

**School of Economics and Finance  
Curtin Business School**

**Oil Consumption, Pollutant Emission, Oil Price Volatility and  
Economic Activities in Selected Asian Developing Economies**

**Shuddhasattwa Rafiq**

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## **Declaration**

This dissertation was written while I was studying at the School of Economics and Finance, Curtin Business School at the Curtin University of Technology. To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

**To the loving memories of,**  
My grandfather, Shamsudding Ahmed  
and  
My mother, Zeenat Ara Rafiq  
Two great persons whose blessings have inspired me to reach at this height.

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*Shuddhasattwa Rafiq*

## Abstract

It is now well established in the literature that oil consumption, oil price shocks, and oil price volatility may impact the economic activities negatively. Studies identifying the relationship between energy and/or oil consumption and output primarily take two different approaches. One approach includes energy or oil consumption in addition to output, labour, and capital. The other approach takes energy and/or oil, output and prices. Based on these two models most of the previous studies suggest energy conservation policies for different economies. However, none of the previous studies considered both of these models jointly to make policy implications and there are not many studies investigating oil consumption-output relationship in a multivariate model in the context of developing economies. Furthermore, one of the important variables in making any conservation policies, carbon emission, is omitted from the models.

Similarly, there has been a large body of literature investigating the impact of oil price shocks in different economies. Nevertheless, studies analysing the impact of oil price volatility on economic activities are very limited. More importantly, studies analysing the impact of oil price volatility in developing economies are almost non-existent. In the light of increasing demand for oil from the developing nations, comprehensive studies on identifying the impact of oil consumption, oil prices, and oil price volatility on developing economies is warranted.

Hence, in this thesis, the contribution of oil in economic development is investigated with the help of two different models. The first model, termed as *supply-side approach*, analyses the contribution of oil consumption in economic activities within the traditional production function framework. The second model, termed as *demand-side approach*, analyses the contribution of energy consumption in economic activities in two stages. In the first stage, oil consumption demand is analysed by a tri-variate model having oil prices as the third variable in addition to oil consumption and GDP. In the second stage, carbon emission output is determined in a tri-variate model with carbon emission as the third variable along with oil consumption and output. This thesis also performs a unique task of analysing the impact of volatility on world crude oil prices on the economic activities of six Asian developing economies.

With respect to the oil consumption-output relationship, despite dissimilarities in results for causality relationships between oil consumption and output in three different models for different countries, one common result emerges. Except for the Philippines, all other countries are found to be oil dependent either from *supply-side* or from *demand-side* or from both of the sides. This implies that for all the considered developing economies, except for the Philippines, oil conservation policies seem to be harder to implement as that may retard their economic growth. In addition to that, one very important findings of the empirical analysis based on the equation regarding pollutant emission output is that for all the countries, except for Malaysia, output Granger causes pollutant emission ( $\text{CO}_2$ ) both in the short run and long run.

With respect to the impact of oil price volatility on economies, this study finds that oil price volatility seems to impact all the economies in the short run. According to the results, oil price volatility affects GDP growth in China and Malaysia, GDP growth and inflation in India and Indonesia, while in the Philippines volatility in oil prices impacts inflation. However, in Thailand the impact channels are different for pre- and post-Asian financial crisis period. For Thailand, it can be inferred that oil price volatility impacts output growth for the whole period; however, after the Asian financial crisis the impact seems to disappear.

Based on the comprehensive study within three different theoretical frameworks the policy implications regarding oil consumption-output relationship can be summarised as follows. For the Philippines, where uni-directional causality from income to oil consumption is found, she may contribute to the fight against global warming directly implementing energy conservation measures. The direction of causality indicates that the oil conservation policies can be initiated with little or no effect on economic growth. For rest of the oil dependent countries where either bi-directional causality or uni-directional causality from oil consumption to output is found in any of the models, since oil is a critical determinant of economic growth in these countries, limiting its use may retard economic growth. Nevertheless, all of these countries may initiate environmental policies aimed at decreasing energy intensity, increasing energy efficiency, and developing a market for emission trading. These countries can invest in research and development to innovate

technology that makes alternative energy sources more feasible, thus mitigating pressure on the environment.

According to the impact analysis of oil price volatility on economic activities, the policy implications are as follows. In Thailand, the results after the financial crisis show that adverse effect of oil price volatility has been mitigated to some extent. It seems that oil subsidization of the Thai government by introduction of the oil fund and the flexible exchange rate regime plays a significant role in improving economic performance by lessening the adverse effect of oil price volatility on macroeconomic indicators. For all other countries, the impact of oil price volatility is also of short term. Hence, the short-term impact of oil price volatility on the concerned economies may be exerted though the uncertainty born by the fluctuations in the crude oil price in the world market. As far as the impact on GDP growth is concerned, the short-run impact may also be transmitted through the investment uncertainties resulting from increased volatility in oil prices. However, from the Thai experience it can be inferred that flexible exchange rate regime insulate the economy in the short run from any adverse impact from oil price volatility on growth. Hence, it can be suggested that good subsidization policy with considerable knowledge on international currency market, both spot and future, may shield the economies from adverse consequences due to the fluctuation in oil prices in the short run. Nevertheless, this may affect other sectors of the economy like, inflation, interest rate, government budget deficit, etc.

**Key Words:** Developing countries, oil conservation, oil price volatility, pollutant emission, cointegration, error correction model, Granger causality, generalized impulse response analysis, generalized forecast error variance decomposition.

**JEL Classification:** O13; C22; C32; Q43; Q48



## Abbreviations

ABDE	Andersen, TG, Bollerslev, T, Diebold, FX, & Ebans, H
ABDL	Andersen, TG, Bollerslev, T, Diebold, FX, & Labys, P
ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criterion
ARDL	Autoregressive Distributed Lag
BP	British Petroleum
BTU	British Thermal Unit
CD	Compact Disk
CES	Constant Elasticity of Substitution
CIRTS	Curtin International Research Tuition Scholarship
CO <sub>2</sub>	Carbon Dioxide
CPI	Consumer Price Index
CV	Conditional Volatility
DF	Degrees of Freedom
DR.	Democratic Republic
EC	Error-Correction
ECM	Error Correction Model
EIA	Energy Information Administration
ETC	Error Correction Term
FPE	Final Prediction Error
G7	Group of Seven
GARCH	Generalized Auto-Regressive Conditional Heteroskedasticity
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product

*Continued*

GGDP	GDP Growth
GGDP_SA	Seasonally adjusted GDP Growth
GNP	Gross National Product
HQC	Hannan and Quinn Criterion
HS	Historical Volatility
IAEE	International Association for Energy Economics
IFS	International Financial Statistics
ILO	International Labour Organization
IMF	International Monetary Fund
INF	Inflation
IRF	Impulse Response Functions
IV	Implied Volatility
KLE	Capital-Labour-Energy
KLEM	Capital-Labour-Energy-Material
KPSS	Kwiatkowski-Phillips-Schmidt-Shin
LCO <sub>2</sub>	Log of Carbon Emission
LK	Log of Capital
LL	Log of Labour
LO	Log of Oil Consumption
LogL or LL	Log Likelihood
LP	Log of Oil Price
LPG	Liquefied Petroleum Gas
LR	Likelihood Ratio
LY	Log of Output
Mb/d	Million Barrels per Day

*Continued*

MEI	Main Economic indicator
MLE	Maximum Likelihood Estimation
MSE	Mean Square Error
NIC	Newly Industrialized Countries
NYMEX	New York Mercantile Exchange
OECD	Organization of Economic Co-operation and Development
OLS	Ordinary Least Square
OPEC	Organization of Petroleum Exporting Countries
OPV	Oil Price Volatility
P&E	Production and Exploration
PIM	Perpetual Inventory Method
PP	Phillips-Perron
R&D	Research and Development
RBC	Real Business Cycle
RV	Realized Volatility or Realized Oil Price Variance
S&P	Standard & Poor
SBC	Schwarz Bayesian Criterion
S.D.	Standard Deviation
S.E.	Standard Error
SV	Stochastic Volatility
UK	United Kingdom
US	United States
USAEE	United States Association for Energy Economics
VAR	Vector Autoregression
VDC	Variance Decomposition

*Continued*

VEC	Vector Error Correction
VECM	Vector Error Correction Model
VMA	Vector Moving Average
WDI	World Development Indicators

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# Chapter 1

## Introduction

### 1.1 The Setting

Oil, like other primary commodities, is a vital input in the production process of an economy. Primary commodity prices affect aggregate price levels positively as commodities are used as raw materials in industrial production (Bloch, Dockery & Sapsford 2006). Similarly, oil is needed to generate electricity, run production machinery, and transport the output to the market. However, like prices of any other commodities the behaviour of crude oil price also portrays price swings in times of shortage or oversupply. The price cycles in world crude oil market may also vary depending on fluctuations from the demand side as well as from the supply possibility from OPEC and non-OPEC supply sources. As the Appendix Figure 1 demonstrates the world experienced two major oil shocks of 1970s, one in 1973-1974 due to Arab Oil Embargo arising from Yom Kippur war in Middle East starting from October 5, 1973, and the other in 1978-1980 due to the Iranian revolution and Iran-Iraq war which led to huge amount of production loss.

