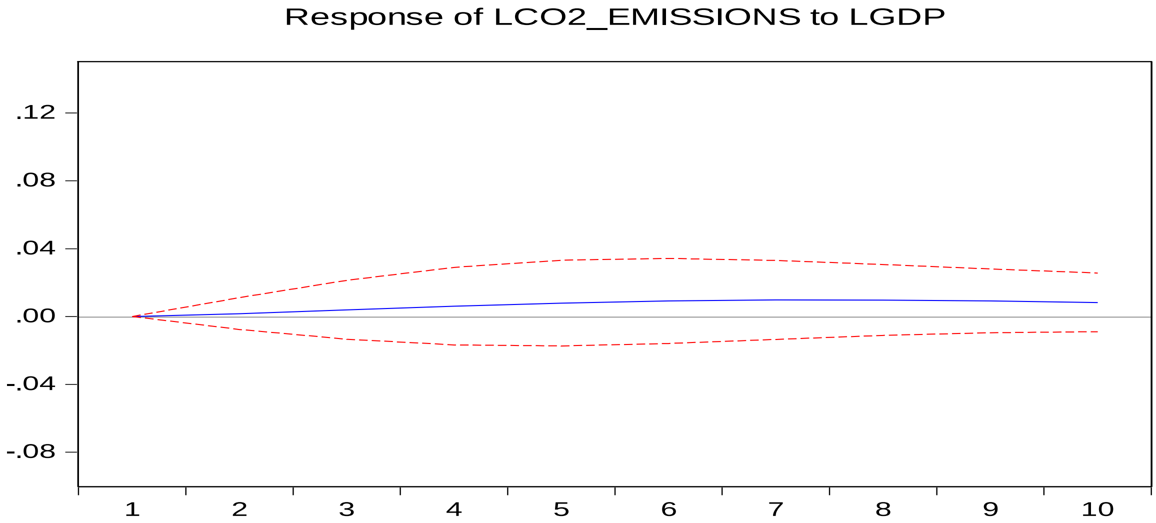
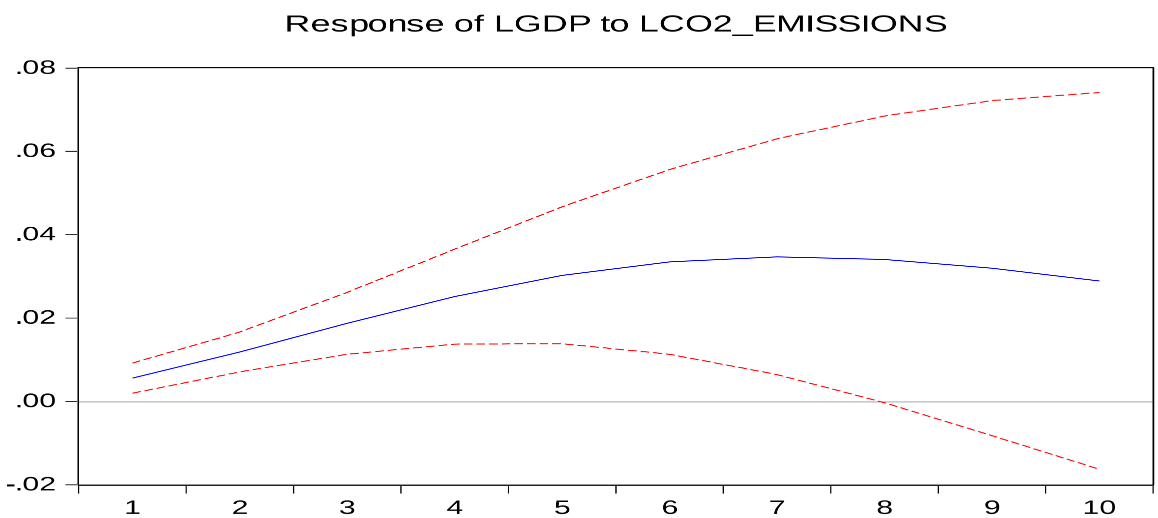


Figure 119 indicates that economic growth of China has a positive impact on carbon emissions upto the eighth period after which a mild decline is observed.

Figure 120: Results of Impulse response function of GDP to carbon emissions for China



Economic growth responds positively to carbon emissions in the short run upto the sixth period followed by a negative response in the long run as indicated in figure 120.

INDIA

Figure 121: Results of Impulse response function of renewable energy consumption to GDP for India

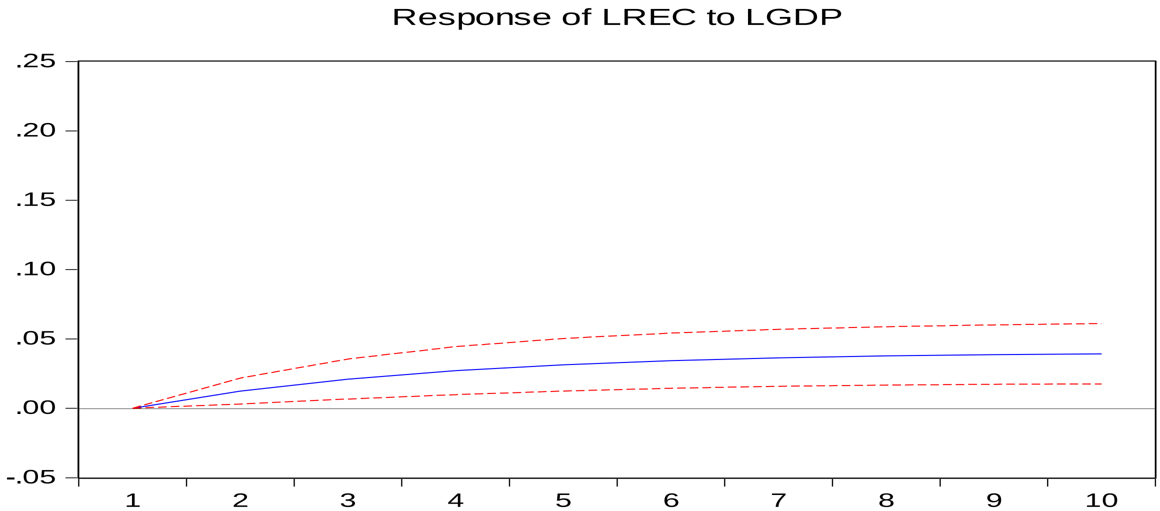
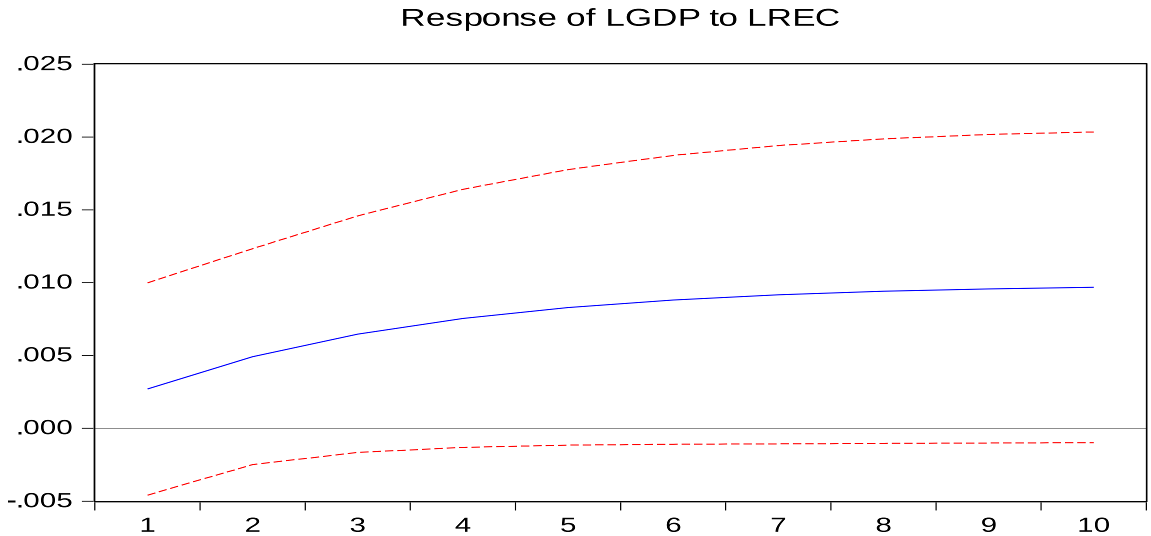


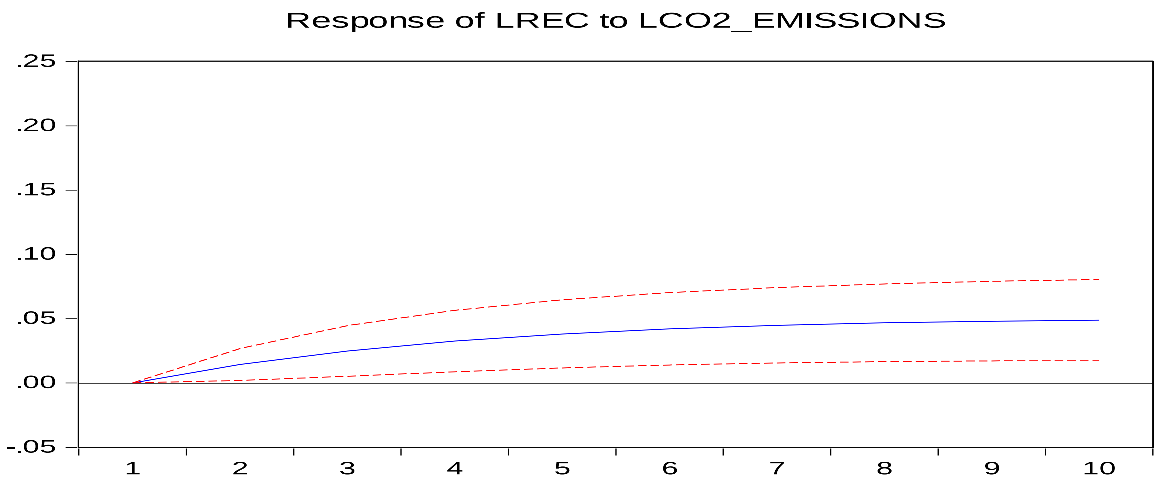
Figure 121 indicates that the response of renewable energy consumption to economic growth of India is positive in the long run.

Figure 122: Results of Impulse response function of GDP to renewable energy consumption for India



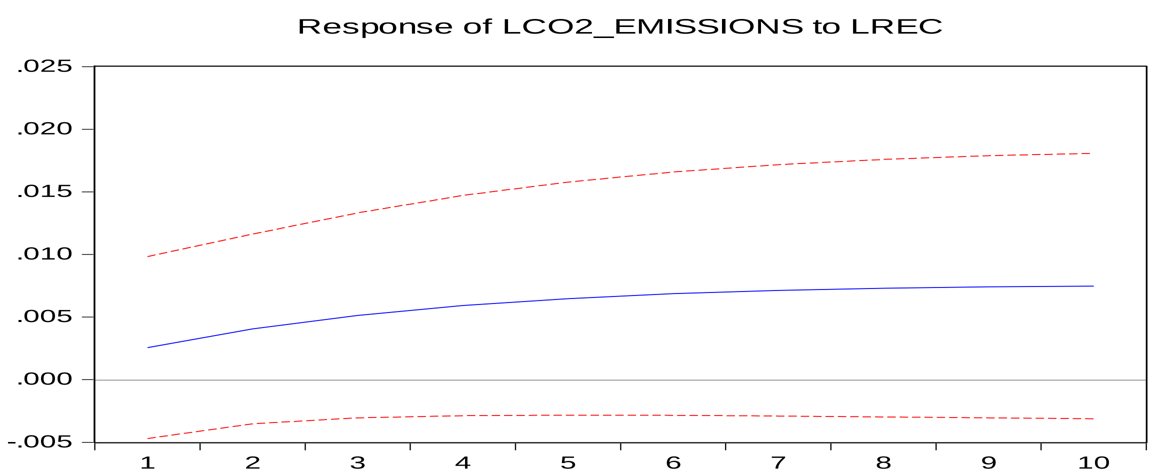
Renewable energy consumption has a positive impact on economic growth of India in the long run according to figure 122.

Figure 123: Results of Impulse response function of renewable energy consumption to carbon emissions for India



According to figure 123, renewable energy consumption responds positively to carbon emissions in the long run.

Figure 124: Results of Impulse response function of carbon emissions to renewable energy consumption for India



Over the ten year period carbon emissions have shown as increasing trend as a response to renewable energy consumption as indicated in figure 124.

Figure 125: Results of Impulse response function of carbon emissions to GDP for India

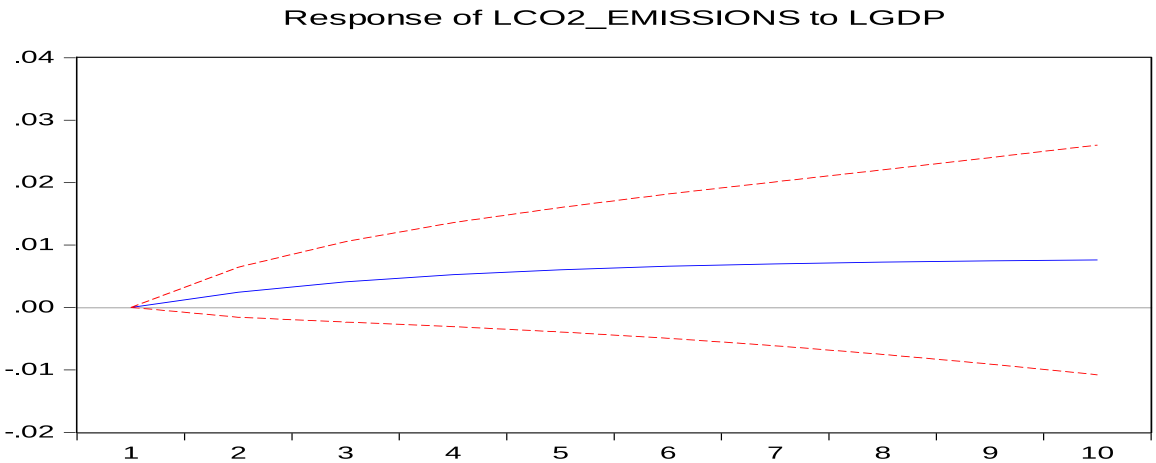
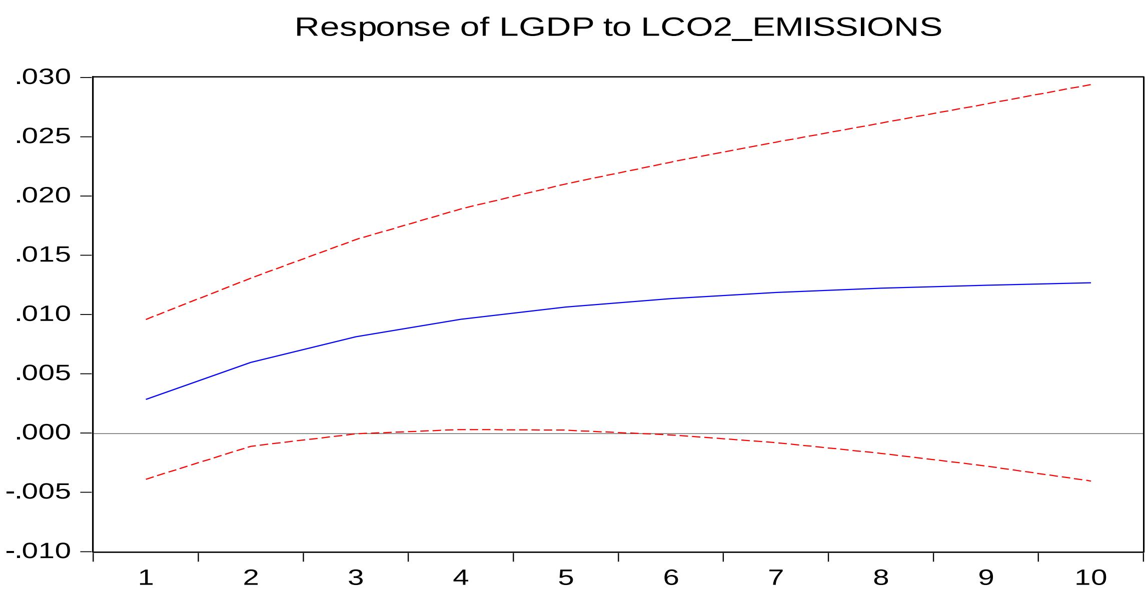


Figure 125 indicates that the economic growth of India has a positive effect on carbon emissions in the long run.

Figure 126: Results of Impulse response function of GDP to carbon emissions for India



The response of GDP to carbon emissions is positive over the ten year period according to figure 126.

INDONESIA

Figure 127: Results of Impulse response function of renewable energy consumption to GDP for Indonesia

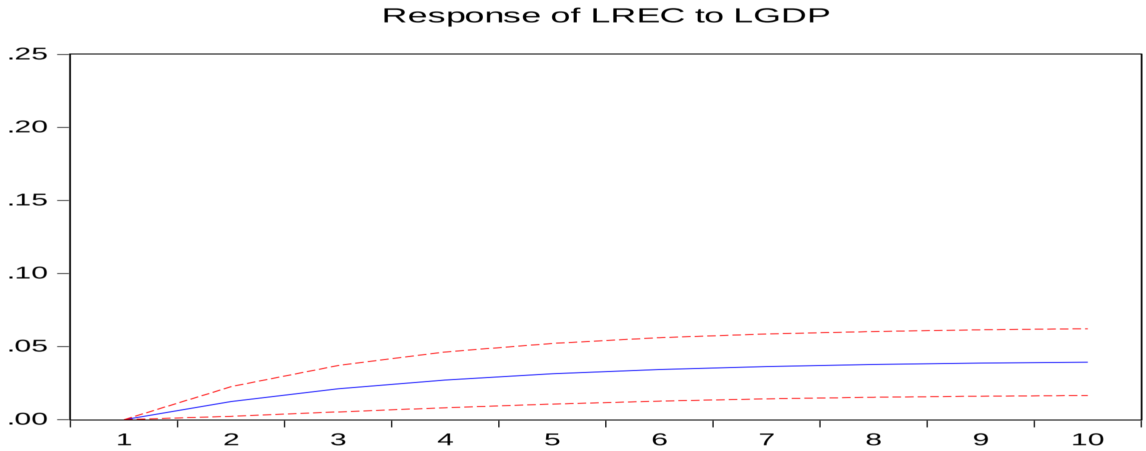
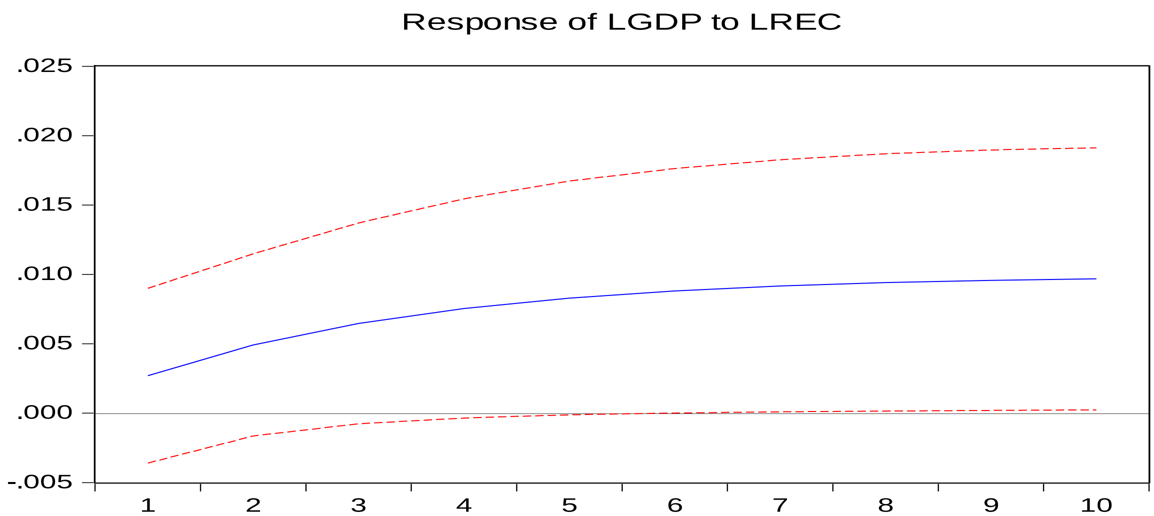


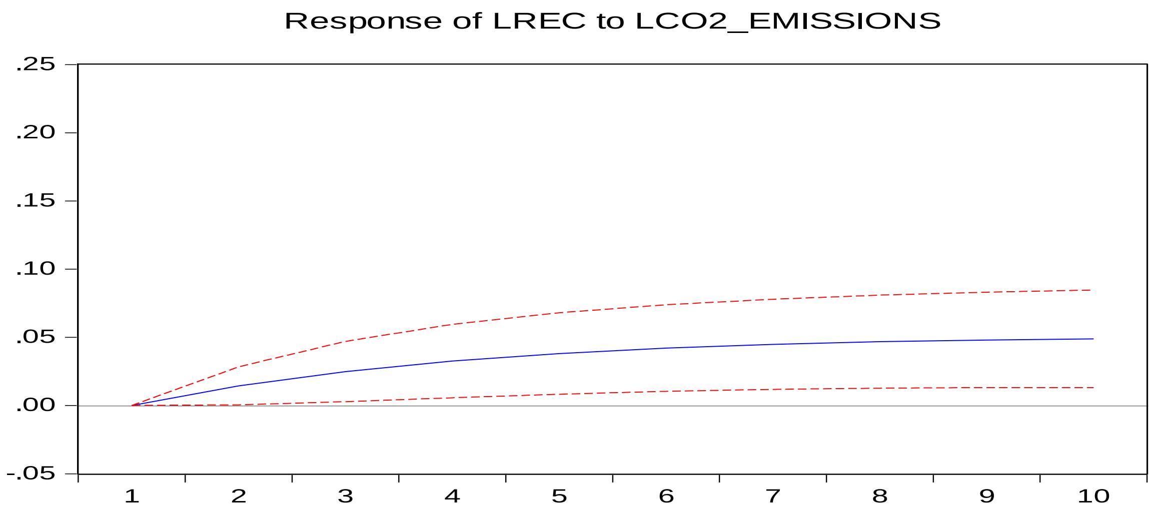
Figure 127 indicates that incase of Indonesia, renewable energy consumption responds positively to economic growth of the country.

Figure 128: Results of Impulse response function of GDP to renewable energy consumption for Indonesia



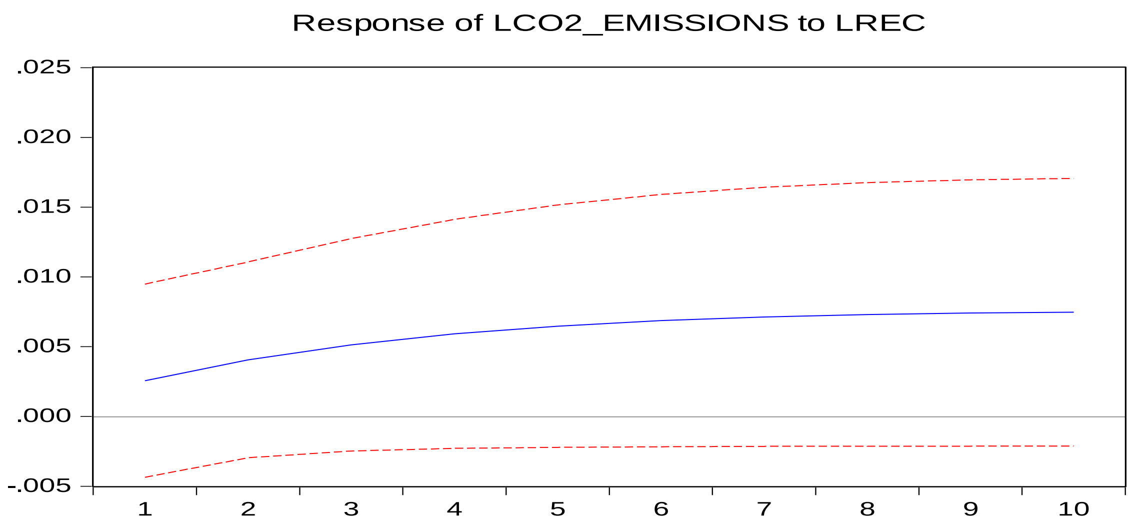
Similarly, economic growth of Indonesia responds positively to renewable energy consumption as displayed in figure 128.

Figure 129: Results of Impulse response function of renewable energy consumption to carbon emissions for Indonesia



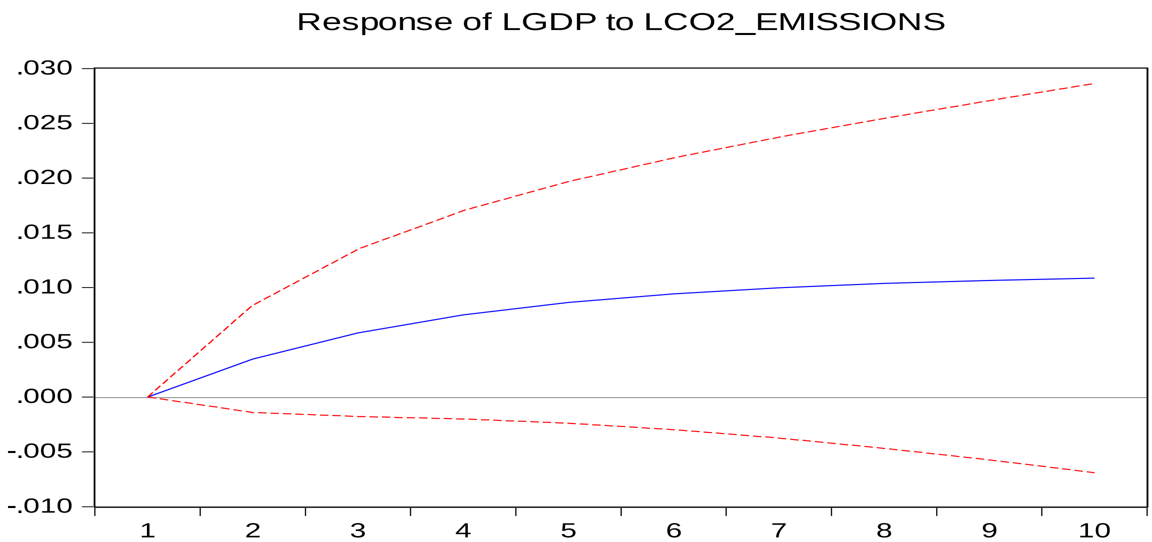
In figure 129, Carbon emissions have a positive effect on renewable energy consumption in the long run.

Figure 130: Results of Impulse response function of carbon emissions to renewable energy consumption for Indonesia



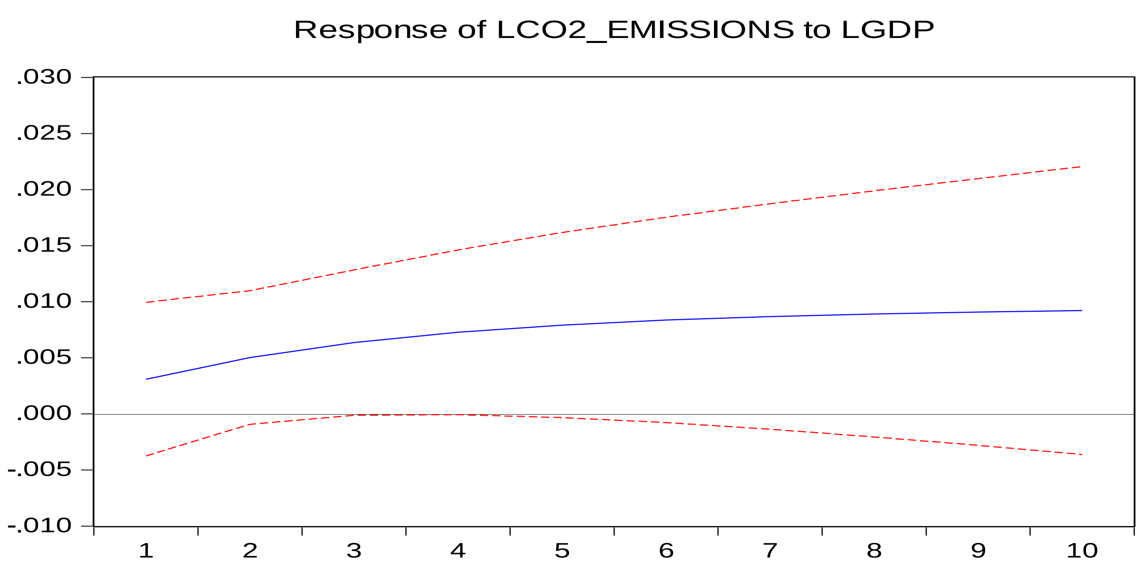
Carbon emissions respond positively to renewable energy consumption in the long run according to figure 130.

Figure 131: Results of Impulse response function of GDP to carbon emissions for Indonesia



Economic growth of Indonesia is positively affected by carbon emissions in the long term as indicated in figure 131.

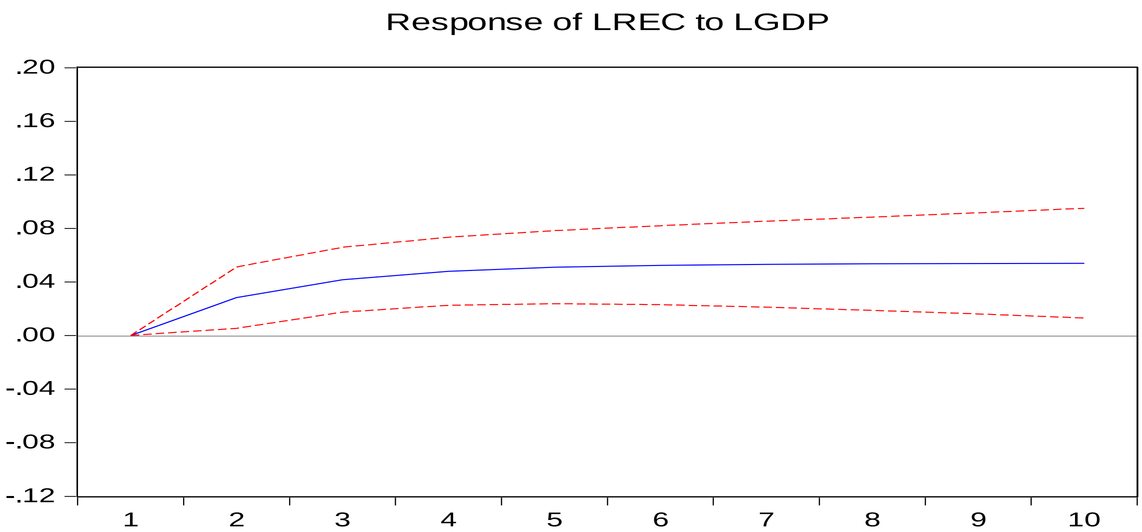
Figure 132: Results of Impulse response function of carbon emissions to GDP for Indonesia



Similarly in figure 132, carbon emissions responds positively to economic growth of Indonesia.

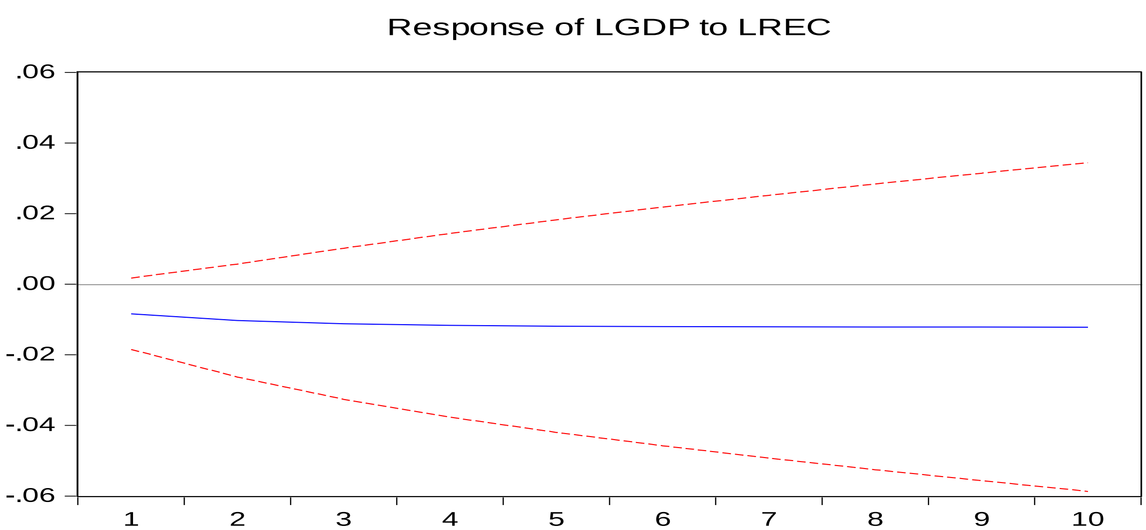
MALAYSIA

Figure 133: Results of Impulse response function of renewable energy consumption to GDP for Malaysia



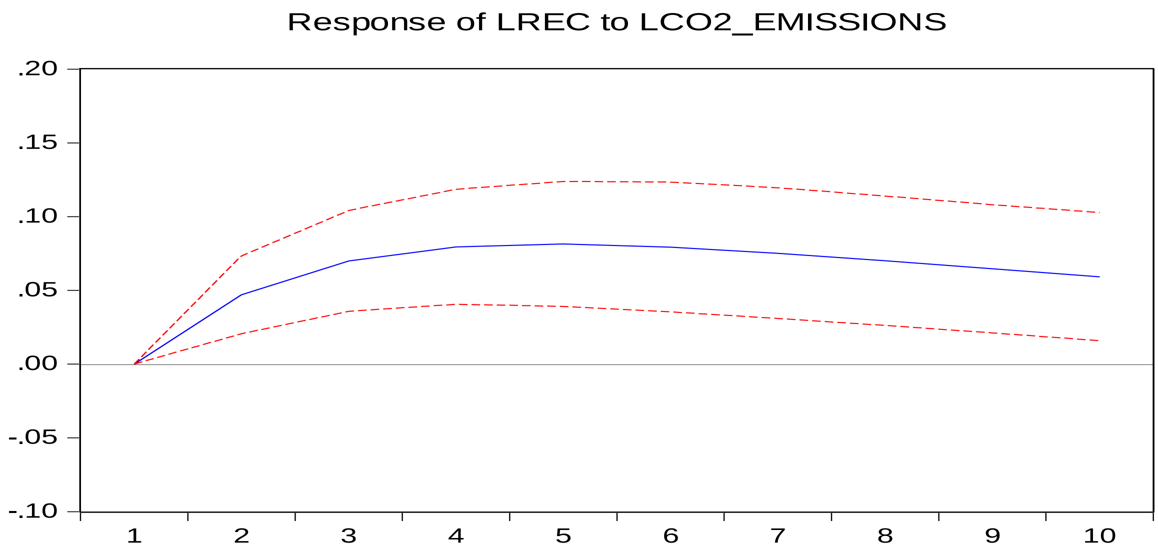
In case of Malaysia, economic growth of the country has a positive impact on renewable energy consumption in the long run as indicates in figure 133.

Figure 134: Results of Impulse response function of GDP to renewable energy consumption for Malaysia



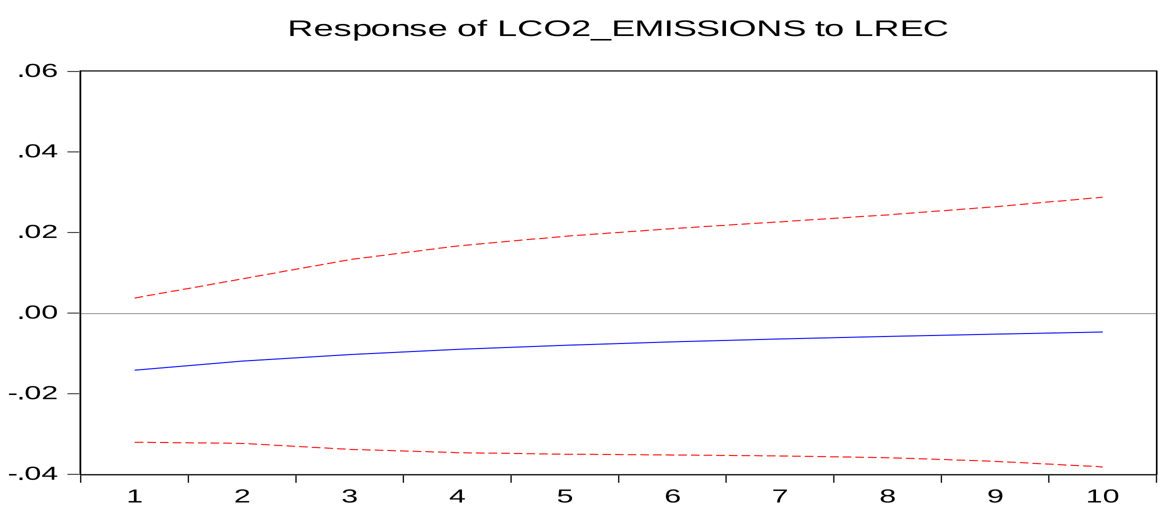
In figure 134, renewable energy consumption has a negative effect on the economic growth of Malaysia in the long run.