In response to these two consecutive oil shocks in the early and late 1970s, a considerable number of studies have examined the impact of oil price shocks on economic activities. Pioneering work by Hamilton (1983) in the early 1980s on the relationship between oil price and economic activities spurred researchers to look into the issue in greater detail. Several path breaking studies, like Burbridge & Harrison (1984), Gisser & Goodwin (1986), Mork (1989), Jones & Kaul (1996), Shiu-Sheng Chen & Chen (2007), followed analysing the relationship between oil prices and economic activities. With the contribution of all these scholarly studies<sup>1</sup> along with other studies in this field, it is now well established in the literature that oil price shocks exert adverse impact on different macroeconomic indicators through raising production and operational costs. Alternatively, large oil price changes, either increases or decreases, *i.e.* volatility may affect the economy adversely because they

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<sup>1</sup> There is a huge body of related studies which could not be mentioned here. Nevertheless, chapter 2 of this thesis endeavours to mention those in detail.

delay business investment by raising uncertainty or by inducing costly sectoral resource reallocation (Guo and Kleisen 2005).

The first study to investigate the impact of oil price volatility in the US economy is Ferderer (1996). Since then, there have been a few studies in the literature that investigate the impact of oil price volatility on economic activities. However, studies analysing the impact of oil price volatility in developing economies are almost non-existent. This may be due to the lack of availability of required data. Hence, this thesis tries to fill this gap by investigating the impact of oil prices and oil price volatility on the economic activities of six major Asian developing countries. It is to be noted here that, to the author's knowledge, this is one of the early studies if not the first study to investigate the impact of oil price volatility on developing economies.

Another major avenue in the energy-economy relationship is the analysis of impact of energy consumption on economic activities. Statistically significant association between energy consumption and economic growth is now well established in the literature. However, it still remains an unsettled issue whether economic growth is the cause or effect of energy consumption. Theoretically, causality may run from both directions; from growth to energy consumption and from energy consumption to growth. Although standard growth models do not include energy as an input of economic growth, the importance of energy in modern economy is undeniable. Increased economic activity requires greater amount of energy to run the wheel of growth. Without energy, the production process of an economy will come to a standstill. Moreover, as the economy grows, income of the people also grows, which in turn leads to higher demand for energy like electricity, oil and gas by households as well as production machinery. The pioneering empirical study in this area was conducted by Kraft and Kraft (1978). Since then, a large body of literature evolved investigating this energy consumption and economy relationship<sup>2</sup>. The popularity of these studies related to identifying the direction of causality emanates from its relevance in national policy-making issues regarding energy conservation.

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<sup>2</sup> Here, the studies analysing energy consumption economy relationship includes all the studies irrespective of whether they investigate the impact of aggregate energy consumption or disaggregate energy consumption from energy sources, like electricity, oil, gas, etc.

Primarily, studies in this field focus on bi-variate causality analysis including energy consumption and output. Afterwards, because of the criticism of bi-variate studies due to omitted variable problem, two different approaches emerge in the empirical literature. In addition to energy consumption and output, one approach includes price as the third variable to have some indication about *demand-side* responses from the economy and the other approach includes labour and capital to have some idea about the impact of energy consumption on output from the *production-* or *supply-side* of the economies. A large body of literature based on both the time-series econometric and panel data analyses have been performed within these frameworks in recent years<sup>3</sup>. In addition to the above studies, some recent studies include other variables in their analysis to investigate the energy consumption-economic activities relationship (Ang (2007, 2008) includes pollutant emission, Karanfil (2008) includes unrecorded economic activity, for example). However, none of the previous studies make policy implications regarding energy conservation possibilities based on a combined analysis of these two frameworks within the same study.<sup>4</sup>

A common practice in the previous studies analysing the impact of energy consumption on economic activities including prices is to take CPI (Consumer Price Index) as the proxy of energy prices since there is no data available to represent aggregate energy prices. The inclusion of disaggregate energy sources like crude oil gives some studies an advantage of including pure commodity prices, oil price for example, in their models. Furthermore, a complete *demand-side* analysis cannot be expected without including pollutant emission in addition to prices in the framework as pollutant emission is a major bi-product of the energy consumption process. Hence, this study includes carbon emission in the *demand-side* analysis. Moreover, to the author's knowledge there is no prior study on developing economies that has studied the impact of oil prices on economic activities taking both of these *supply-* and *demand-side* frameworks together. This study also fills this gap in the literature by investigating oil conservation possibilities of the developing countries by implementing a combined analysis of *supply-* and/or *production-side* and a complete *demand-side* mechanism. The *supply-side* analysis is performed within a traditional

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<sup>3</sup> For detail survey of recent literature please see Karanfil (2009).

<sup>5</sup>This thesis discusses substitution possibilities between energy and other inputs in section 2.3. In this section the author cites some articles like Stern (1993), Kaufmann and Azary-Lee (1991) *etc.* analysing this issue.



production function framework. The *demand-side* analysis is performed through implementing two different models for oil consumption demand and pollutant emission output.

According to a testimony prepared for the United States Committee on Energy and Natural Resources, Birol (2007a) projects that demand for oil will grow at an average rate of 1.30 percent every year through 2030, which is equal to a daily oil demand of 116 million barrels by 2030 compared to 84 mb/d (million barrels per day) in 2005<sup>5</sup>. This report further claims that most of the increase in oil demand will come from developing countries due to their rapid economic expansion (Appendix Table-1.1). Based on similar analyses of the trends in the increased oil demand from emerging economies, most of the policy makers and energy economists seem to reach a consensus that the major cause of ‘soaring oil prices’ is the increased demand for oil from the rapidly growing economies of Asia. Hence, during this period of ‘peak oil’ concern around the globe, an in-depth study on the oil-growth nexus in the context of major developing countries of Asia is warranted. In this backdrop, this study investigates the impact of oil consumption, oil prices, and oil price volatility on six major developing economies of Asia. Essentially, the economies considered for this purpose are: China, India, Indonesia, Malaysia, Philippines, and Thailand. A brief introduction of the countries is presented below followed by a discussion of research issues and questions. The chapter outline of this thesis is presented at the end.

## **1.2 A Brief Introduction to the Countries Studied**

This thesis investigates the impact of oil consumption, oil prices, and oil price volatility in the deployment process of the six major developing countries of the world, interestingly enough all of these six major developing economies of the world are from Asia. The country selection process is primarily based on the recent history of economic growth, the rate of increase in oil demand in recent years, the projected increase in oil consumption demand based on World Energy Outlook (2007) reference scenario, recent pace of industrialization and trade openness. In this regard,

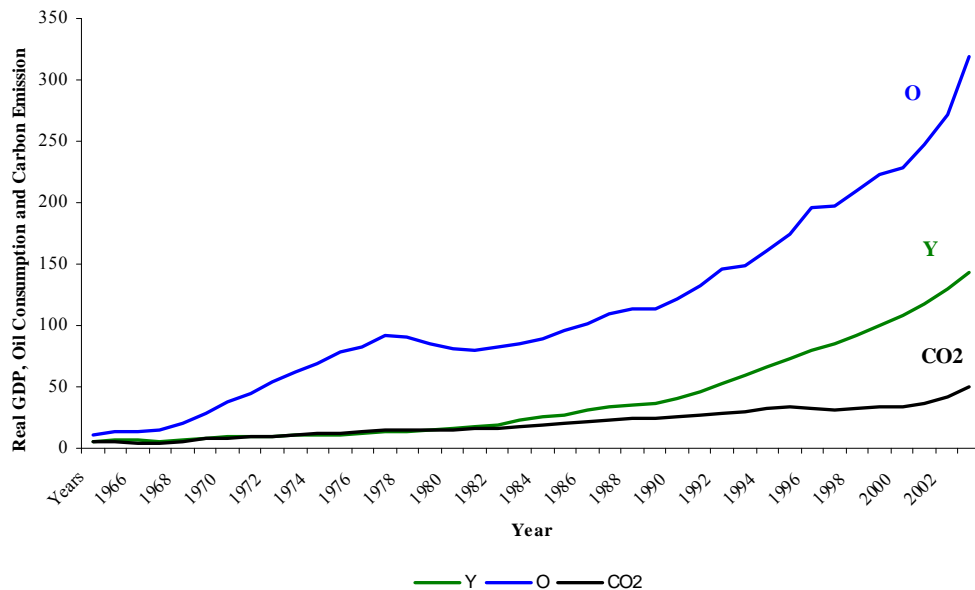
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<sup>5</sup> It is to be noted here that, since Dr. Fatih Birol is the chief economist of International Energy Agency (IEA) his projection is based on the World Energy Outlook (2007), a publication of IEA.

it is worth mentioning that, in 2007 these six countries constitute almost 15.97% of the world's aggregate oil consumption (Appendix Figure 1.2).

The Chinese economy experienced phenomenal growth during the last three decades. Since the initiation of market reforms in the late 1970s, China's growth has been about 9.70% per annum (World Bank Country Brief). Being the world's most populous country with a population of over 1.3 billion, this rapid economic growth has enabled China to lift several hundred million people out of absolute poverty level. However, with strong economic growth, China's demand for energy is surging rapidly, so is China's output of pollutant emission (Figure 1.1).