Figure 135: Results of Impulse response function of renewable energy consumption to GDP for Malaysia



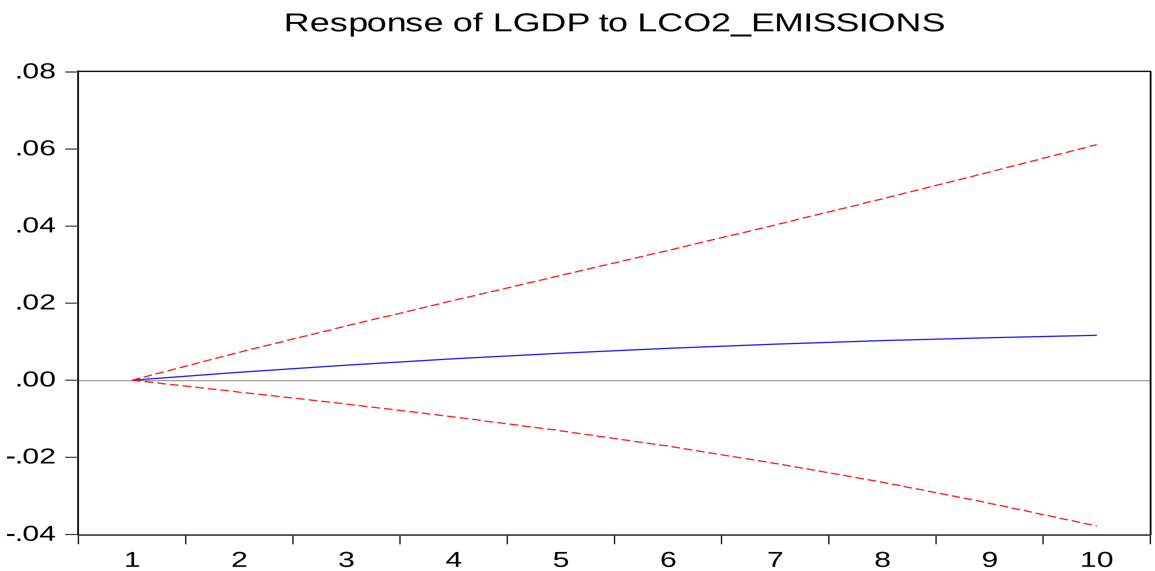
Renewable energy consumption responds positively in the short run i.e. till the fifth period and then gradually declines in the long run indicating a negative impact according to figure 135.

Figure 136: Results of Impulse response function of carbon emissions to renewable energy consumption for Malaysia



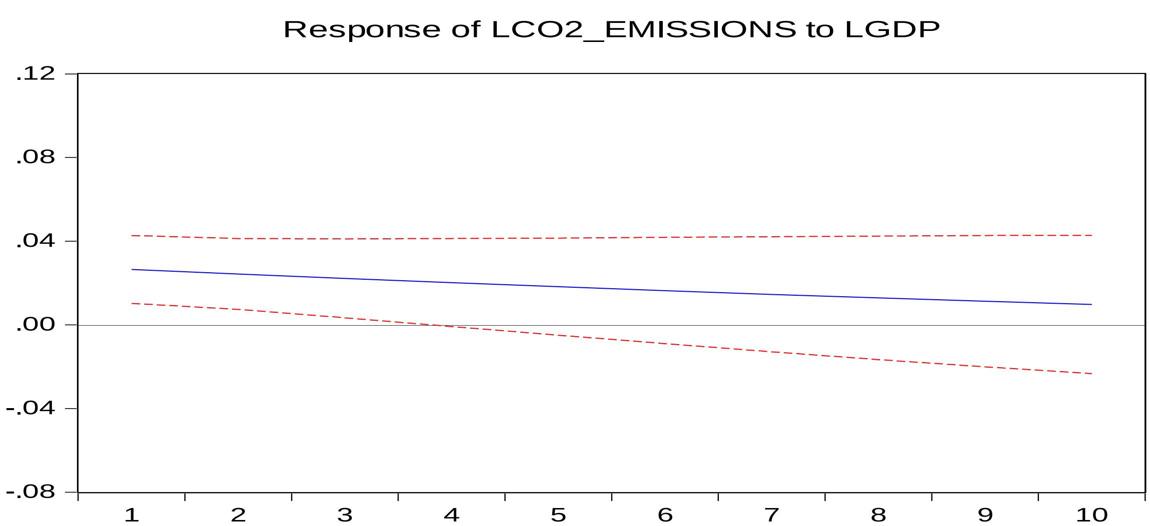
In figure 136, in the long run renewable energy consumption has a positive impact on carbon emissions.

Figure 137: Results of Impulse response function of GDP to carbon emissions for Malaysia



Economic growth of Malaysia exhibits an increasing trend in the long run as a response to carbon emissions as indicated in figure 137.

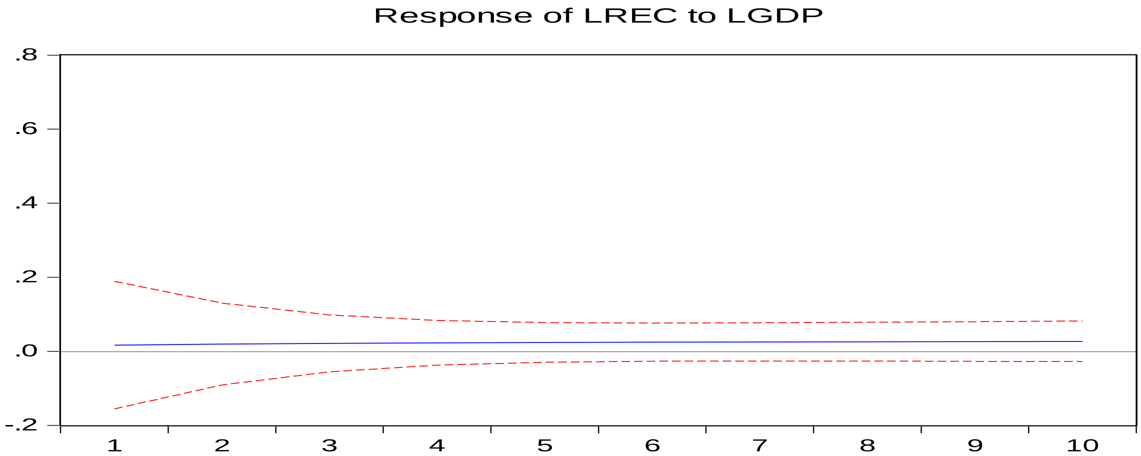
Figure 138: Results of Impulse response function of carbon emissions to GDP for Malaysia



According to figure 138, economic growth of Malaysia has a negative impact on carbon emissions.

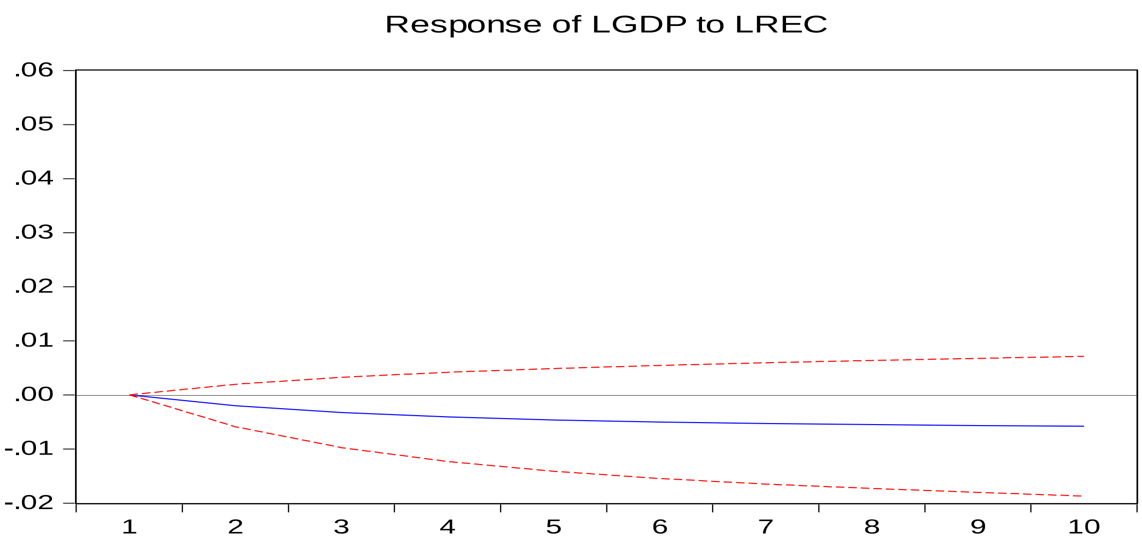
PHILIPPINES

Figure 139: Results of Impulse response function of renewable energy consumption to GDP for Philippines



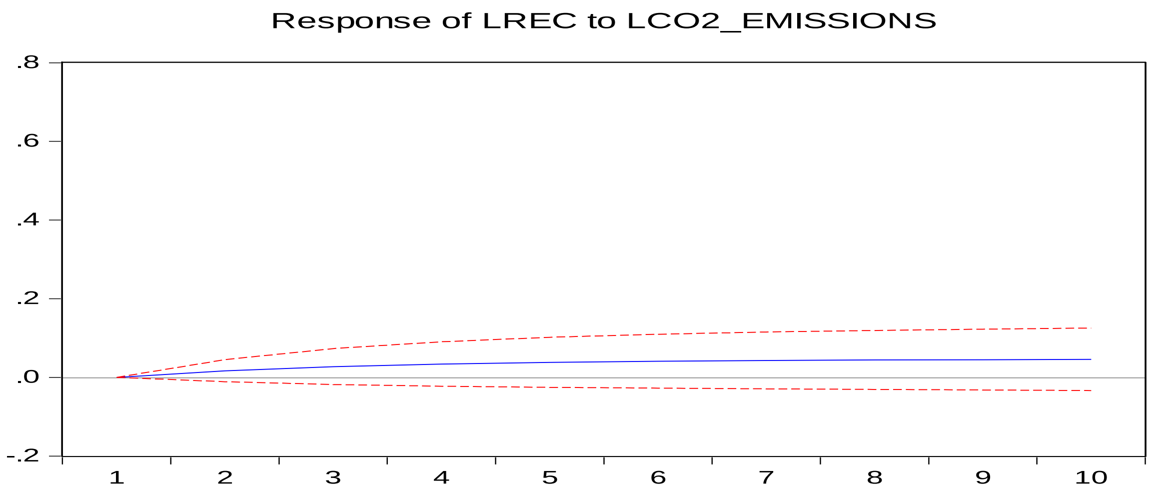
According to figure 139, renewable energy consumption responds positive to economic growth in the long run.

Figure 140: Results of Impulse response function of GDP to renewable energy consumption for Philippines



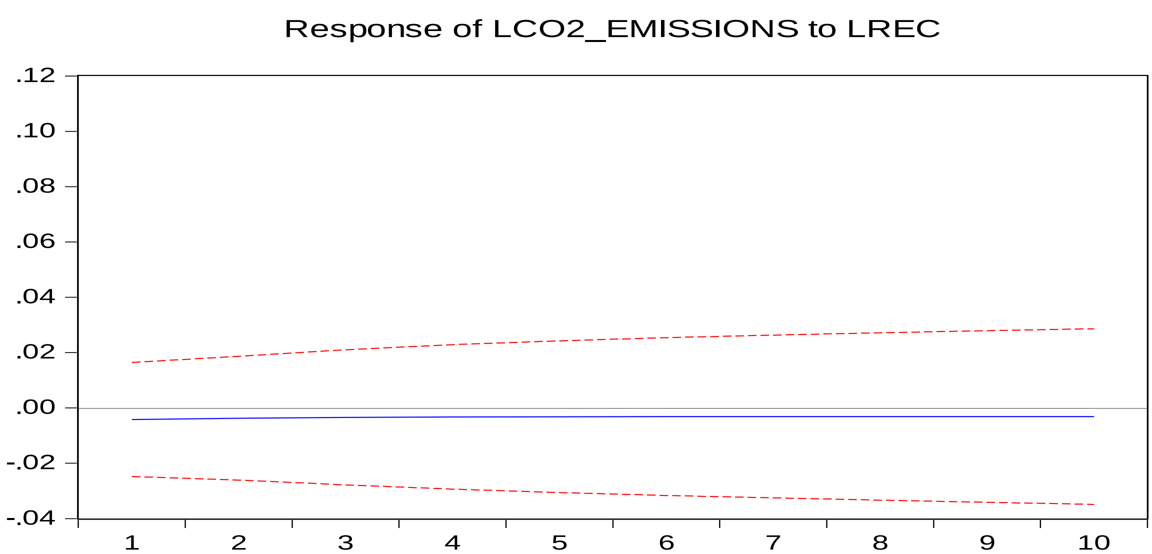
Renewable energy consumption has a negative impact on economic growth of the Philippines in the long run as indicated in figure 140.

Figure 141: Results of Impulse response function of renewable energy consumption to carbon emissions for Philippines



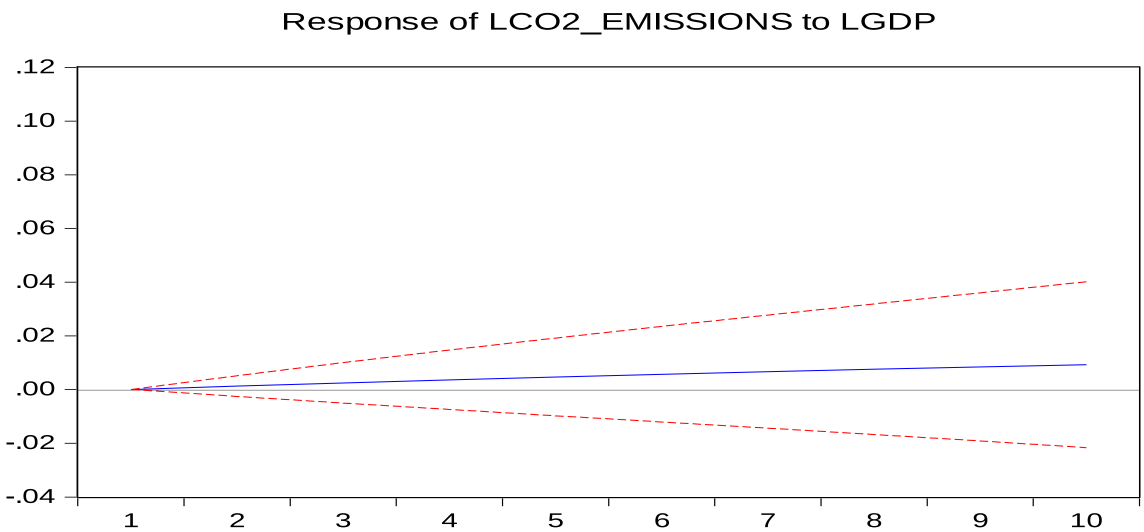
Carbon emission have a positive impact on renewable energy consumption in the long run according to figure 141.

Figure 142: Results of Impulse response function of carbon emissions to renewable energy consumption for Philippines



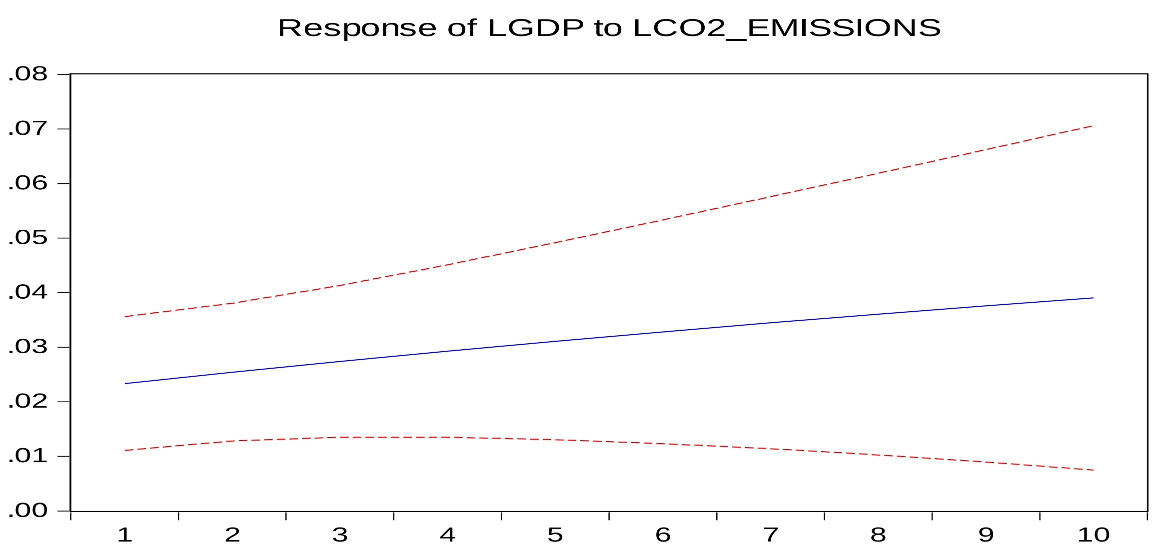
In figure 142, the response of carbon emissions to renewable energy consumption exhibits a mild positive trend which is consistent over the entire period of time.

Figure 143: Results of Impulse response function of carbon emissions to GDP for Philippines



Carbon emissions respond positively to economic growth in the long run as per figure 143.

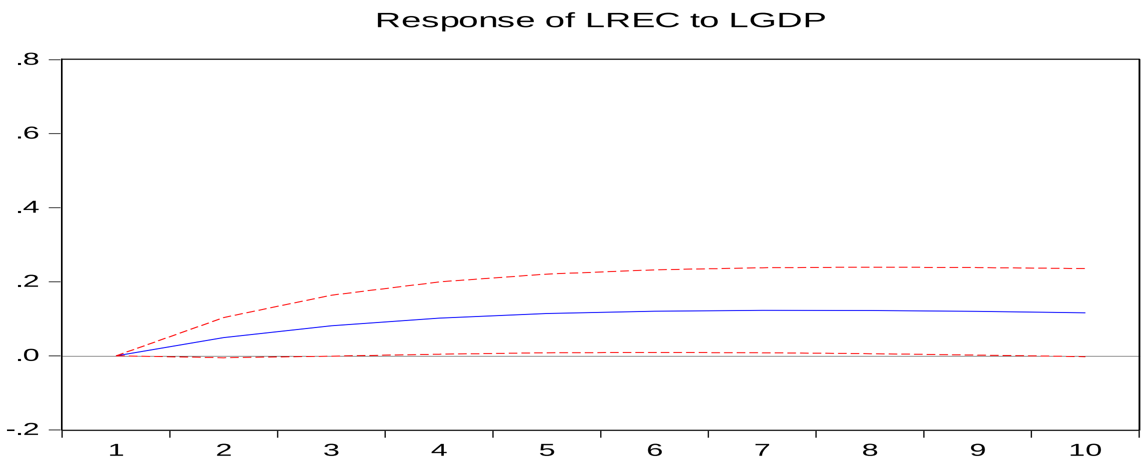
Figure 144: Results of Impulse response function of GDP to carbon emissions for Philippines



In the long run GDP responds positively to carbon emissions incase of the Philippines as indicated in figure 144.

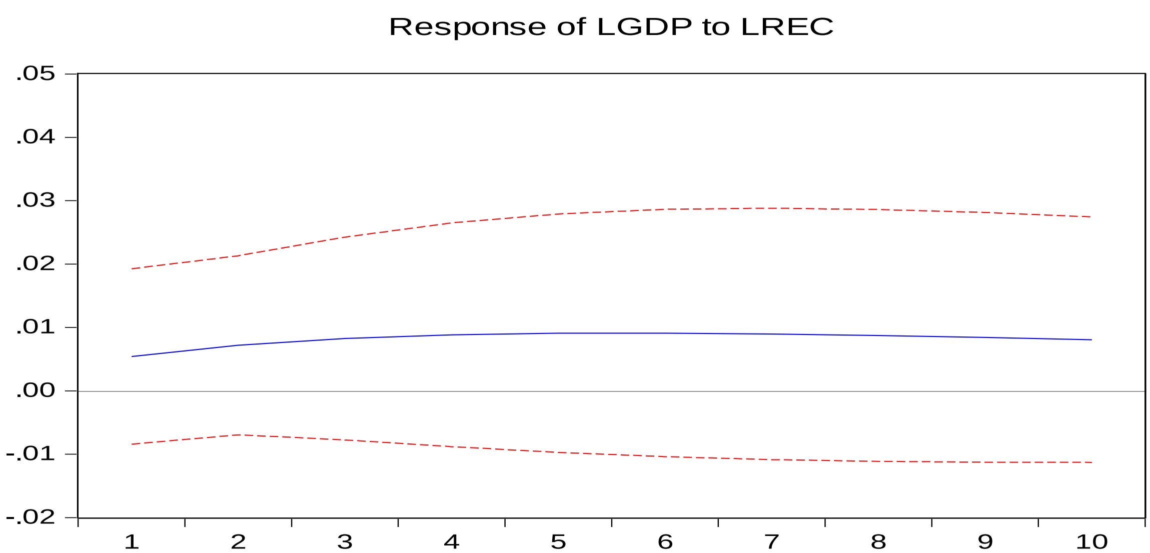
THAILAND

Figure 145: Results of Impulse response function of renewable energy consumption to GDP for Thailand



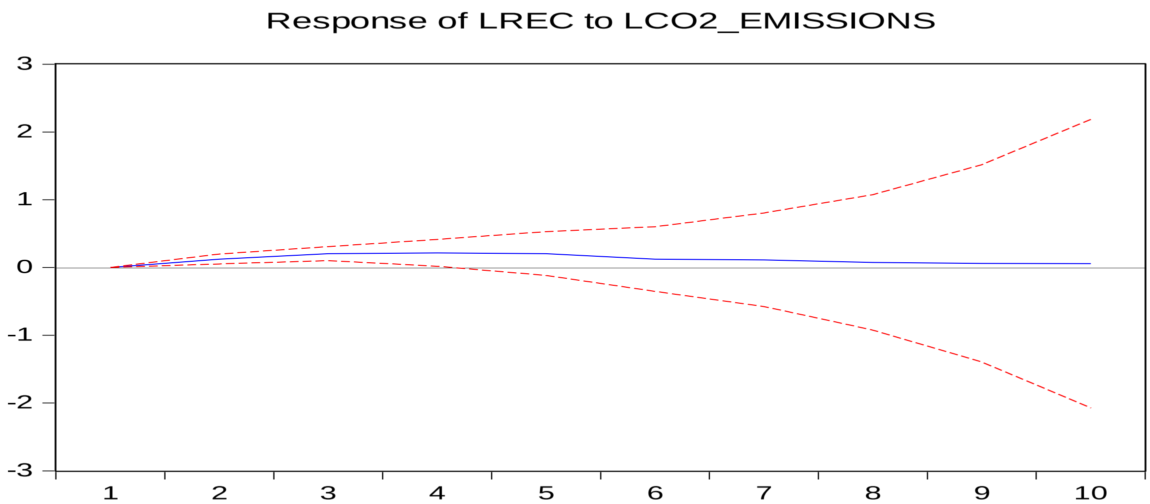
Economic growth of Thailand has a positive effect on renewable energy consumption according to figure 145.

Figure 146: Results of Impulse response function of GDP to renewable energy consumption for Thailand



In Figure 146, in the short run, economic growth responds to renewable energy consumption positively however after the seventh period a decreasing trend is observed indicating a negative impact of renewable energy consumption on GDP.

Figure 147: Results of Impulse response function of renewable energy consumption to carbon emissions for Thailand



In the short run, renewable energy consumption responds positively to carbon emission however in the long run a negative response is observed as indicated in figure 149.

Figure 148: Results of Impulse response function of carbon emissions to renewable energy consumption for Thailand

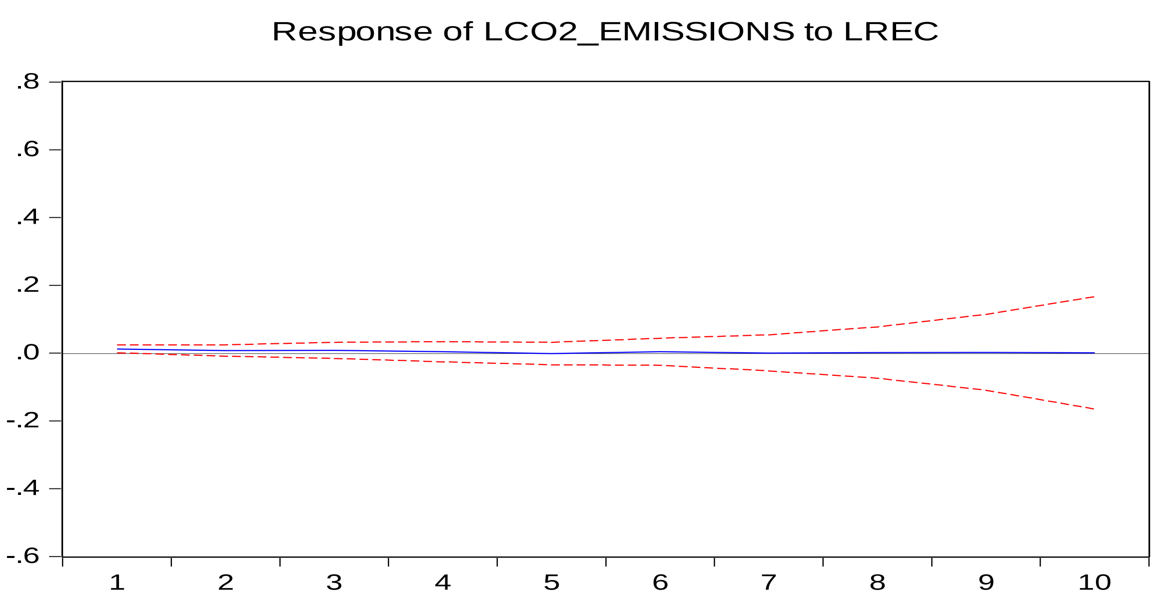
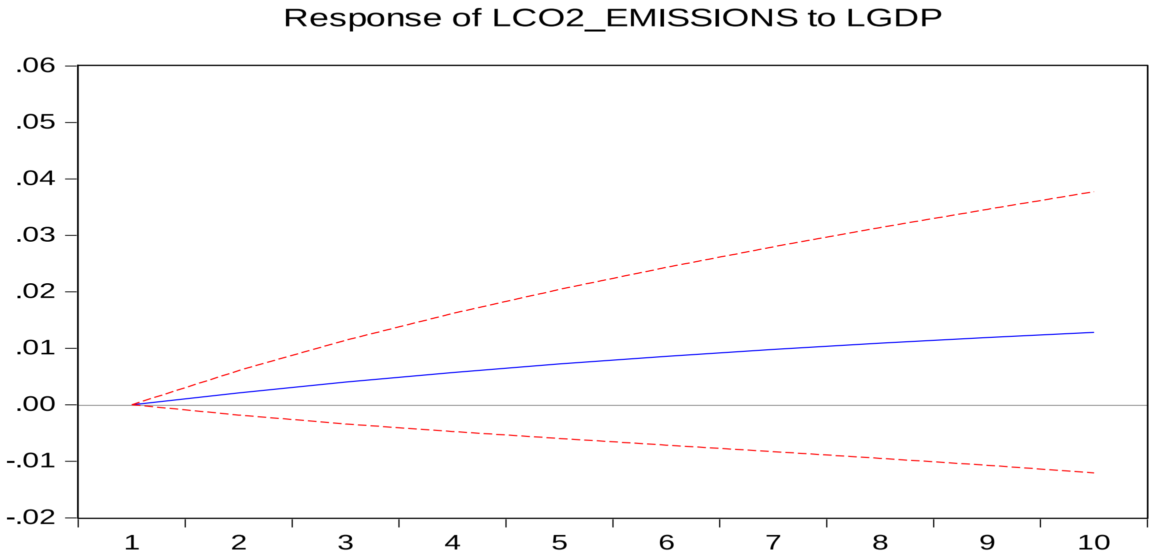


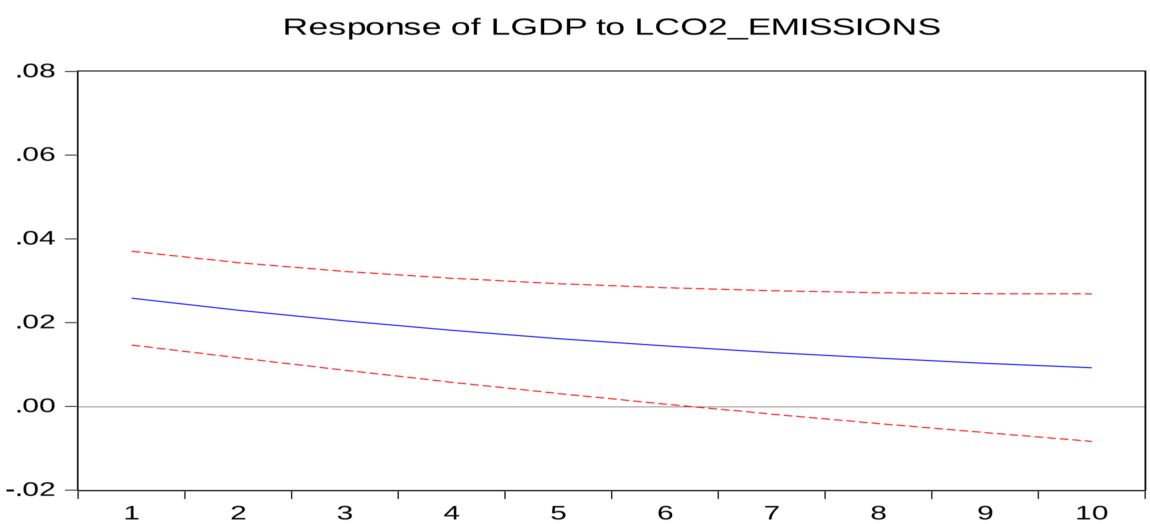
Figure 148 indicates that the response of carbon emissions to renewable energy consumption is consistent in the long run.

Figure 149: Results of Impulse response function of carbon emissions to GDP for Thailand



In the long run, carbon emissions increase as a response to economic growth of Thailand according to figure 149.

Figure 150: Results of Impulse response function of GDP to carbon emissions for Thailand

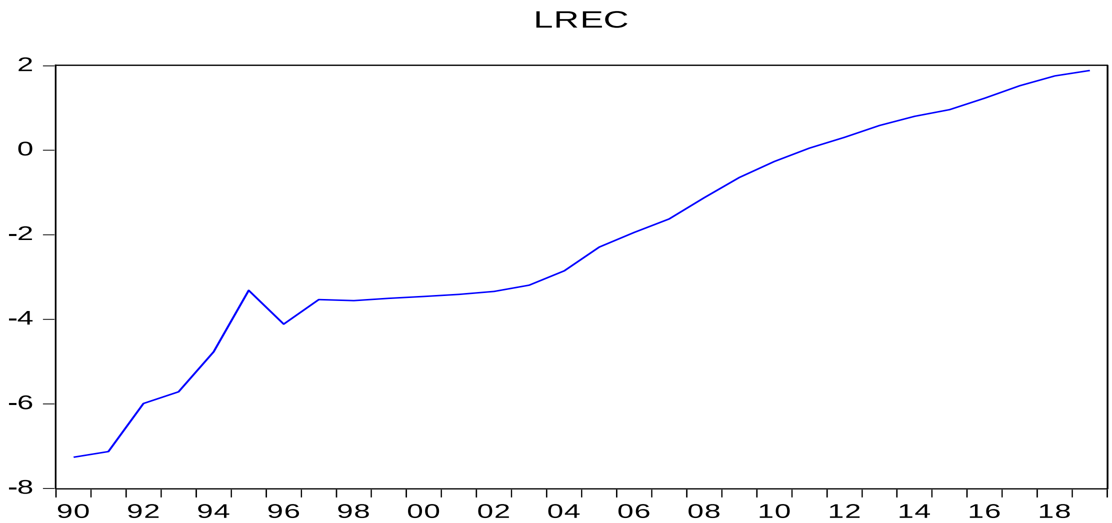


Economic growth of Thailand responds negatively to carbon emissions in the long run according to figure 150.

5.11 TREND ANALYSIS

CHINA

Figure 151: Results of trend analysis of renewable energy consumption for China



In the above figure 151, the X axis indicates the quantum of renewable energy consumption while the Y axis indicates years from 1990 to 2019. Since the year 1990, the consumption of renewable energy initially indicates a sharp increase till 1995 and a mild decline from 1995 to 1996 after which consumption has consistently risen with the highest consumption in the year 2020.

Figure 152: Results of trend analysis of GDP for China

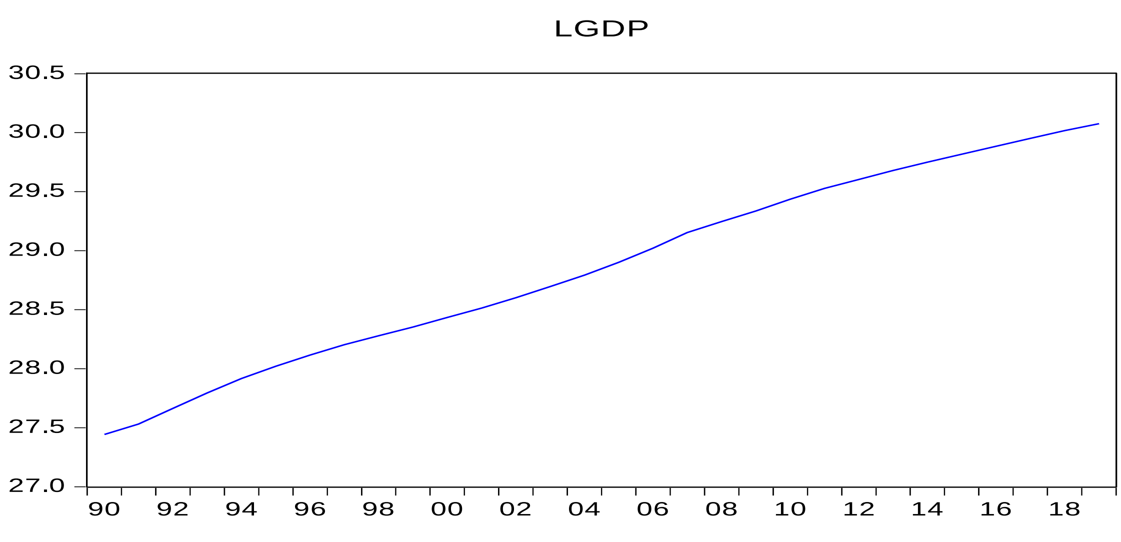
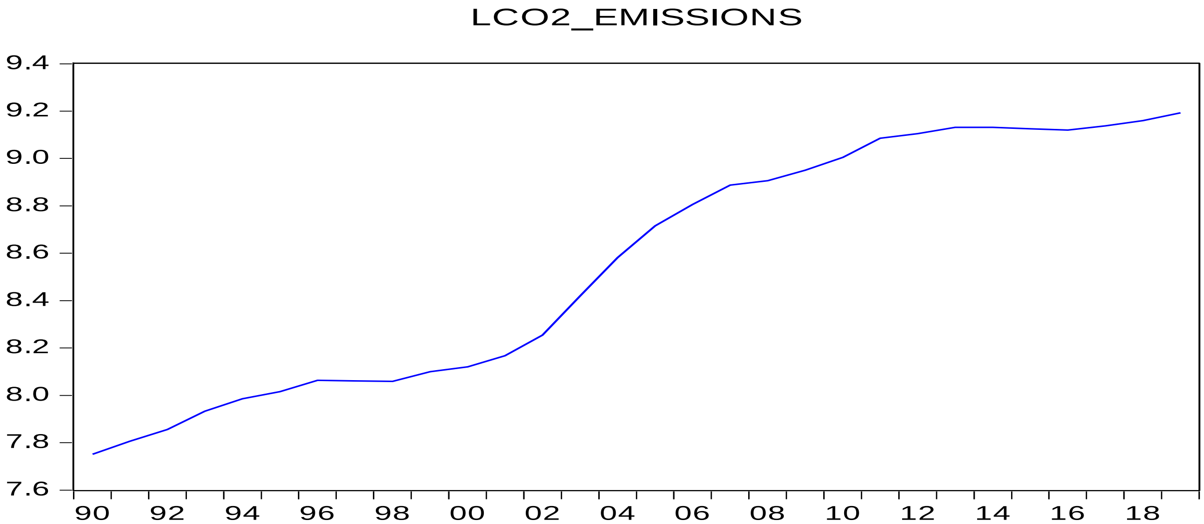


Figure 152 displays the trend of GDP for China from 1990 to 2019. The economic growth of China has risen over the last 30 years indicating that the economy is robust.