**Figure 1.1: Real GDP, Oil Consumption, and Carbon Emission Scenario in China**



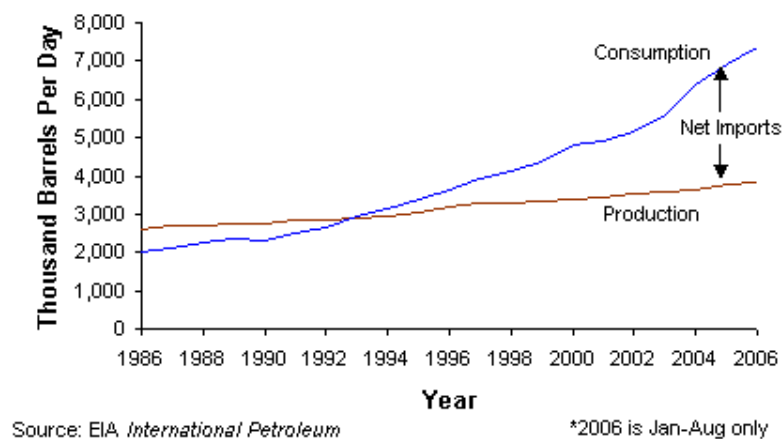
Note: Y, O and CO<sub>2</sub> represents real output, oil consumption in million tonnes and carbon emission in hundred million tonnes, respectively. Real output data is collected from World Development Indicators (WDI) by World Bank, while oil consumption and carbon emission data is found from BP (2008).

According to British Petroleum (BP) (2008), in 2007, China was the second largest consumer of energy products in the world behind the United States, more specifically second largest consumer of oil (9.31% of world total, Appendix Table 1.2). In addition to that, consumption of all fuel types in China has increased significantly in recent years to support this increasing trend in economic growth. Crompton & Wu (2005) shows that in 2003, China consumed 31% of the world's

total coal, 7.6% of oil, 10.7% of hydroelectricity and 1.2% of world's total gas. According to the Appendix Table 1.2, consumption figures for all of the fuels types increased. In 2007, China accounted for 41.27% of world's coal consumption, 9.31% of oil consumption, 15.41% of hydroelectricity consumption and 2.30% of gas consumption. However, the growth of output and energy consumption has its consequences; during this period pollutant emission has also increased raising much concern to world's environmentalists. In addition to coal, oil, gas, and hydroelectricity, the Chinese economy also consumes a significant amount of primary solid and liquid biomass including fuel wood and biogas. Two of the major energy consuming sectors in China are the transportation and industrial sectors. Moreover, EIA (2009) argues that China is not only the world's second largest oil consuming country but also the third-largest importer of oil after the US and Japan. Figure 1.2 shows that due to increased oil consumption China's import for oil is also increasing after 1993.

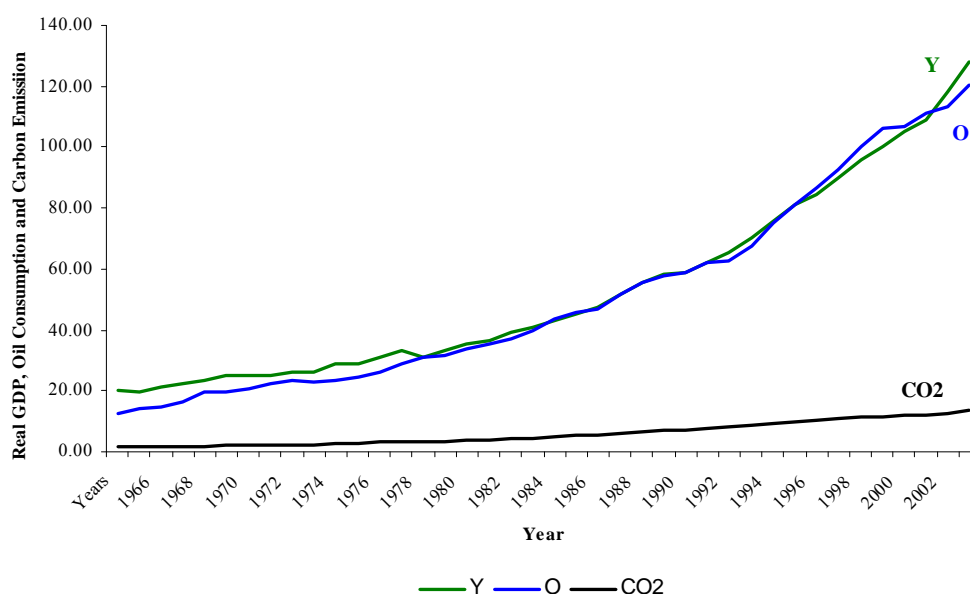
Chinese retail prices for petroleum products are regulated according to locations and the types of consumers. The Government maintains domestic price ceilings on finished petroleum products that have not been consistent with the soaring international energy prices. Furthermore, the refineries get government subsidies to ease the gulf between low domestic prices compared to international oil price trends.

**Figure 1.2: Oil production, Oil Consumption, and Net Export Scenario of China, 1986-2006\***



Rapid economic expansion has also driven up India's energy and oil demand, boosting the country's share of global energy and oil consumption. Being the largest democracy in the world with more than 1.1 billion people, India has also experienced an unprecedented economic growth in recent decades. It is to be noted that, from 2006 to 2007, India's economic growth was about 8.4%. Figure 1.3 demonstrates that this rapid economic growth is associated with significant growth in oil consumption, and carbon emission. Since the Indian government heavily subsidize domestic prices of oil products, such as diesel, LPG (Liquefied Petroleum Gas) and kerosene for its consumers, the demand for petroleum products in India is influenced by the government's pricing schemes.

**Figure 1.3: Real GDP, Oil Consumption, and Carbon Emission Scenario in India**

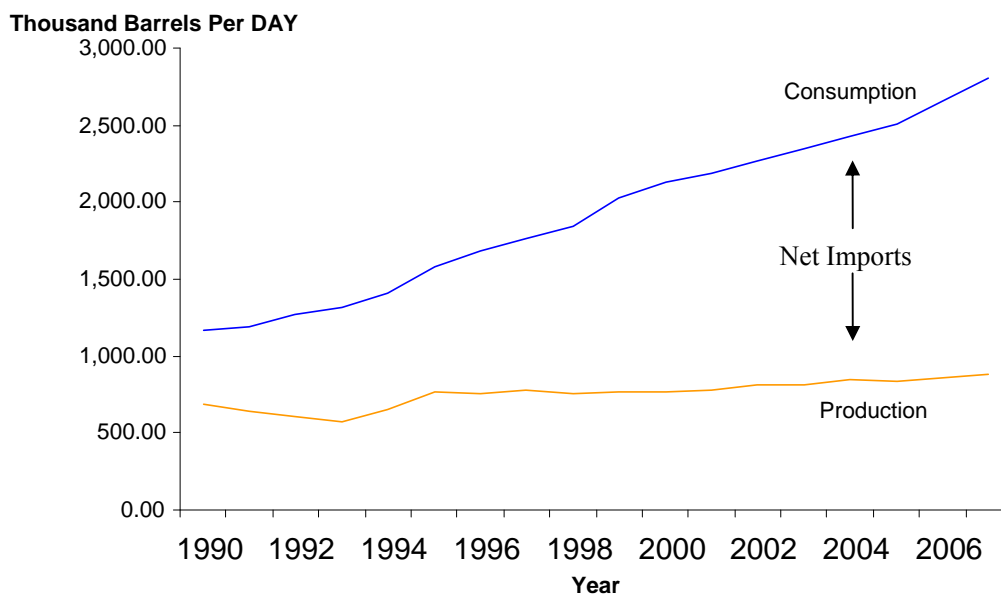


Note: Y, O and CO<sub>2</sub> represents real output, oil consumption in million tonnes and carbon emission in hundred million tonnes, respectively. Real output data is collected from World Development Indicators (WDI) by World Bank, while oil consumption and carbon emission data is found from BP (2008).

With 3.6% and 3.25% of world's total consumption of aggregate energy and oil in 2007 (Appendix Table 1.1), respectively, India is the fourth largest energy and oil consumer in the world following the United States, China, and Japan. However, since India lacks sufficient domestic energy sources, she must import much of her growing energy and/or oil demand. The combination of rising oil consumption and relatively flat production has left India increasingly dependent on imports to meet its

oil demand. Hence, the country is not only experiencing electricity shortage in major areas but is also dependent on oil imports to satisfy increasing demand from industries and transportation sectors (Figure 1.4, overleaf). However, India also consumes a significant amount of primary solid biomass which includes fuel wood.