Figure 153: Results of trend analysis of carbon emissions for China



The above figure 153 indicates that carbon emissions of China increased since 1990 and after 2002 a sharp increase is observed with the highest carbon emissions in the year 2020.

INDIA

Figure 154: Results of trend analysis of renewable energy consumption for India

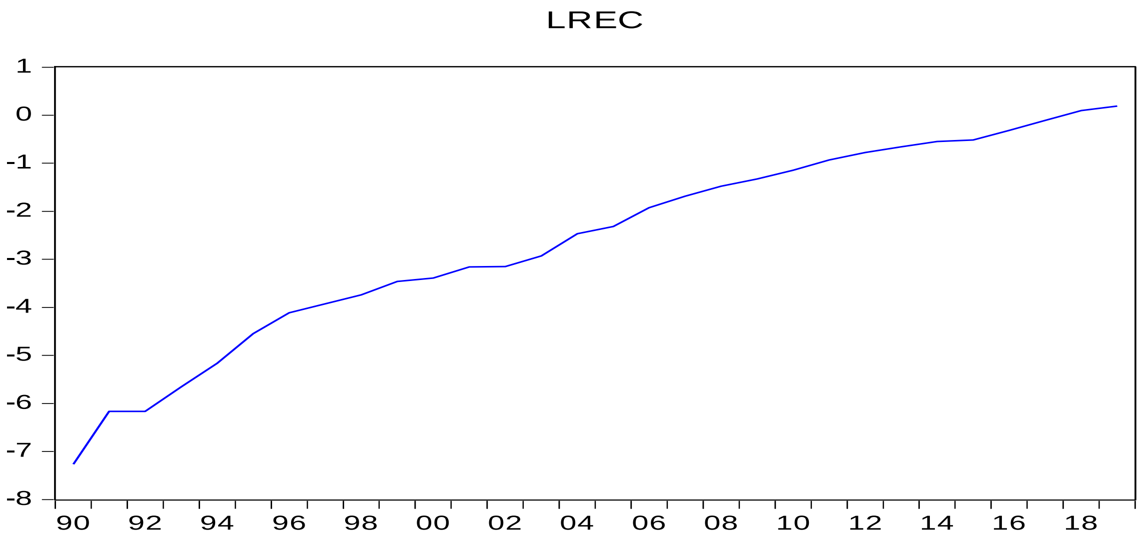
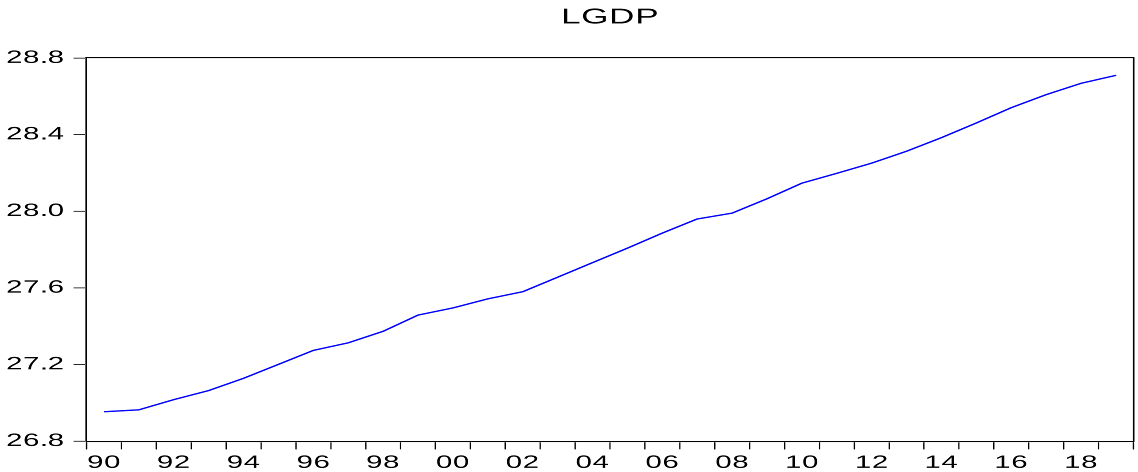


Figure 154 indicates that renewable energy consumption of India has exhibited a steady increasing trend over the last 30 year with the highest consumption of renewable energy consumption in the year 2020.

Figure 155: Results of trend analysis of GDP for India



In the above figure 155, Y axis indicates GDP in constant 2010 USD and X axis indicates years. The economic growth of India over the last 30 years had sharply increased steadily since 1990.

Figure 156: Results of trend analysis of carbon emissions for India

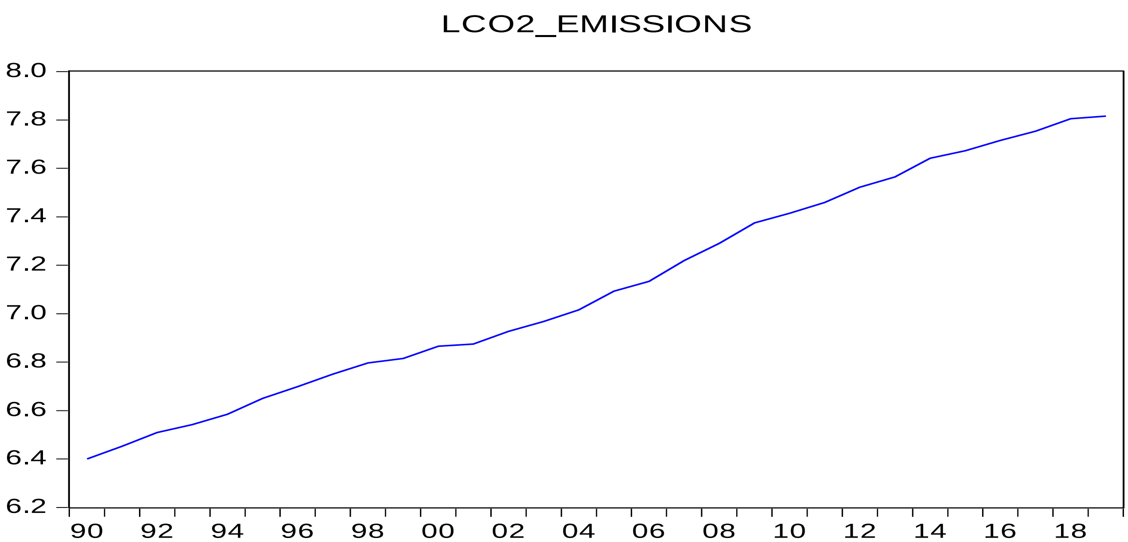
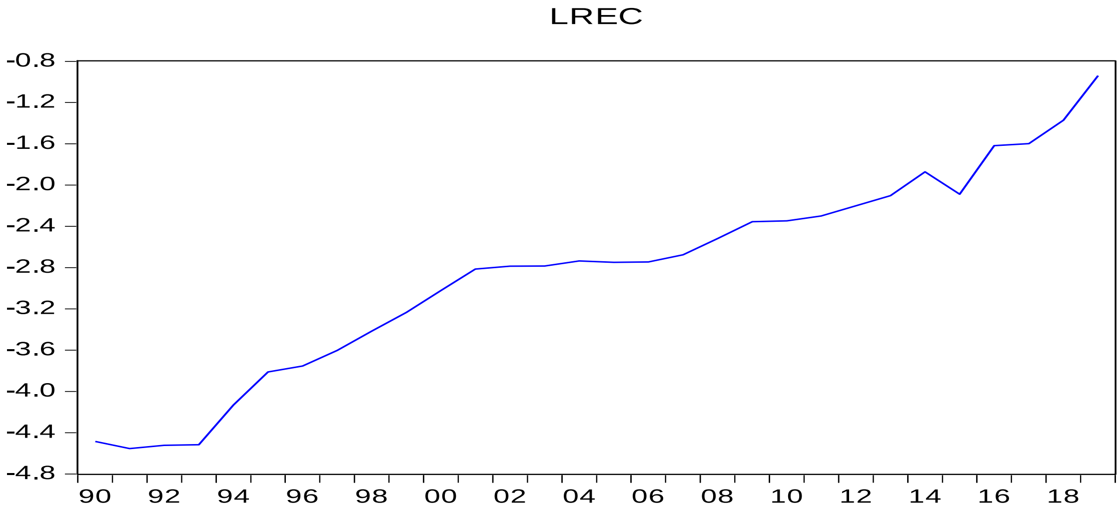


Figure 156 indicates that the carbon emissions of India has sharply increased with the growth of the country

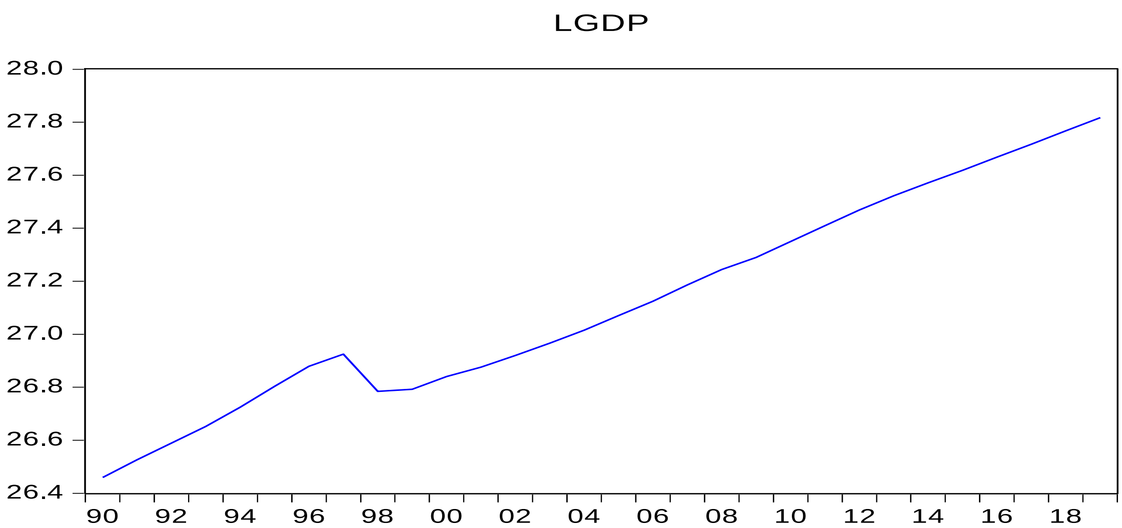
INDONESIA

Figure 157: Results of trend analysis of renewable energy consumption for Indonesia



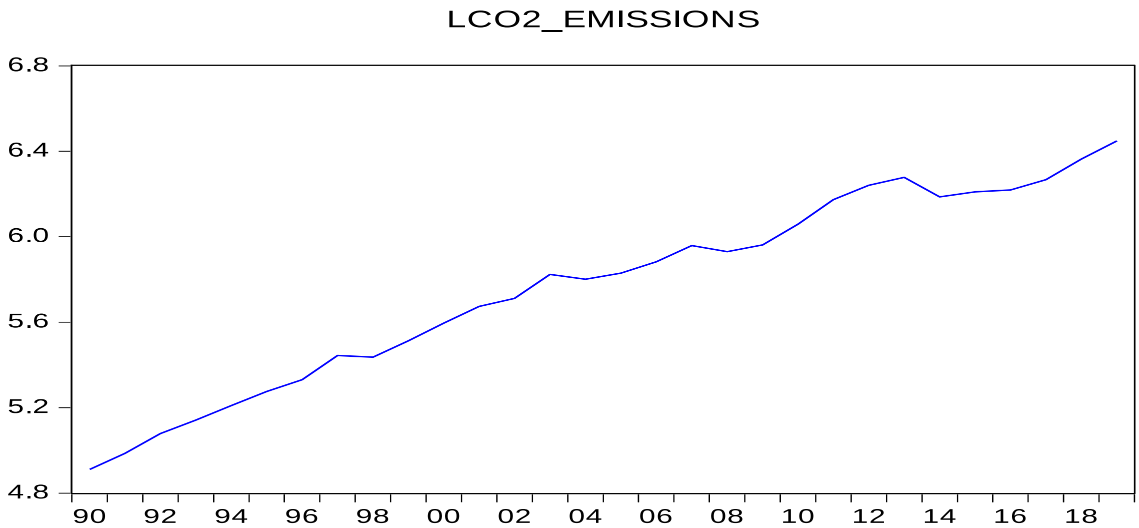
In case of Indonesia, the consumption of renewable energy consumption has been volatile since 1990. Initially consumption remained constant and after 1993 an increase is observed till 2015. After a decline, in 2015 a steady increase is observed as indicated in the above figure 157.

Figure 158: Results of trend analysis of GDP for Indonesia



Incase of economic growth of Indonesia indicated in figure 158, from 1990 a sharp increase is observed followed by a sharp decline in the year 1997 after which the GDP steadily increased till 2020.

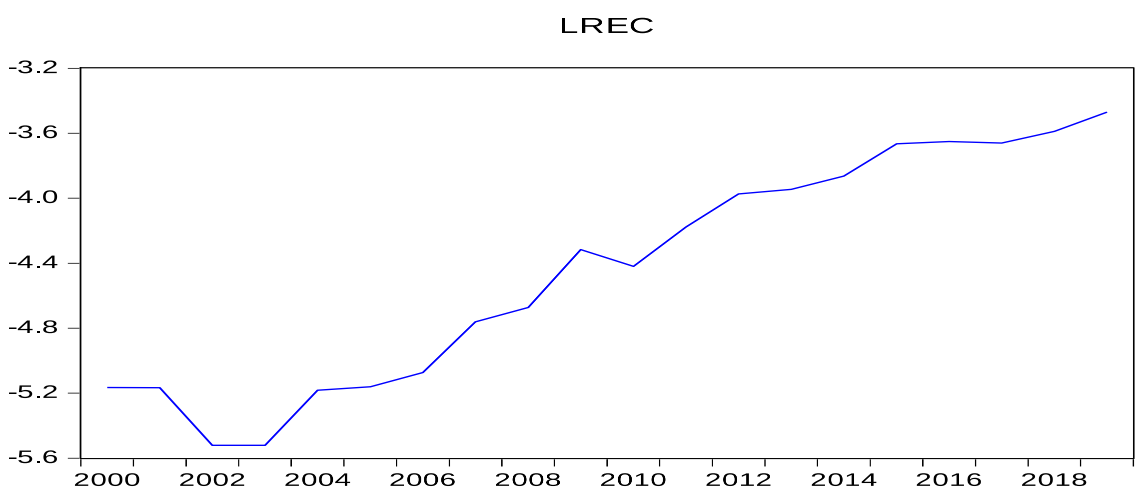
Figure 159: Results of trend analysis of carbon emissions for Indonesia



The carbon emissions of Indonesia increased from 1990 till 2020 with minor declines in 1997, 2003, 2008 and 2014 as observed in the above figure 159.

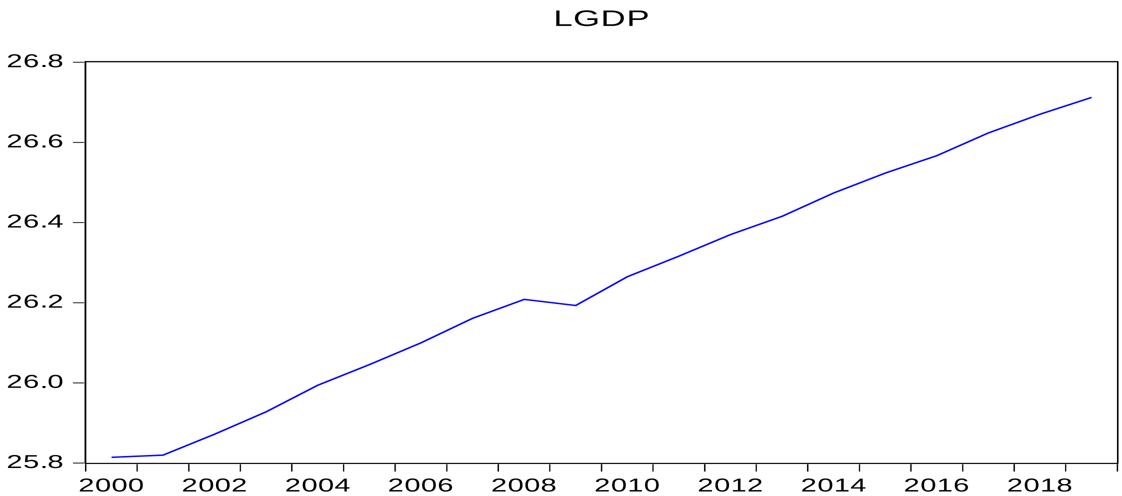
MALAYSIA

Figure 160: Results of trend analysis of renewable energy consumption for Malaysia



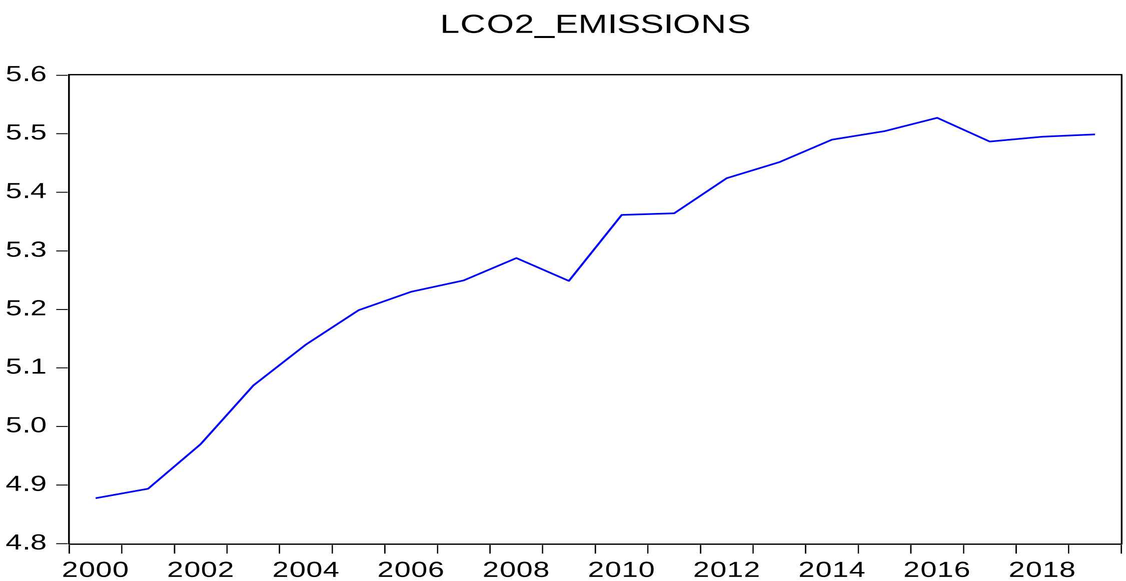
In figure 160, after the year 2001, Malaysia saw a fall in the consumption of renewable energy consumption. Towards the end of 2003 a recovery is observed till 2010 after which a mild decline took place. Since 2001 there has been an increasing trend in renewable energy consumption with the highest consumption in recent years.

Figure 161: Results of trend analysis of GDP for Malaysia



The economic growth of Malaysia has steadily grown since the year 2000. Although a mild decline is observed in the year 2008 during the depression a quick recovery is visible after 2009 as indicated in figure 161.

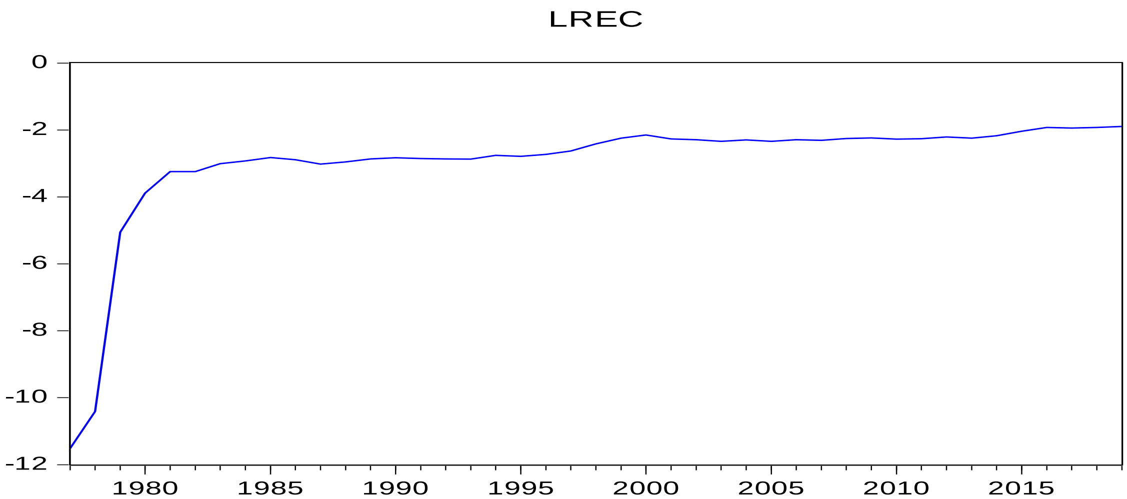
Figure 162: Results of trend analysis of carbon emissions for Malaysia



In case of carbon emissions in figure 162, in the initial year since 2001, a rapid increase till 2008 is observed followed by a decline corresponding to the decline in economic growth during the depression in 2008 after which increase in carbon emissions is visible consistently till recent years with the growth of the economy.

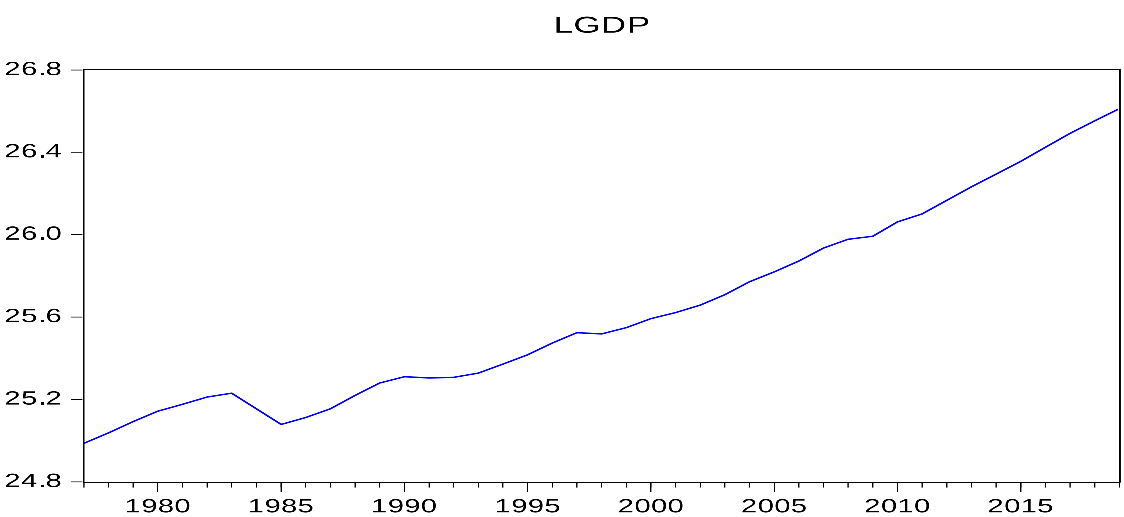
PHILIPPINES

Figure 163: Results of trend analysis of renewable energy consumption for Philippines



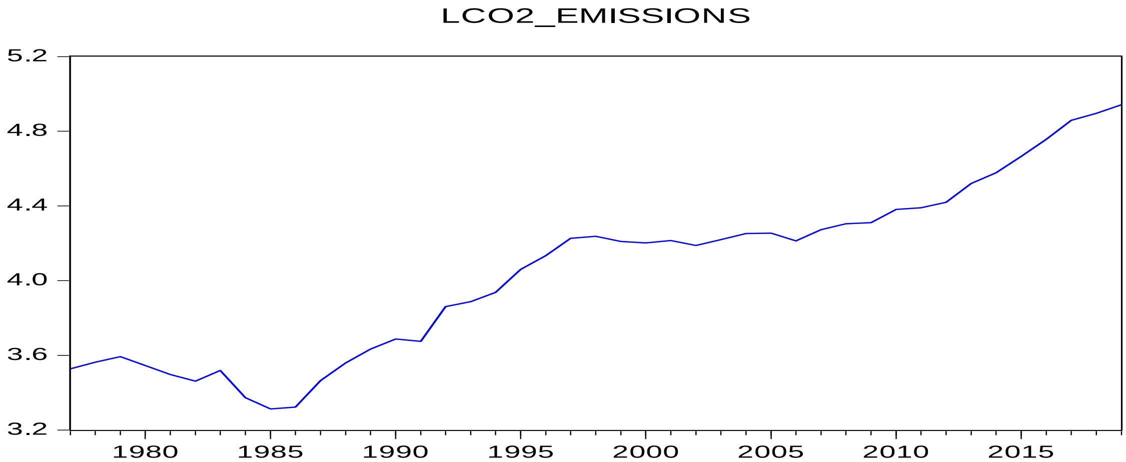
Incase of the Philippines, in the year 1977, a sharp increase in the consumption of renewable energy consumption till 1981 is observed which became constant over the year till 2019 as indicated in 163.

Figure 164: Results of trend analysis of GDP for Philippines



According to figure 164, the economy of the Philippines has grown since 1977. There was a contraction in the year 1983 however since then the economic growth has drastically increased till recent years.

Figure 165: Results of trend analysis of carbon emissions for Philippines



Carbon emissions have been volatile over the years with a decrease in 1983 followed by an increase from 1986. However, in recent years a continuous increase in carbon emissions is observed upto 2019 as observed in figure 165.

THAILAND

Figure 166: Results of trend analysis of renewable energy consumption for Thailand

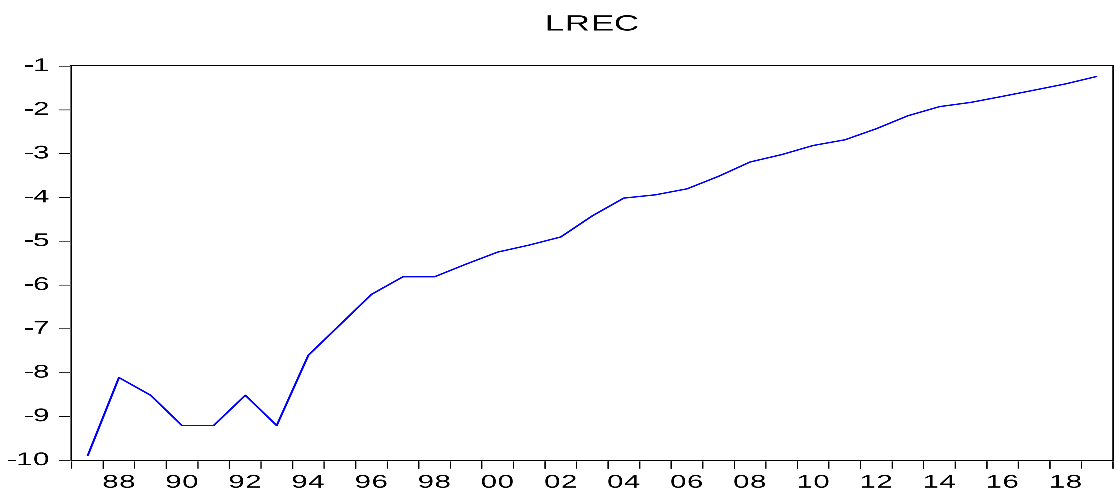
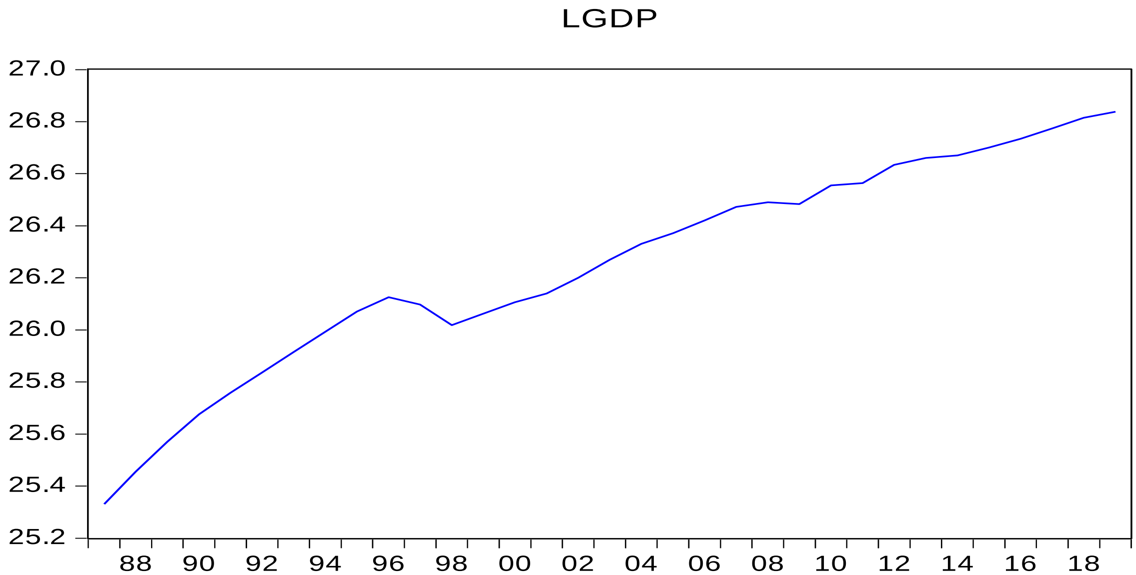


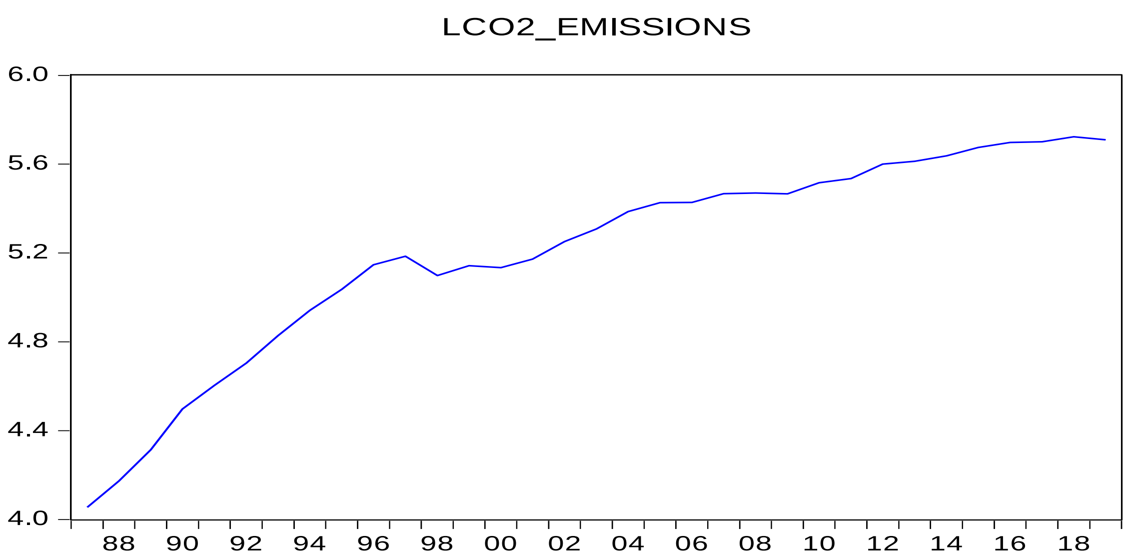
Figure 166 indicates that in the initial years since 1987, renewable energy consumption has shown volatility with a sharp increase in 1987 followed by a fall after 1988 and an increase again in 1992 and a fall in 1993. Since 1994 consumption of renewable energy has increase substantially.

Figure 167: Results of trend analysis of GDP for Thailand



The economic growth of Thailand has increased rapidly with a mild decrease after the year 1996 after which an increasing trend is observed till 2020 as indicated in the above figure 167.

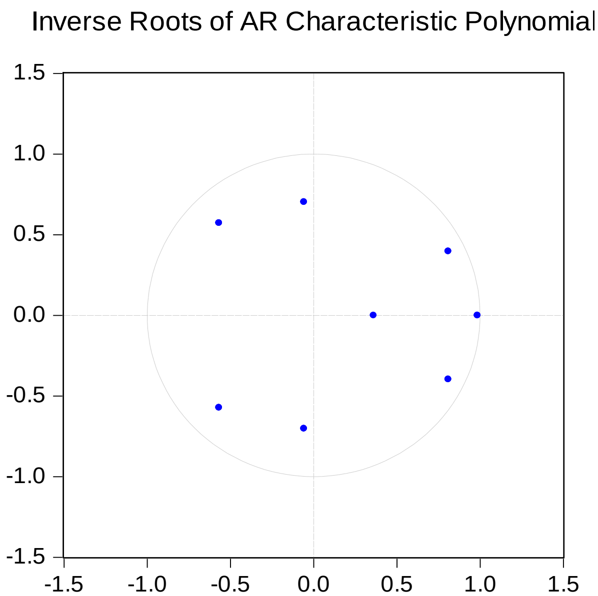
Figure 168: Results of trend analysis of carbon emissions for Thailand



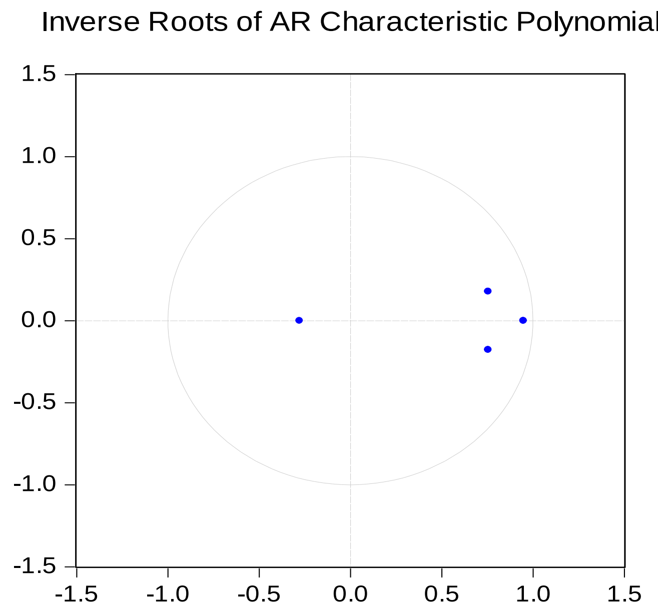
In figure 168, in the initial years since 1987 carbon emissions have rapidly increased with the increase in GDP followed by a decrease in the year 1997 after which a constant increase is observed with mild fluctuations.