**Figure 1.4: Oil production, Oil Consumption, and Net Export Scenario of India, 1990-2009\***

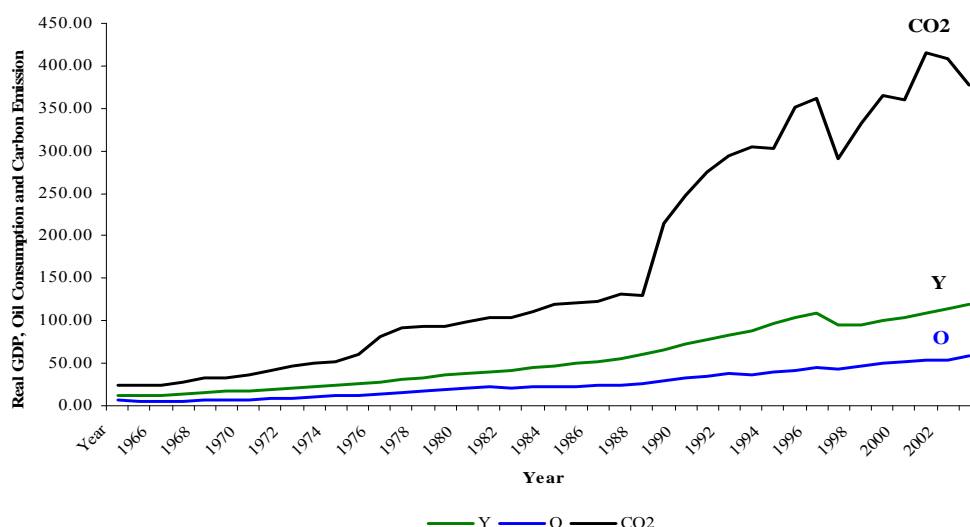


Source: US Energy Information Administration

\*2008-09 is forecast

Indonesia is the fourth largest populous country in the world behind China, India, and the United States. Through transition to democratic process and introduction of rapid decentralization measures, Indonesian economy has experienced strong economic recovery from the Asian financial crisis of 1997. Indonesia joined the Organization of the Petroleum Exporting Countries (OPEC) in 1962. Oil has been the major source of fuel for the Indonesian economy with a consumption of 47.48% of the total consumption of energy (Appendix Table 1.2). According to Figure 1.5 (overleaf), since 1967, the Indonesian economy is steadily growing along with rapid growth in both oil consumption and pollutant emission output.

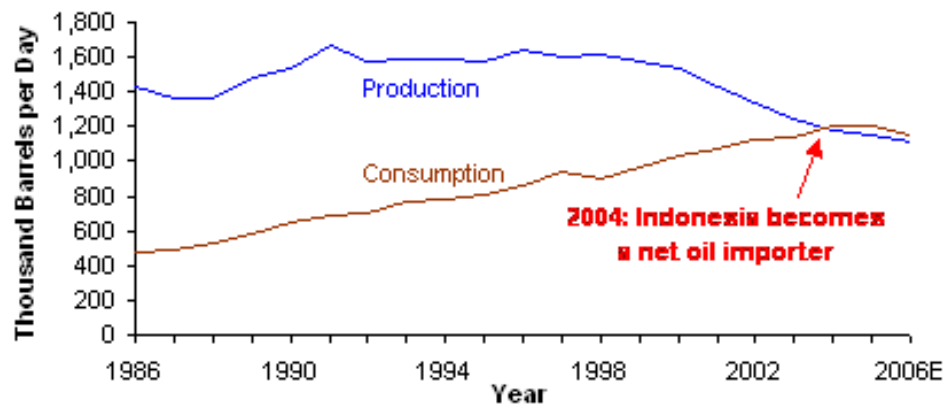
**Figure 1.5: Real GDP, Oil Consumption, and Carbon Emission Scenario in Indonesia**



Note: Y, LO and CO<sub>2</sub> represents real output, oil consumption in million tonnes and carbon emission in million tonnes, respectively. Real output data is collected from World Development Indicators (WDI) by World Bank, while oil consumption and carbon emission data is found from BP (2008).

In 2004 Indonesia became a net importer of oil due to the steady decrease in oil production during the preceding decade (Figure 1.6, overleaf). The loss in production is arguably contributed by disappointing exploration efforts and declining production at the country's large, mature oil fields. Since 1996, Indonesia's total oil production has dropped by 32%, while the country's current OPEC output quota for crude oil is set at 1.45 million barrels per day which is well above its production capacity (EIA 2009). Furthermore, since the governance issues in Indonesia remain an impediment to progress, increasing investment which is required for the long term growth of the country – particularly in infrastructure - is an area of concern for the economy. According to the Figure 1.6 (overleaf), the country's oil consumption in 2006 reached to 1.2 million barrels per day which makes the country a slightly net importer of oil in that year. Historically, Indonesia has always subsidized oil prices for domestic retail fuel consumers, with selling energy products at a discounted price well below the world market parity prices. In addition to fossil fuels (like oil, coal and natural gas) and hydroelectric sources, Indonesia also consumes renewable energy sources like, primary solid biomass including fuel wood and geothermal sources.

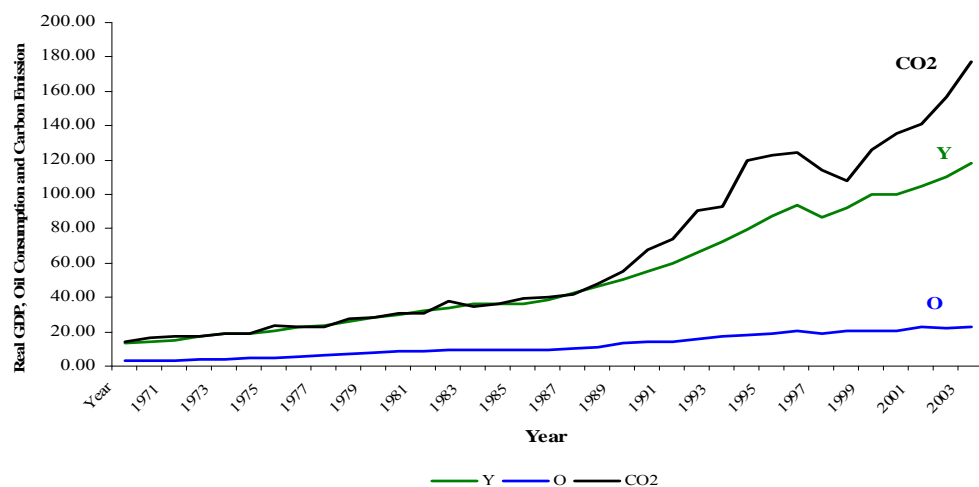
**Figure 1.6: Oil production, Oil Consumption, and Net Export Scenario of Indonesia, 1986-2006\***



Source: EIA *International Energy Annual*; *Short-Term Energy Outlook*

Since the 1997 crisis, the Malaysian economy has recovered convincingly. Real GDP grew by 6.3% in 2007 from 5.9% in 2006 due to the increase in domestic demand. Gross investment has also reached at 10.2% in 2007- a three fold increase from 2002. Being consistent with the increasing trend in real GDP, both oil consumption and pollutant emission also show an increasing trend (Figure 1.7).

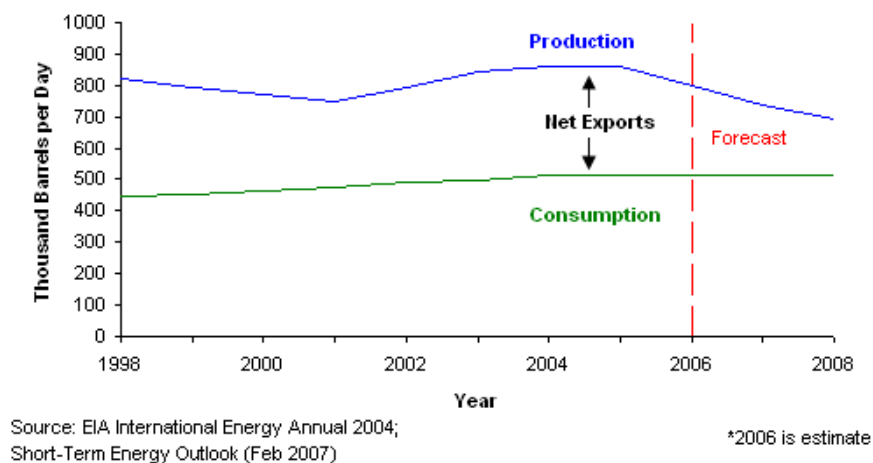
**Figure 1.7: Real GDP, Oil Consumption, and Carbon Emission Scenario in Malaysia**



Note: Y, O and CO<sub>2</sub> represents real output, oil consumption in million tonnes and carbon emission in million tonnes, respectively. Real output data is collected from World Development Indicators (WDI) by World Bank, while oil consumption and carbon emission data is found from BP (2008).

In 2007, Malaysia consumed 0.60% of the world oil. Oil is the second largest fuel source of the country behind natural gas (Appendix Table 1.2). The country is a significant producer of oil and natural gas in the Southeast Asia. Malaysia is the only net oil exporting country among the considered countries in this study. Despite growth in oil production and exploration (P&E) activities, Malaysia's proven oil reserves and production have declined after 2005 (Figure 1.8). The upstream and downstream oil exploration and production activities in the country are dominated by a nationally owned oil company, namely Petroleum Nasional Berhad (Petronas). Similar to other considered countries, the Malaysian government also significantly subsidizes domestic oil prices. In addition to crude oil, natural gas, coal and hydroelectric, primary solid biomass is also used in a minimal level.