5.12 STABILITY TEST

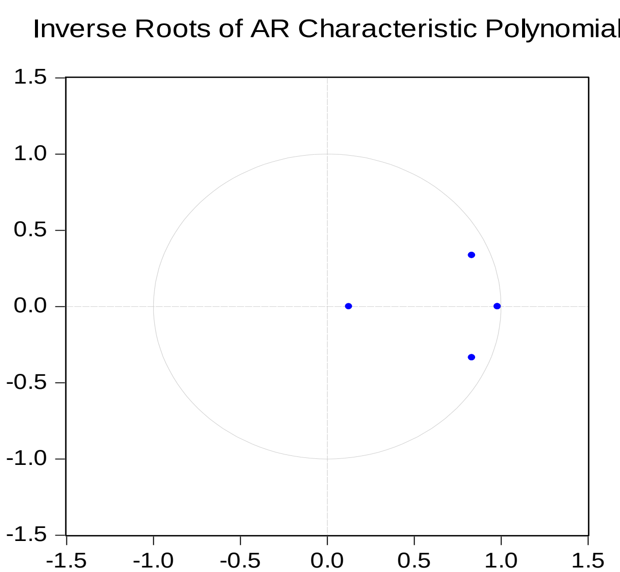
Figure 169: Results of stability test for China



REC & GDP

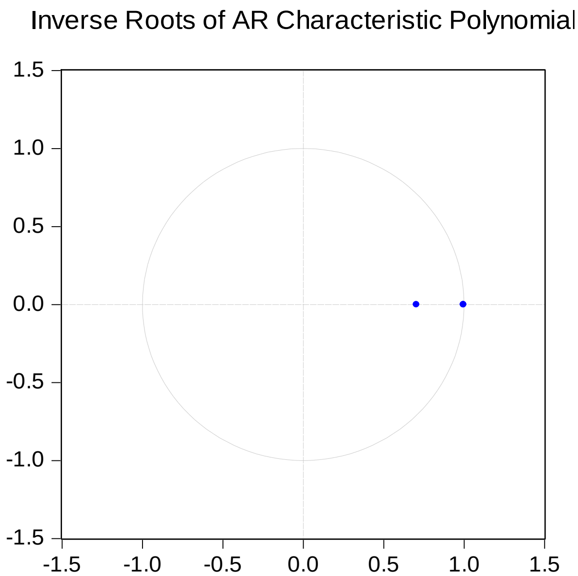


REC & CO2 EMISSIONS

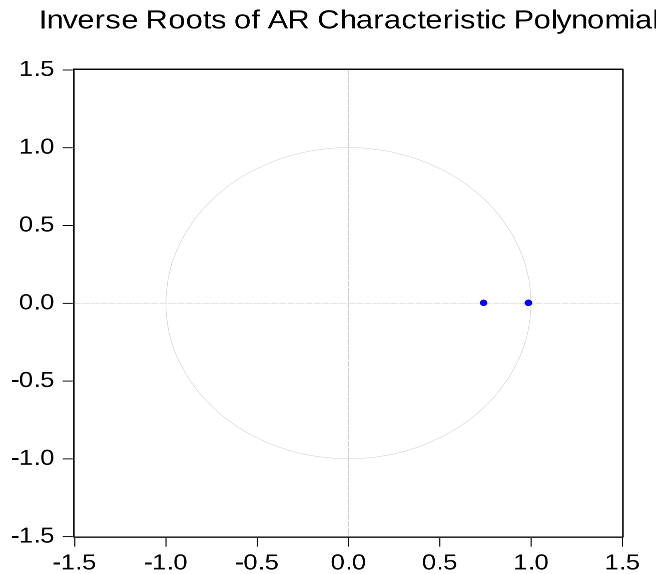


CO2 EMISSIONS & GDP

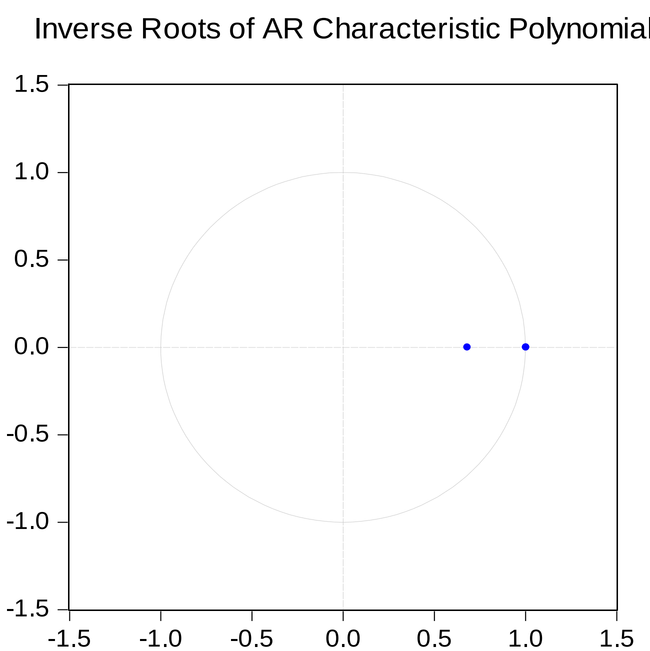
Figure 170: Results of stability test for India



REC & GDP

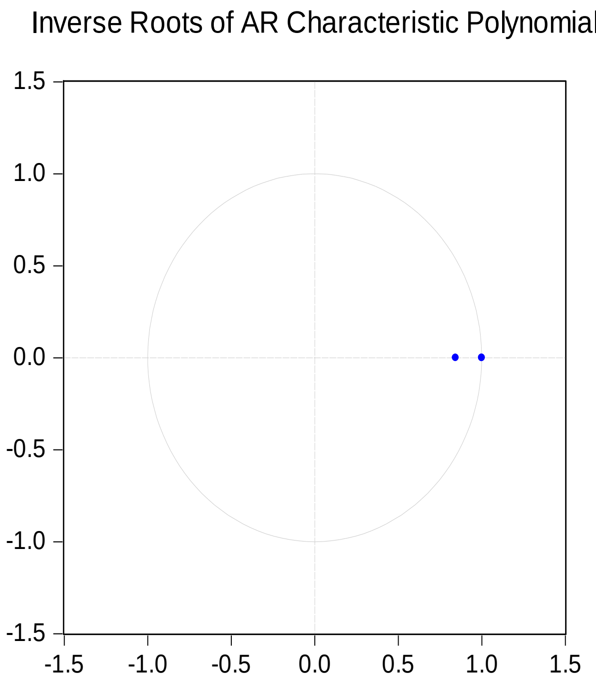


REC & CO2 EMISSIONS

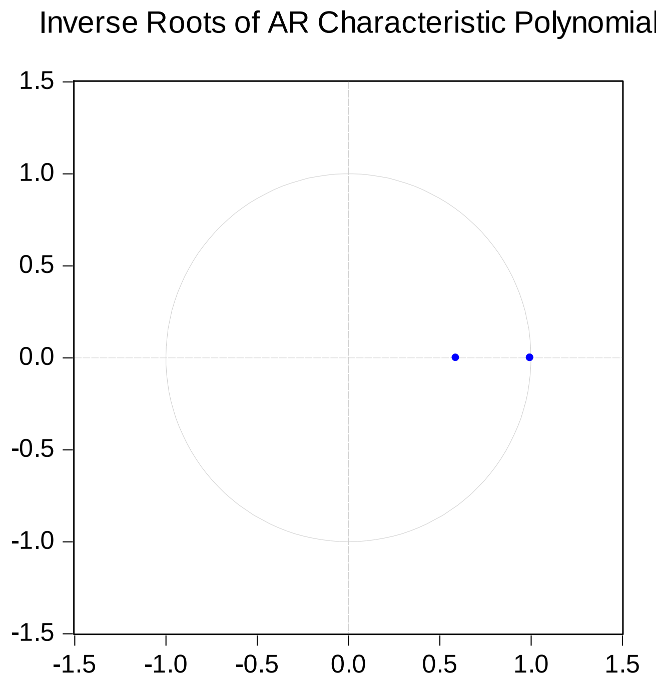


CO2 EMISSIONS & GDP

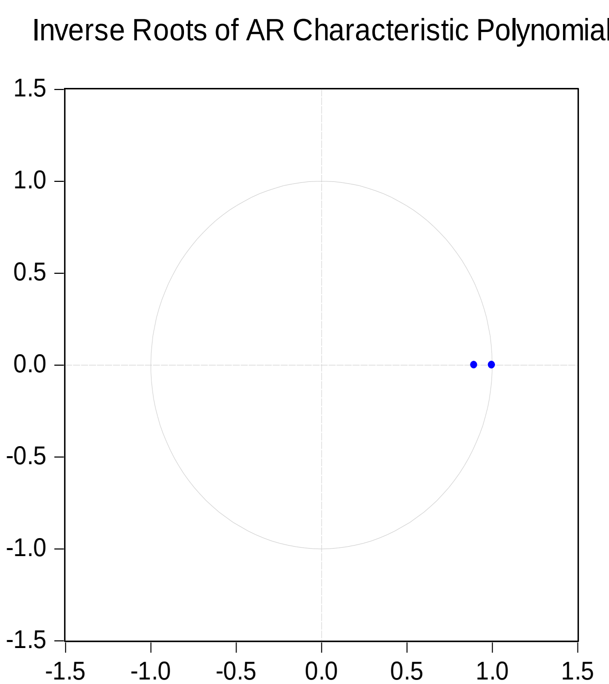
Figure 171: Results of stability test for Indonesia



REC & GDP

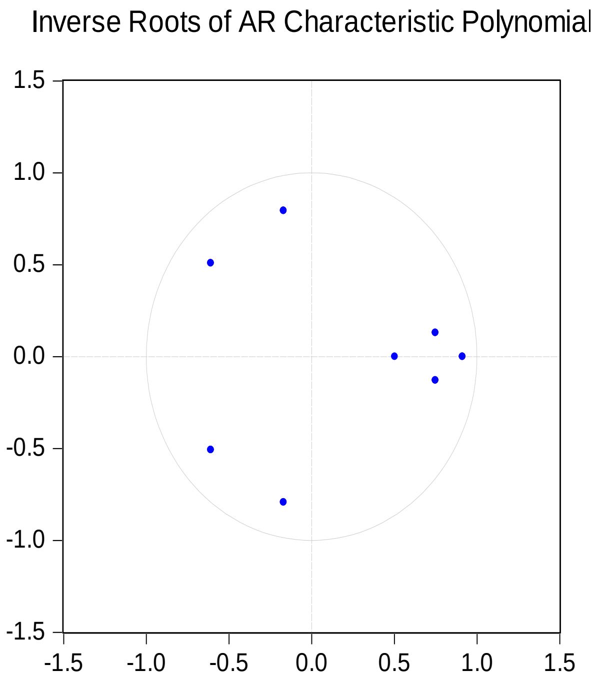


REC & CO2 EMISSIONS

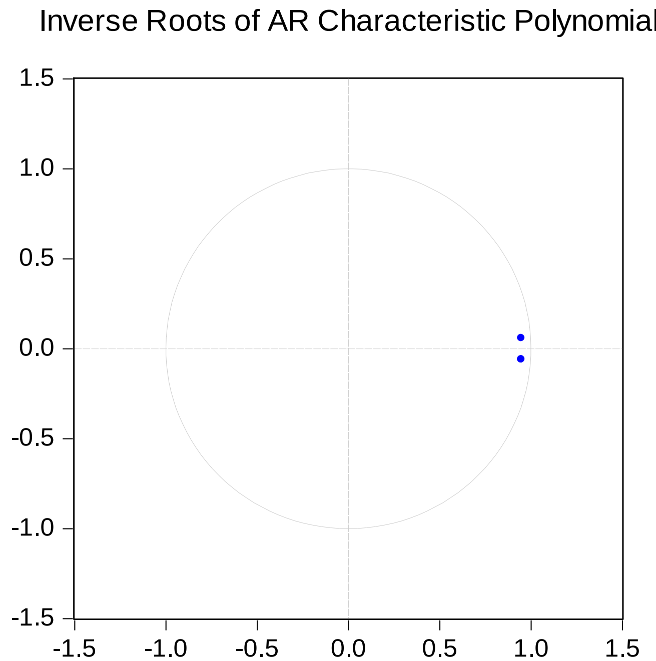


CO2 EMISSIONS & GDP

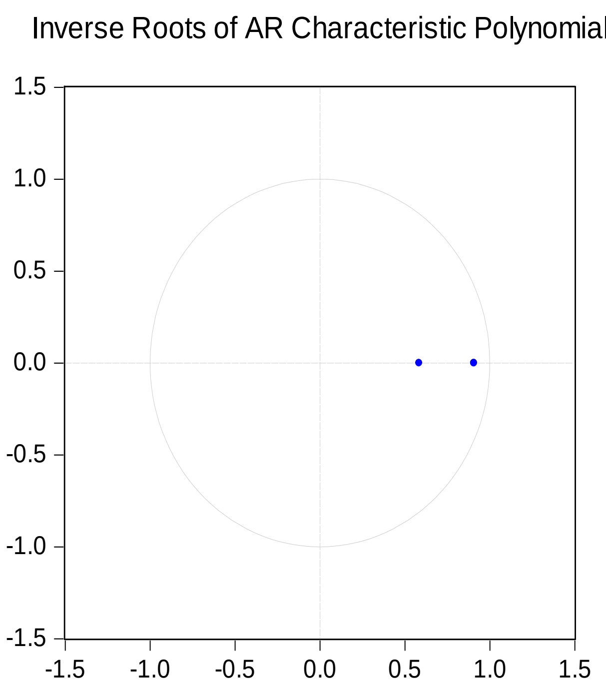
Figure 172: Results of stability test for Malaysia



REC & GDP

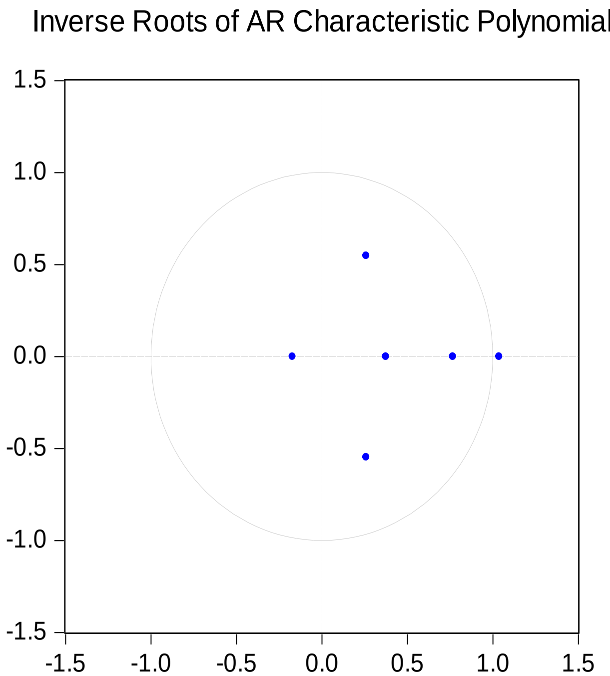


CO2 EMISSIONS & GDP

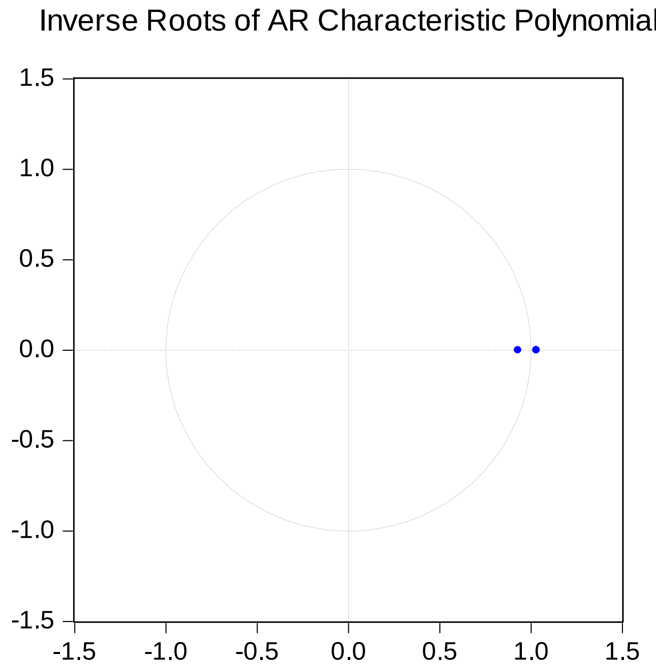


REC & CO2 EMISSIONS

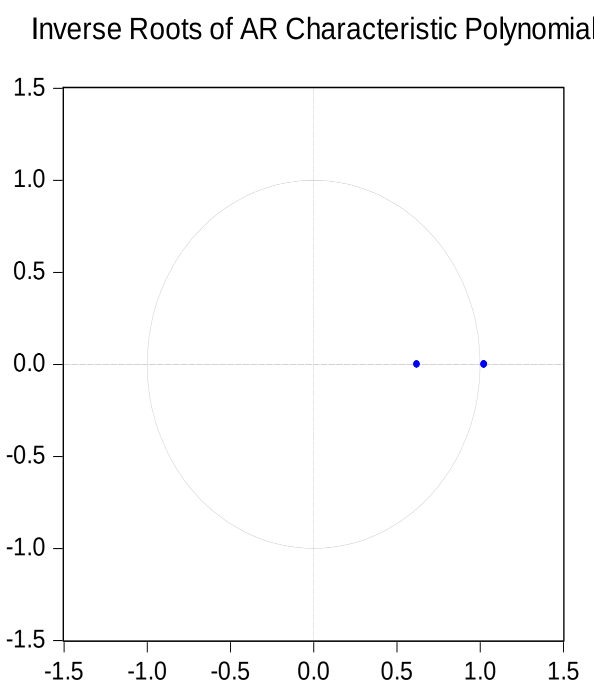
Figure 173: Results of stability test for Philippines