**Figure 1.8: Oil production, Oil Consumption, and Net Export Scenario of Malaysia, 1998-2008\***



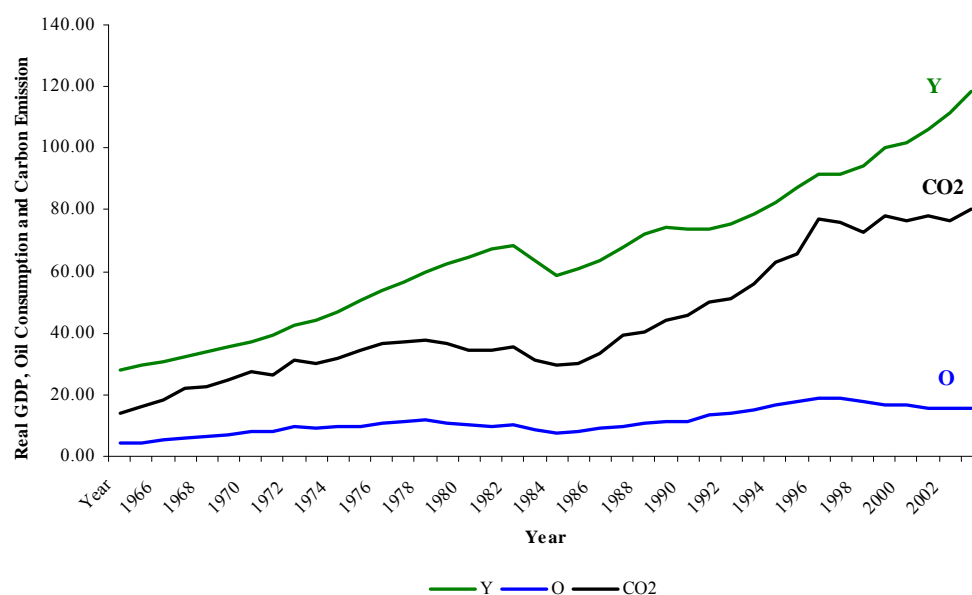
Despite increasing political instability and market volatility, the Philippines economy has been experiencing steady economic growth in recent years. However, the economy is showing persistent weaknesses in some of the sectors like, a poor tax effort<sup>6</sup>, high unemployment and underemployment rate, and consistent increase in the poverty level. Hence, there is concern whether the growth can be sustained in the light of the above mentioned weaknesses and mounting global uncertainties and political tensions. The growth in recent years in Philippines is associated with growth in oil consumption and carbon emission. Figure 1.9 (overleaf) shows the

<sup>6</sup> Low efficiency in collecting taxes by the Government institutions.



increasing trends in output along with the rise in oil consumption and carbon emission trends.

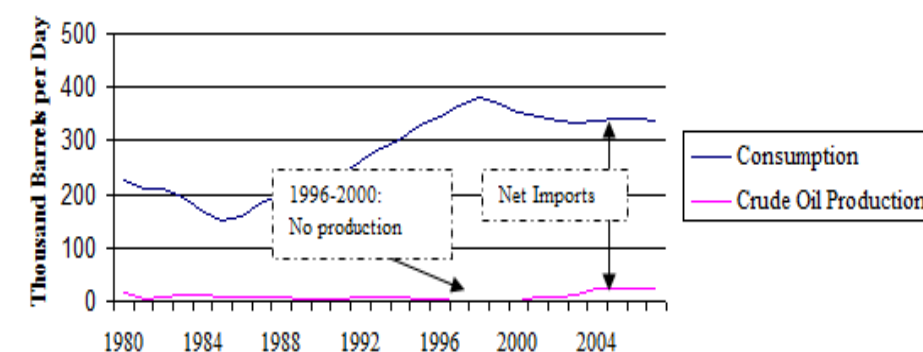
**Figure 1.9: Real GDP, Oil Consumption, and Carbon Emission Scenario in Philippines**



Note: Y, O and CO<sub>2</sub> represents real output, oil consumption in million tonnes and carbon emission in million tonnes, respectively. Real output data is collected from World Development Indicators (WDI) by World Bank, while oil consumption and carbon emission data is found from BP (2008).

Oil consumption accounted for more than half (55.91%) of the Philippine's final energy consumption mix in 2007, followed by coal at 23.87% (Appendix Table 1.2). Through the 1990s, oil was the dominant energy source in the Philippine's energy consumption mix. Nevertheless, oil's share has dropped due to increased consumption in natural gas and coal in the power sector. Thus, oil demand in the Philippines has been declining since 1998. Domestic oil production started in the 1970. However, the production is very minimal with no production of oil from 1996 to 2000 (Figure 1.10, overleaf). The oil industry in the Philippines is mostly deregulated, except for the price setting of petroleum products where oil companies are required to seek government's consent in setting up oil prices, especially the prices of diesel. There is an informal cap on weekly price increases of 50 centavos per liter. The Philippines economy also consumes primary solid biomass and geothermal energy in their industrial and agricultural sectors.

**Figure 1.10: Oil production, Oil Consumption, and Net Export Scenario of Philippines, 1980-2007\***

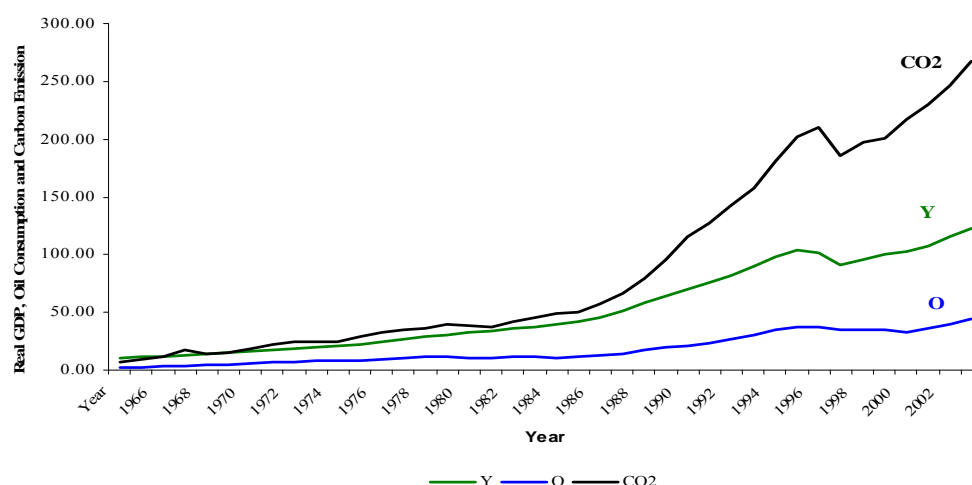


Source: EIA.

\*2007 figures are estimates.

The Thai economy has also shown a persistent economic growth after the financial crisis of 1997. However, the economy has been impacted by political uncertainty over the past years. Despite of this political uncertainty and economic crisis, Thailand has also made substantial progress in social development like, higher income for the people and greater access to health care. With all these increasing socio economic trends, oil consumption and pollutant emission also shows a steady increasing trend over time (Figure 1.11).

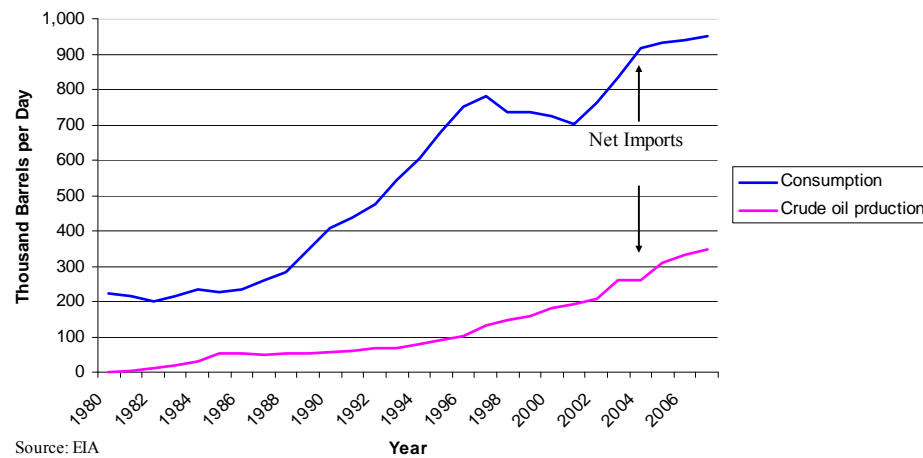
**Figure 1.11: Real GDP, Oil Consumption, and Carbon Emission Scenario in Thailand**



Note: Y, O and CO<sub>2</sub> represents real output, oil consumption in million tonnes and carbon emission in million tonnes, respectively. Real output data is collected from World Development Indicators (WDI) by World Bank, while oil consumption and carbon emission data is found from BP (2008).

The Thai energy consumption portfolio is dominated by oil. Oil consumption accounts for 50.30% of the total energy consumption by the economy followed by natural gas. Crude oil production and exploration activities have increased in recent years, but the increased effort in P&E have not been able to catch up with the increase in domestic consumption demand by the industrial and transportation sectors. As a result the oil import in the Thai economy is also in an increasing trend (Figure 1.12). Thailand also uses a significant amount of biomass including fuel wood.

**Figure 1.12: Oil production, Oil Consumption, and Net export Scenario of Thailand, 1980-2007\***



From the above discussion some important observations emerge. One, in recent years all the concerned economies have experienced substantial economic developments. Two, these development efforts are considerably linked with increased consumption of energy, particularly oil, and increased pollutant emission.

### 1.3 Research Questions and Issues

A number of industrialized and developing countries agreed to the terms of Kyoto protocol to conserve energy and reduce emission. Since oil is a major energy source across the economies, conservation of oil plays an important role in the overall energy conservation effort. However, the oil conservation possibility of an economy is heavily dependent on the linkage between oil consumption and economic activities. Furthermore, despite the increasing dependence of the Asian developing

countries on oil, there has been very little study regarding oil and development relationship in the context of these economies. Hence, with increased demand for oil in developing countries, especially from emerging economies like China and India, a study on identifying statistically significant association between oil consumption and economic activities in developing economies, especially the ones considered in this study is warranted.

Based on the gaps in literature discussed earlier, this thesis intends to analyse the importance of oil consumption on the economic activities of these countries. The dependence of these economies on oil consumption is investigated by employing both *supply-* and *demand-side* approaches together. The *supply-side* model is built upon the traditional Cobb-Douglas type production function where oil consumption is included as an additional factor of production. The *demand-side* analysis is performed within two different model specifications. The first model explores oil consumption demand which is considered as a function of GDP and oil prices. And the second model is for pollutant emission output which is determined by the level of output and oil consumption demand. The importance of identifying the direction of causality between oil consumption and output stems from its relevance in national policy-making issues regarding oil conservation. The oil conservation issue is more different when oil acts as a contributing factor in economic growth than when it is used as a result of higher economic growth. Based on a comprehensive empirical analysis of these three models investigating the relationship between oil consumption and output, the possibilities of oil conservation for these countries are explored.

The carbon emission output model also provides information regarding the impact of oil prices on the economic activities of these countries. Like oil price shocks, volatility in oil prices may reduce aggregate output temporarily as it delays business investment by raising uncertainty or by inducing expensive sectoral resource reallocation (Guo and Kleisen, 2005). Although industrialized developed countries seem to be more dependent on oil, evidence shows that the demand for oil in developing countries is on an increasing trend (Birol 2007). Since these countries are presently experiencing increased demand for oil and there has been no prior study on identifying the impact of volatility in oil prices on these economies, a thorough investigation of the impact of oil price variability on these emerging economies is

warranted. Hence, this study also analyses the impact of oil price volatility on output and price levels of these economies by employing realized oil price variance as the measure of price volatility. Furthermore, for the economies who have suffered from Asian financial crisis, this study performs the impact analysis for two different time frames one is for the whole sample period and the other for the period after the crisis. The sole purpose of this decomposition of sample is to investigate whether the impact channels for the oil price volatility have been altered in the post-crisis period.

#### **1.4 Thesis Organization**

This thesis comprises seven chapters. The first chapter provides an introduction to the subject matter of this research. A brief introduction of the exiting literature on the linkage between energy and/or oil, oil price, oil price volatility and the economy along with their relationship with world oil price trends is presented. Based on the gaps in existing literature and the energy and oil consumption scenarios of the studied countries, the key research objectives of this thesis are outlined.

Chapter two reviews both theoretical and empirical studies analysing the impact of energy consumption, oil price shocks, and oil price volatility on economic activities. This chapter explores the theoretical literature related to identifying the role of energy in the neoclassical growth and the real business cycle models. It also discusses the empirical studies investigating the broader relationship between energy and/or oil consumption and the macroeconomy; and contains discussion on empirical literature regarding impact of oil prices and oil price volatility on aggregate economic activities.

Chapter three offers the analytical framework for this thesis. In the first part of this chapter, the theoretical settings for analysing the impact of oil consumption based on both *supply-* and *demand-side* approaches and oil price volatility on economic activities are presented. The second part provides a thorough discussion of the time-series econometric techniques employed to achieve the objectives of this thesis.

Chapter four investigates the relationship between oil consumption and output for the concerned countries within a multivariate production function framework. The chapter performs the Granger causality tests in a vector error correction (VEC) framework in this regard. The generalized impulse responses and generalized

variance decompositions are employed to check the robustness of the empirical findings. A simple panel data estimation taking all these countries together is also presented.

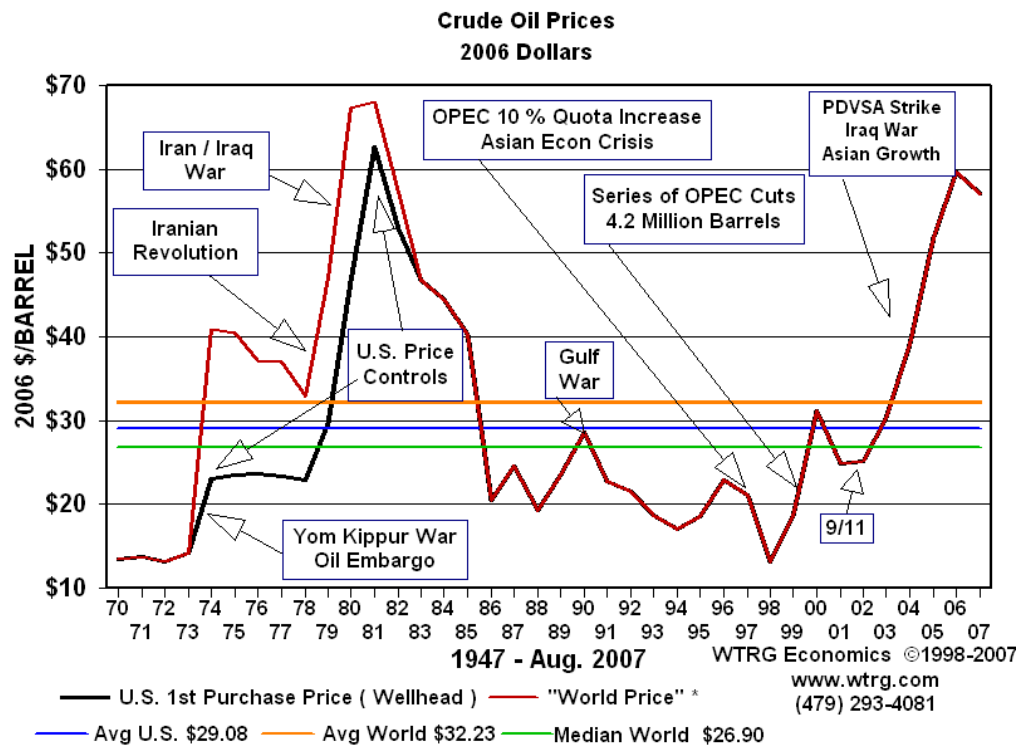
Chapter five is arranged around two different building blocks; one is the model of oil consumption demand and the other is the model of carbon emission output. The chapter performs cointegration test and the Granger causality tests in a vector error correction (VEC) framework for both of the models. The generalized impulse responses and variance decompositions (as out of sample causality tests) tests are also employed for both of the models along with a simple panel data estimation for the oil consumption demand and carbon emission output models taking all the countries together.

Chapter six investigates the short-term impact of oil price volatility in the concerned economies. One of the unique features of this chapter is that, here the oil price volatility for each country is calculated using a non-parametric approach namely, realized oil price variance. The chapter performs Granger causality tests within the vector autoregressive (VAR) framework. The chapter also presents the generalized impulse response functions and variance decompositions analyses.

Chapter 7 provides a summary of the major findings of this study and draws conclusions from the study. It also discusses policy implications for these economies regarding oil conservation and possible measures to minimise the adverse impacts of oil prices and oil price volatility on the economies.

# Appendix to Chapter 1

Appendix Figure-1.1: Prices in World Crude Oil Market



Source: James Williams of WTRG Economics, Arkansas.