REC & GDP



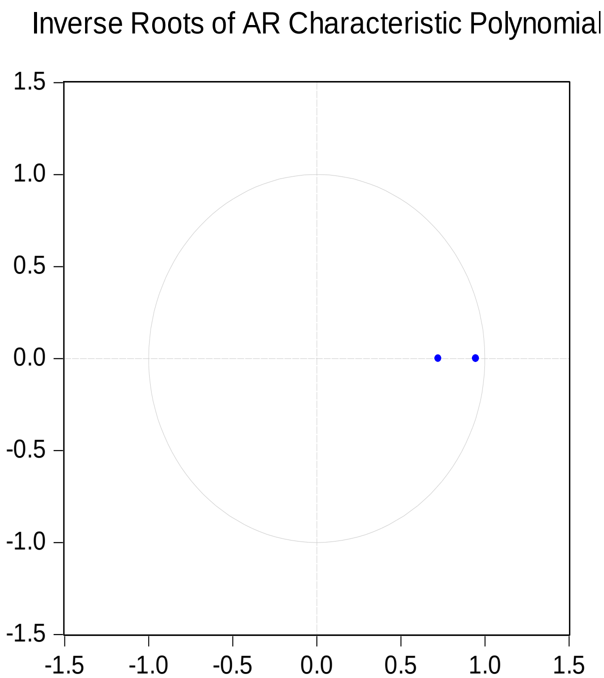
CO2 EMISSIONS & GDP



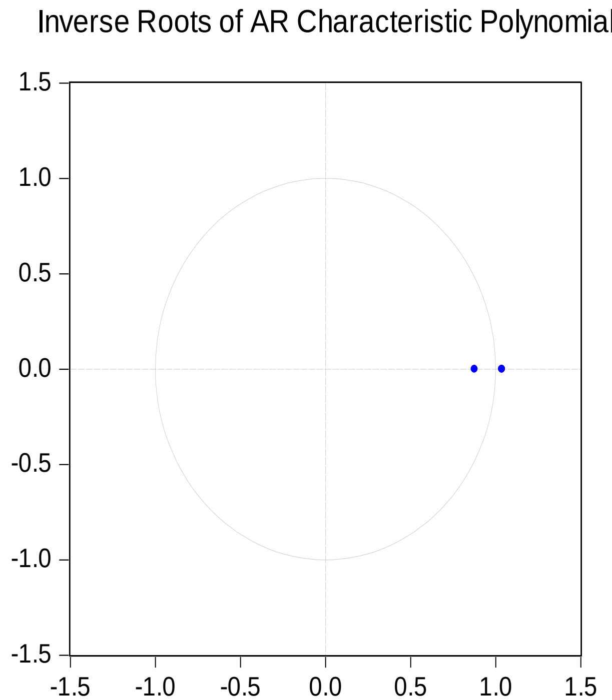
REC& CO2 EMISSIONS

Figure 174: Results of stability test

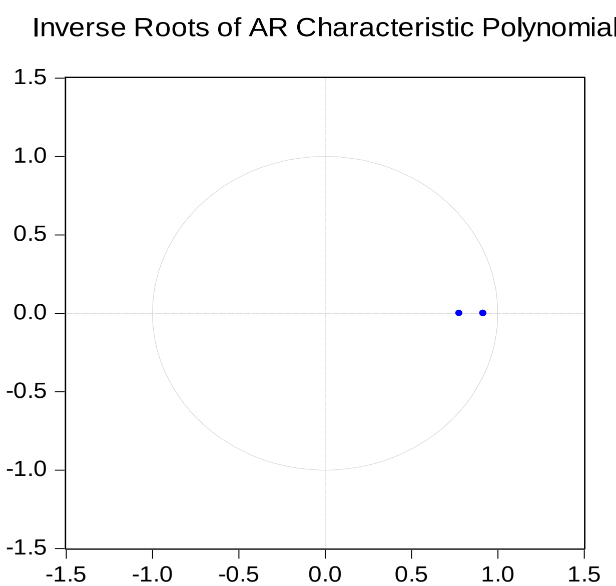
Thailand



REC & GDP



CO_2 EMISSIONS & GDP



REC & CO_2 EMISSION

In case of the stability tests conducted to check whether the model is stable, for each of the countries as indicated in figures 169,170,171,172,173 and 174 the roots lie within the circle indicating stability.

CHAPTER 6

FINDINGS, CONCLUSION AND SUGGESTIONS

6.1 Determinants of energy consumption

Economic growth, Exchange rate, financial development and trade openness have a significant impact on energy consumption for China. Since the 13th Five Year Plan which ended in the year 2020 focused on expanding exports, increasing outbound and inbound investment as well as strengthening the domestic currency and the GDP of the country, energy use will have increased. A positive sign is that the 14th Five Year Plan had stressed upon the need to cap carbon emissions and reducing coal consumption (non- renewable energy consumption) in addition to expanding non-fossil fuel (hydro power and nuclear energy) energy generation by 20% of energy mix. **(chinadialogue.net).** Therefore, although energy needs will have increased, China is making efforts to reduce the negative impact of energy consumption on the environment. A long run relationship among the variables also exists where the energy consumption of China is able to correct itself towards long run equilibrium by 27% after a shock in the previous period. According to Toda Yamamoto Causality test, exchange rate and trade openness causes energy consumption in China. In India, results suggest that GDP, Industrialisation and exchange rate have a significant impact on energy consumption. In addition, energy consumption is caused due to financial development and GDP according to Toda Yamamoto causality test. The Government of India has stressed upon encouraging domestic production and consumption through ‘Make in India’ initiatives and encouraging exports which leads to industrialization, financial development and economic growth thereby encouraging energy consumption.

While for Indonesia and Malaysia, Industrialisation and Trade openness causes energy consumption and for Malaysia there exists a long run relationship between the variables according to VECM which is in line with **Islam et al. (2013); Shahbaz et al. (2015)**. The 11th Five Year Plan (2016-2020) of Malaysia has focused on increasing exports to improve the country’s trade balance. Besides, the government has aimed to promote productivity and investment to increase sustainable economic growth in other words green growth. Therefore, energy needs of Malaysia will expand. In case of the Philippines, GDP, Industrialization, financial development and trade openness have a significant impact on the energy consumption. By 2022, the development plan of the Philippines focuses on alleviating the country to upper middle income by lowering poverty and unemployment rates in rural areas through inclusive growth. **(pdp.neda.gov.ph)** This will further increase energy consumption.

GDP, exchange rate, financial development and trade openness has a significant impact on energy consumption of Thailand. However, Toda Yamamoto causality test indicates that GDP causes energy consumption of Thailand. The 12th National Economic and Social Development Plan focuses on promoting its industrial sector through advanced science, technology and innovation thereby generating economic value added (EVA) as well as enhancing the potential of existing production and service base by strengthening connectivity in the manufacturing sector. Besides, the development plan aims to expand Thai outward investment and making the financial sector more efficient and competitive. This will lead to the overall growth and development of the country resulting in increased energy requirements.

It is evident that the energy consumption needs of all countries under study will increase in the future as analysis indicate that the various select factors have a significant impact on energy consumption. Therefore, there is a need to invest in discovering renewable sources of energy to sustain economic development.

6.2 Relationship between energy consumption and economic growth

In case of China both variables i.e. energy consumption and GDP were found to have mixed integration. Therefore, in order to find out long term relationship we employed ARDL Bounds testing approach where both variables were concluded to have long term relationship however VECM indicated that variables are unable to adjust to equilibrium after a deviation. Toda Yamamoto causality test indicated that there exist a unidirectional causal relationship from economic growth to energy consumption for China.

Energy consumption and GDP for India were found to be stationery at first difference. Therefore, we applied Johansen's Cointegration test to identify long term cointegrating relationship. Results indicated that there exists no long term cointegrating relationship between the variables which allowed us to run a VAR modal. VAR indicated that GDP are being affected by the past values of energy consumption at lag 1 and its own past values at lag 2. In Addition there exist a causal relationship running from GDP to Energy consumption supporting the conservation hypothesis which is in line with **Benjamin S.Cheng (1999)**. Therefore, the economic growth of India is not dependent on energy consumption.

Energy consumption and GDP of Indonesia were found to be stationery at first difference through ADF and PP unit root test. Therefore, Johansen's cointegration test could be applied to find out if there exists a long run relationship. Results indicated that there exists no long run cointegration between the variables. VAR was employed where results indicated that GDP is affected by the past values of energy consumption at lag 1. Toda Yamamoto causality test indicated that there is no causal relationship between the variables supporting neutrality hypothesis.

In case of Malaysia, energy consumption and GDP were found to be stationery at first difference therefore Johansen's cointegration test was employed to test long run cointegrating relationship between the variables. Results indicated that there is no cointegrating relationship. There VAR was employed to find out if GDP is affected by energy consumption and its past values as well as its own past values. GDP is affected by the past values of energy consumption at lag 1. Toda Yamamoto causality test indicated that there exist a unidirectional causal link running from energy consumption to economic growth supporting the growth hypothesis.

Energy consumption and GDP of Philippines and Thailand were found to be stationery at first difference according to ADF and PP unit root test. Therefore, we employed Johansen's cointegration test to understand if there is a long- term cointegrating relationship between the variables. Results indicated that there is no long run cointegrating relationship. VAR model was applied where that GDP are being affected by the past values of energy consumption at lag 1 and its own past values at lag 2. Toda Yamamoto causality test indicates that economic growth causes energy consumption supporting the conservative hypothesis.

In case of China, India, Philippines and Thailand, economic growth leads to energy consumption. Since these economies are rapidly growing and expanding, the consumption of energy will continue to grow requiring these countries to rely on non-conventional sources of energy to prevent the harmful effects of conventional energy consumption on the environment. while for Malaysia energy consumption leads to economic growth. For Malaysia, since energy consumption drives growth of the economy, sustainable growth and development is vital through the reliance on clean energy.

6.3 Relationship between energy consumption and economic growth in select sectors of Newly Industrialised Countries

Industrial energy consumption is cointegrated with economic growth in China according to ARDL bound testing approach and the same is able to correct itself after a deviation in the previous period according to VECM by 31%. Besides, growth in the agricultural sector causes energy consumption while the reverse is in the case of the industrial sector. In case of India, energy use and value added are cointegrated in the industrial and residential sector however only in the industrial sector energy consumption is achieves equilibrium affect a shock in the previous period while growth in the agricultural, industrial and service sector causes its energy consumption in each sector which is in line with the findings of a study conducted **Nain et al. (2017).** Energy consumption and value added of the agricultural sector in Indonesia is cointegrated however VECM does not indicate a long run relationship. Toda Yamamoto causality test advocates that energy use in the agricultural sector causes growth of the sector. For Malaysia, ARDL bounds test does not indicate cointegration between energy consumption and economic growth for all select sectors under study while Toda Yamamoto causality test indicate that energy consumption causes economic growth only in the service sector. Cointegration is found only in the service sector between the energy consumption and economic growth for the Philippines and VECM also indicates that there exists a long run relationship. Moreover, growth in the agricultural, industrial and service sector causes energy consumption according to Toda Yamamoto causality test. Cointegration exists only in the agricultural sector between energy consumption and economic growth in Thailand however there is no long run relationship between variables according to VECM. Moreover, a bi-directional causal link exists between agricultural energy consumption and economic growth.

The Industrial sector of China supports the growth hypothesis where energy consumption leads to growth of the sector i.e. the sector is energy dependent while the conservative hypothesis hold true in case of the agricultural, industrial and service sector of India and Philippines where growth leads to energy consumption. Similar to China, energy use in the agricultural sector causes growth of the sector in case of Indonesia and growth hypothesis hold true for the service sector in case of Malaysia. Therefore, it is important that China and Indonesia focus on identifying and employing sustainable and eco-friendly sources of energy to support its industrial sector so that growth is of the industrial sector does not have an adverse impact on the environment. Similarly, Malaysia should follow the same so that sustainable growth and development of the service sector is ensured by relying on replenishable sources of energy. India and the Philippines should also direct efforts towards employing renewable sources of energy to satisfy energy requirements as the primary, secondary and tertiary sector of both economies are growing and developing at an increasing rate.

6.4 Relationship between renewable energy consumption, carbon emissions and economic growth

With respect to China since renewable energy consumption and GDP as well as renewable energy consumption and CO2 emissions had mixed order of integration, ARDL bound testing approach to cointegration was employed. Both pairs of variables were found to be cointegrated. While in case of CO2 emissions and GDP, both variables were stationery at level and therefore linear regression was employed which indicated that GDP does have an impact on CO2 emissions to the extent of a 0.62% increase in CO2 emissions. Toda Yamamoto causality test results indicates that there exists a unidirectional causality running from economic growth to renewable energy consumption and from CO2 emissions to economic growth. Carbon emissions causes economic growth and therefore consistent efforts should be made and policies implemented to ensure that the economy relies on renewable energy consumption to fuel economic activities as growth and development of the Chinese economy promotes reliance on renewable energy consumption.

In India, renewable energy consumption and CO2 emission as well as CO2 emissions and GDP had mixed integration and therefore ARDL bound testing approach to cointegration was applied to find out if the variables were cointegrated. Results indicate that only Renewable energy consumption and CO2 emissions are cointegrated. Since renewable energy consumption and GDP were stationery at levels, linear regression was applied to check for impact or dependence. Renewable energy consumption does have an impact on economic growth of India where a percent change in renewable energy consumption leads to 0.25% increase in GDP. Moreover, GDP causes renewable energy consumption according to Toda Yamamoto causality test and renewable energy consumption causes CO2 emissions while carbon emissions causes economic growth. These results are in line with the findings of a study conducted by **(Destek, 2016)**.

These results indicate that renewable energy consumption has a significant impact on GDP and GDP causes renewable energy consumption. However, renewable energy consumption causes CO2 emissions as well. Therefore, as the use of renewable energy consumption increases, growth and development of the economy takes place which results in further increase in renewable energy consumption. 'India is one of the largest producer and consumer of coal in the world. Though there is a small decline of 2.66% in 2019-20 over 2018-19, there has been an upward trend in the consumption of coal in the country during the period 2010-11 to 2018-19. CAGR is 5.28% from 2010-11 to 2019-20(P).' (**Energy Statistics India 2021**). This could be the reason as to why renewable energy consumption has not yet been able to mitigate CO2 emissions. However, with recently concluded COP 26, the Indian Government has committed to install 500 GW of renewable energy by the year 2030.

All three pairs of variables for Indonesia were stationery at first difference, therefore Johansen Cointegration test was applied and results indicated that no cointegration exists among the variables. However there exists a unidirectional causality from carbon emissions to renewable energy consumption. This is in line with the finds of a study conducted by **Personal et al., (2018).** This is because as carbon emissions have increased over the years, the country has recognized the importance of renewable energy consumption and efforts are made to invest and employ non-conventional sources of energy. For Malaysia, cointegration does not exist between renewable energy consumption and GDP however cointegration exists between CO2 emissions and GDP according to ARDL bound testing approach to cointegration and the same is in the case of renewable energy consumption and CO2 emissions according to Johansen's Cointegration test. Toda Yamamoto causality test indicates that renewable energy consumption causes CO2 emissions and GDP and carbon emissions causes GDP. These results are in line with the findings of **Watthanabut & Jermsittiparsert (2020); Odugbesan (2020)** This indicates that although renewable energy consumption leads to economic growth, Malaysia still relies on conventional energy sources to sustain economic activities. Therefore, carbon emissions cause GDP. The country should strive to achieve the Sustainable Development Goals (SDG's) eg. efforts to increase the use of non-conventional energy.

In the Philippines, there exist a long run cointegrating relation between renewable energy consumption and CO2 emissions but the same is not in the case of renewable energy consumption and GDP as well as CO2 emissions and GDP according to ARDL bound testing approach to cointegration and Johansen's Cointegration test resp. However, Toda Yamamoto causality test results indicate no causality between variables.

Recently India, Indonesia, Philippines along with South Africa have come together under a pilot program known as Accelerating Coal Transition investment program where funds worth 2.5 billion USD is granted under the Climate Investment fund to aid in the transition from coal to clean energy with the objective to limit the global temperature rise to 1.5 degrees Celsius by 2030. Therefore, countries are making efforts to reduce dependence on conventional energy.

With respect to Thailand, a long run cointegrating relationship exists between CO2 emissions and GDP as well as renewable energy consumption and CO2 emissions but not between renewable energy consumption and GDP according to ARDL bound testing approach to cointegration and Johansen's Cointegration test resp. There exists a unidirectional causal relationship from CO2 emissions to renewable energy consumption. This indicates that Thailand is dependent on conventional energy to fuel growth and development which in turn leads to increase in CO2 emission of the country. Increase in carbon emissions leads the country to understanding and promoting the need to rely on renewable energy.

6.5 CONTRIBUTION OF THE STUDY

- This study enhances ones understanding on the energy consumption- economic growth nexus with reference to the Newly Industrialised countries of Asia.
- This study identifies the relationship between energy consumption and economic growth at an aggregate and sectoral level as well the factors that influence energy consumption.
- Besides examining the relationship between renewable energy consumption and economic growth, emphasis is laid upon the urgent need to identify sources of renewable energy so that the ever-increasing energy requirements of these countries can be satisfied in a sustainable manner.

6.6 POLICY IMPLICATIONS

- The rapid growth and development of the Newly Industrialised Countries require the continuous availability of energy. The energy requirements are largely satisfied through conventional sources which are non- renewable and therefore the threat of depletion is a cause for concern. Moreover, consumption of conventional energy causes a negative impact on environment and biodiversity.
- Therefore, the need to employ renewable energy is essential to ensure sustainability and to prevent environmental degradation. Therefore, understanding how renewable energy consumption interacts with economic growth and carbon emissions helps to focus on renewable energy consumption as the means to achieve sustainable growth and development of a country.

6.7 SCOPE FOR FUTURE RESEARCH

A similar study could be conducted for specific panel of countries as members of certain international organisations through panel data econometric techniques.

The variable renewable energy consumption can be studied for the first and third objective dealing with determinants of energy consumption and the relationship between sectoral energy consumption and economic growth.

This study could be applied to the dependence of economic growth on the supply of various sources of energy.

<u>Research Paper Publications</u>

Karen Fernandes, Y.V. Reddy 'Energy Consumption and Economic growth in Newly Industrialised Countries of Asia' - **International Journal of Energy Economics and Policy**, 2020, 10(4), 384-391. **Scopus Q1 journal**

Karen Fernandes, Y.V. Reddy 'Determinants of Energy Consumption and Economic growth in Newly Industrialised Countries of Asia' **International Journal of Energy Economics and Policy**, 2021, 11(1), 93-100. **Scopus Q1 journal**

<u>Research Paper Presentations:</u>

Presented a poster at Conversations on Research (CoRe): IGIDR PHD Colloquium, from November 5th- 8th 2019, Goregaon East Mumbai.

Presented a paper titled 'Energy Consumption and Economic growth in Newly Industrialised Countries of Asia' at the 3rd International Conference on Business, Economics and Sustainable development (ICBESD 2020) at NISM Campus Patalganga, Mumbai on 3rd March 2020.

Presented a paper titled 'Determinants of Energy Consumption and Economic growth in Newly Industrialised Countries of Asia' at the Global Conference on Advances In Business and Social Sciences (Online) at Tsuruoka, JAPAN on December 5-6, 2020.

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