**Appendix Table 1.1: World Primary Oil Demand\* (million barrels per day)**

	1980	2004	2005	2010	2015	2030	2005-2030**
<b>OECD</b>	<b>41.9</b>	<b>47.5</b>	<b>47.7</b>	<b>49.8</b>	<b>52.4</b>	<b>55.1</b>	<b>0.6%</b>
North America	21.0	24.8	24.9	26.3	28.2	30.8	0.9%
<i>United States</i>	<i>17.4</i>	<i>20.5</i>	<i>20.6</i>	<i>21.6</i>	<i>23.1</i>	<i>25.0</i>	<i>0.8%</i>
<i>Canada</i>	<i>2.1</i>	<i>2.3</i>	<i>2.3</i>	<i>2.5</i>	<i>2.6</i>	<i>2.8</i>	<i>0.8%</i>
<i>Mexico</i>	<i>1.4</i>	<i>2.0</i>	<i>2.1</i>	<i>2.2</i>	<i>2.4</i>	<i>3.1</i>	<i>1.6%</i>
Europe	14.7	14.5	14.4	14.9	15.4	15.4	0.2%
Pacific	6.2	8.2	8.3	8.6	8.8	8.9	0.3%
<b>Transition economies</b>	<b>8.9</b>	<b>4.3</b>	<b>4.3</b>	<b>4.7</b>	<b>5.0</b>	<b>5.7</b>	<b>1.1%</b>
Russia	n.a.	2.5	2.5	2.7	2.9	3.2	1.0%
<b>Developing countries</b>	<b>11.4</b>	<b>27.2</b>	<b>28.0</b>	<b>33.0</b>	<b>37.9</b>	<b>51.3</b>	<b>2.5%</b>
Developing Asia	4.4	14.2	14.6	17.7	20.6	29.7	2.9%
<i>China</i>	<i>1.9</i>	<i>6.5</i>	<i>6.6</i>	<i>8.4</i>	<i>10.0</i>	<i>15.3</i>	<i>3.4%</i>
<i>India</i>	<i>0.7</i>	<i>2.6</i>	<i>2.6</i>	<i>3.2</i>	<i>3.7</i>	<i>5.4</i>	<i>3.0%</i>
<i>Indonesia</i>	<i>0.4</i>	<i>1.3</i>	<i>1.3</i>	<i>1.4</i>	<i>1.5</i>	<i>2.3</i>	<i>2.4%</i>
Middle East	2.0	5.5	5.8	7.1	8.1	9.7	2.0%
Africa	1.4	2.6	2.7	3.1	3.5	4.9	2.4%
<i>North Africa</i>	<i>0.5</i>	<i>1.3</i>	<i>1.4</i>	<i>1.6</i>	<i>1.8</i>	<i>2.5</i>	<i>2.4%</i>
Latin America	3.5	4.8	4.9	5.1	5.6	7.0	1.5%
<i>Brazil</i>	<i>1.4</i>	<i>2.1</i>	<i>2.1</i>	<i>2.3</i>	<i>2.7</i>	<i>3.5</i>	<i>2.0%</i>
<b>Int. marine bunkers</b>	<b>2.2</b>	<b>3.6</b>	<b>3.6</b>	<b>3.8</b>	<b>3.9</b>	<b>4.3</b>	<b>0.6%</b>
<b>World</b>	<b>64.4</b>	<b>82.5</b>	<b>83.6</b>	<b>91.3</b>	<b>99.3</b>	<b>116.3</b>	<b>1.3%</b>
<i>European Union</i>	<i>n.a.</i>	<i>13.5</i>	<i>13.5</i>	<i>13.9</i>	<i>14.3</i>	<i>14.1</i>	<i>0.2%</i>

\* Includes stock changes. \*\* Average annual growth rate.

n.a.: not available.

Source: Oil Market Outlook and Policy Implications, a prepared Testimony by Dr. Fatih Birol, Chief Economist, International Energy Agency. The testimony was presented to United States Senate Committee on Energy and Natural Resources, Washington on 10 January 2007.



**Appendix Table 1.2: Primary Energy Consumption by Fuel in the Studied Countries (million tonnes oil equivalent)**

Country/ Region	Oil	% of World	% of Country	Natural Gas	% of World	% of Country	Coal	% of World	% of Country	Nuclear Energy	% of World	% of Country	Hydro- electric	% of World	% of Country	2007 Total
China	367.97	9.31	19.75	60.57	2.30	3.25	1311.41	41.27	70.38	14.22	2.29	0.76	109.26	15.41	5.86	1863.44
India	128.53	3.25	31.78	36.16	1.37	8.94	208.00	6.55	51.43	4.03	0.65	1.00	27.70	3.90	6.85	404.42
Indonesia	54.42	1.38	47.48	30.42	1.15	26.55	27.81	0.88	24.27	-	-	-	1.95	0.27	1.70	114.60
Malaysia	23.59	0.60	41.11	25.43	0.96	44.32	6.93	0.22	12.08	-	-	-	1.43	0.20	2.49	57.38
Philippines	13.90	0.35	55.91	3.09	0.12	12.42	5.93	0.19	23.87	-	-	-	1.94	0.27	7.79	24.86
Thailand	43.03	1.09	50.30	31.82	1.21	37.20	8.86	0.28	10.35	-	-	-	1.84	0.26	2.15	85.55
Total Sample	631.43	15.97	24.76	187.50	7.11	7.35	1568.95	49.38	61.52	18.26	2.94	0.72	144.11	20.32	5.65	2550.25
World	3952.82	100		2637.74	100		3177.54	100		622.02	100		709.22	100		11099.34

Source: BP (2008)

Note: Primary energy comprises commercially traded fuels only. Excluded, therefore, are fuels such as wood, peat and animal waste which, though important in many countries, are unreliably documented in terms of consumption statistics. Also excluded are wind, geothermal and solar power generation. Oil consumption is measured in million tonnes; other fuels in million tonnes of oil equivalent. ‘% of World’ represents percentage of total world consumption for the same fuel type, while ‘% of Country’ represents percentage of aggregate fuel consumption of the country for all the five fuel types together.

# **Chapter 2**

## **Energy Consumption, Oil Price Shocks, Oil Price Volatility, and the Economy**

### **2.1 Introduction**

Economic activities heavily rely upon energy. The industrial sector needs energy in every step of its supply chain: from procuring raw materials and running production machinery to transporting and marketing final goods and services. Historically, oil has been a prime source of energy for running the wheel of economic growth. Hence, oil consumption has been a key indicator of the state of economic activities of an economy. However, the consumption of oil in an economy is dependent on two important factors: the level of oil prices and the oil price volatility. The consumption of oil depends, on the one hand, on oil price through its effect on the operating costs; and on the other hand, on oil price volatility through its impact on uncertainty in the production process. Therefore, identifying the impacts of energy and/or oil consumption, oil prices, and oil price volatility on economic activities are of utmost importance, especially in the time when “peak oil” and energy conservation are major concerns for the policy makers, politicians and academics.

This chapter reviews both theoretical and empirical studies analysing the impact of energy consumption, oil price shocks, and oil price volatility on economic activities. The chapter begins by exploring the theoretical literature related to identifying the role of energy in the neoclassical growth and the real business cycle models, then it discusses the empirical studies investigating the broader relationship between energy and/or oil consumption and macroeconomy. This chapter continues by presenting an overview of the empirical literature regarding the impact of oil prices on the aggregate economy followed by a narrower relationship between oil price volatility and the economic activities. A summary is presented in the final section of this chapter.

### **2. 2 Energy and the Economy: Theoretical Insights**

Economists have long been intrigued by the empirical evidence which advocates that energy consumption and oil price shocks may be closely tied to the macroeconomic

activities. Since the 1970s, numerous empirical studies have accumulated that examine the link between oil consumption and/or prices and macroeconomic aggregates. Concurrently, a number of academic studies endeavour to shed light on establishing this link between energy (oil, more specifically) and macroeconomy on theoretical ground. For this purpose, the neoclassical growth models and real business cycle models are commonly used in the literature.

### *2.2.1 The role of energy in neoclassical growth models*

Despite the extensive empirical work examining the role of energy in the growth process, the mainstream theory of economic growth pays little attention to the contribution of energy or other natural resources in promoting and facilitating economic growth. Toman and Jemelkova (2003) state that the focus of most of the literature on energy and economic development is discussing how economic development affects energy use, not the vice versa. In this study, the authors attempt to identify ways in which energy might exert an important impact on development process by conceptual discussion of both theoretical and empirical work regarding the energy-development relationship. The mainstream literature of economic growth can be divided into two categories: those based on the Solow growth model and those based on the idea of endogenous growth.

The basic model of economic growth is the work by Noble-prize winning economist, Robert Solow (1956), and the contemporaneous work by Swan (1956), which do not include natural resources at all. Assuming perfect competition prevails in the economy and constant returns to scale in production, the Solow model emphasizes capital accumulation, exogenous rates of change in technological progress and population as sources of economic growth (Solow 1956, 1957 ). The Solow growth model predicts that, given the same rate of technological progress and population growth, all market-based economies will eventually reach the same constant (steady-state) rate of economic growth. Under the assumption of the model, policymakers do not have any role on influencing the long-run growth rate of an economy (Gould & Ruffin 1993).

On the contrary, instead of assuming technological progress as “manna from heaven”, Romer (1986, 1990) considers technology as endogenous. These seminal papers of Romer open up the avenue of further studies named as “endogenous”

growth theory. The theory argues that instead of being in the steady state, as assumed by the neoclassical growth theory, over the long-run, countries can have accelerating growth rates. The theory further indicates that long-run growth rate among countries may differ substantially. This acceleration and differentiation in the growth rates among countries are determined by economic incentives for technological growth. The popular ‘endogenous’ growth models consider technological progress as the ‘engine of economic growth’ and argue that inventions are intentional and generate technological spillovers. This spillover mechanism lowers the cost of future innovations.

The neoclassical literature on growth and resources differs in its approaches to address the energy-growth relationship. Some studies attempt to ascertain the impact of energy on the economic activities under different assumption scenarios within the growth model, whereas some other attempt to find out the appropriate conditions for sustainable use of energy.

To identify the impact of access to non-renewable energy on aggregate real output, Solow (1978) analyses the following production function:

$$F(K, L, R) = [aR^{(\sigma-1)/\sigma} + bC^{(\sigma-1)/\sigma}]^{\sigma/(\sigma-1)}$$

where,  $R$  is the current flow of natural resources,  $C$  is the composite index of labour and capital inputs, *i.e.*  $C = f(K, L)$ ,  $a$  and  $b$  are intrinsic measures of the relative “importance” of  $R$  and  $C$ , respectively. The elasticity of substitution between  $R$  and  $C$  is represented by  $\sigma$ . Based on the US time-series data on the ratio of non-renewable resource inputs to GNP, the results indicate that the non-renewable resources have not been ‘important’ in the US from 1900 to 1973. In other words, the economic growth in the US neither has gained very much from cheaper or more abundant access to non-renewable resources nor lost very much from the opposite (Solow (1978), Page 11).

However, Hall (1988) rejects Solow’s (1957) invariance property of productivity residual<sup>7</sup>. The author finds significant negative correlations between the growth rates

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<sup>7</sup> According to Solow (1957), the invariance property of productivity residual states that, the Solow residual is uncorrelated with all variables known to be neither causes of productivity shifts nor to be caused by productivity shifts. Key assumptions of this derivation are competition and constant returns to scale.

of sectoral Solow residuals and the nominal price of oil for most sectors of the US economy. Hall provides three possible explanations for the failure of the invariance property of Solow residual. First, under monopolistic competition, instead of perfect competition, with free entry and fixed costs, firms achieve a zero-profit equilibrium in which both the original and cost-based Solow residuals will fail invariance. In this case, increasing rather than constant returns to scale is the basic explanation. Second, possible error in the data of labour input as it measures formal (agreed) hours of work not the actual work effort given by the labour in the production process. Third, the existence of thick-market external benefits which arise when output is high.

In contrast to Hall (1988), Finn (1995) develops a model that quantitatively captures the endogenous production transmission channels underlying the observed Solow residual correlations. The model features the same assumptions of perfect competition and constant returns to scale as Solow (1957). This study uses annual US data over the period 1960-1989 and finds that the correlation between the growth rates of the aggregate Solow residual and the real price of energy is -0.55. Furthermore, the results show that the correlation between the growth rate of aggregate Solow residual and total government spending is only 0.09. Since the explanation of this study is consistent with the assumptions of perfect competition and constant returns to scale, it sharply differs from Hall (1988, 1990) in which the author's explanation relies primarily on imperfect competition and increasing returns to scale.

A major fraction of neoclassical literature on growth and resources concentrates on finding the appropriate conditions that enable continuing growth or intergenerational sustainability of the level of consumption and utility. According to the literature, this sustainability depends on technical and institutional conditions. The initial capital and natural resources endowment, easy substitutability among inputs, and the mix of both renewable and non-renewable resources are the key technical conditions. The institutional conditions include values concerning welfare of the future generation, market structure (competitive vs. central planning), and the property right infrastructure (commonly owned vs. private owner property system).

According to Solow (1974), intergenerational sustainability in consumption is achievable under the model where non-renewable natural resources are finite with no

extraction cost and non-depreciating capital. In this model, the elasticity of substitution between natural resources and labour goods and capital goods is unity. Growth in consumption can occur indefinitely when the utility of individuals is given identical weight irrespective of time, and the objective is to maximize the sum of utilities over time. Stiglitz (1974a) further argues that even in an economy in which natural resources are limited in supply, exhaustible and essential, sustained growth in per capita income is feasible. In this study the author also derives an optimum rate of resource utilization for the economy. However, the same model of economic growth under competition results in exhaustion of the resource with consumption and social welfare falling to zero (Joseph E. Stiglitz 1974b).

Dasgupta and Heal (1979) stress the need for capital investment to overcome the depletion of natural resources. Assuming a constant discount rate, they assert that the efficient growth path will eventually lead to depletion of natural resources and the economy will collapse if insufficient capital is invested to replace the natural resources depletion. Hartwick (1977) also shows that intergenerational equity is possible if an economy invests all profits or rents from exhaustible natural resources in other forms of reproducible capital, which in turn can substitute for resources. Later on, Hartwick (1995) and Dixit *et al.* (1980) extend the model to open economies and multiple capital stocks, respectively. However, the model they use is hard to apply as the model requires that the rents and capital are valued at sustainability compatible prices (Asheim 1994, Stern 1997, and Asheim *et al.* 2003).

A common result emerges from the body of work discussed above is that most of the neoclassical economists are primarily interested in what institutional arrangement, and not what technological arrangement (*i. e.* substitutability between energy and capital, both human and physical, and substitutability among different energy sources itself), will lead to sustainability. Thus, they typically assume *a priori* that sustainability is technically feasible and then analyse under what sort of institutional arrangements sustainability is possible. Solow (1993, 1997) also suggests that there is a tendency among mainstream economists to assume that sustainability is technically feasible unless proven otherwise.

### *2.2.2 Role of energy in real business cycle models*

Mitchell (1927) and von Hayek (1932) initiated the analysis of identifying the dynamics of different shocks that impact upon the economic systems across time and across sectors in the economy. However, with the introduction and popularity of the Keynesian model and the huge optimism of the macroeconomists in the 1960s, it seems that the business cycle models have lost their ground in explaining economic fluctuations. The business cycle models revived their importance in the 1970s in response to the shocking experience of high rates of inflation in the US and by the seminal works of Friedman (1968), Lucas (1976) and Lucas (1977), in which the authors critically examine the macroeconomic foundation of Keynesian models by demonstrating empirical evidence. These monumental works opened up the avenue of modern macroeconomics (Plosser 1989).

In 1982, Kydland and Prescott introduce three revolutionary ideas in a seminal paper titled, “Time to Build and Aggregate Fluctuations.” The ideas presented in that study are: (i) business cycles can be studied by using dynamic general equilibrium models; (ii) both the business cycle and growth theory can be unified given that the business cycle models must be consistent with the empirical regularities of long-run growth; and (iii) researchers, if they wish, can go way beyond the qualitative comparison of model properties with stylized facts of business cycles and endogenous Solow residuals that dominated theoretical work on macroeconomics until 1982. Kydland and Prescott (1982) further argue that if the neoclassical growth model of Solow (1956) is modified to include a stochastic shock to technology, the model is capable of replicating many of the features of modern business cycles.

The wave of models that first followed Kydland and Prescott’s study are primarily referred to as ‘real business cycle (RBC)’ models, as the emphasis of those works has been on the role of real shocks, specifically technological shocks, in driving business fluctuations. However, the magnitude of the role of technological shocks on economic fluctuation has been subject to a lot of both theoretical and empirical debate, which ultimately influenced and inspired the researchers to develop models in which technological shocks are either less important or play no role at all. In fact, many of these alternative theories take the basic RBC models as their point of

departure. Other than technological shocks, suspects as reasons for business fluctuations are monetary, fiscal, and energy (more specifically, oil) price shocks.

In fact, McCallum (1989) stresses the need for RBC studies which should explicitly model exogenous energy price changes. Here, the author points out one of the limitations of Kydland-Prescott and Hansen models that these models do not have foreign sectors, thus treating any type of ‘supply-side’ shocks, oil shocks for example, as ‘residuals’- shifts in the production function. This study concludes that as aggregate data regarding energy price changes are available and as it is analytically undesirable to lump input price changes together with shifts in the production function, future RBC models should lead to modelling the impacts of “supply-side” energy shocks to reduce their reliance on unobserved technological shocks. Some of the papers which study the effect of oil price shocks in RBC models are Kim and Loungani (1992), Rotemberg and Woodford (1996), Finn (2000), and Barsky & Kilian (2004b).

Using annual data of the US economy for the period 1949 to 1987, Kim and Loungani (1992) set out two different objectives for their study. First, to extend the RBC model by introducing energy price shocks and to observe whether this introduction reduces the RBC model’s reliance on unobserved technology shocks. Second, to compare the correlation between real wages and hours worked in an energy-inclusive model. For the purpose of including the energy prices, this study extends Hansen’s (1985) indivisible labour economy<sup>8</sup>. Furthermore, while choosing the parameters for the model, following Kydland and Prescott’s approach of model calibration, this study calibrates Hansen’s model with respect to microeconomic evidence and certain historical averages of the US economy. The major finding from this study is that, in the energy-inclusive indivisible labour economy, the inclusion of the energy price in the RBC model brings a very minor reduction in the reliance on unobserved technological shocks. It also finds that the predicted correlation between hours worked and real wages in the basic RBC model is lowered once energy price shocks are included.

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<sup>8</sup> In the RBC literature, one of the two alternate assumptions is the indivisible labour economy, which assumes that in this particular economy individuals either work full time or not at all. Therefore, fluctuations in aggregate labour hours are born from changes in the number of people employed in the economy, termed as the extensive margin.



Rotemberg and Woodford (1996) contribute to the energy-inclusive RBC literature by analysing the impact of energy prices on economic activities in the context of imperfect competition. This study uses real oil prices and private value-added of the US from 1948:2 to 1980:3. The purpose of this paper is to estimate the impact of oil price shocks in two different model scenarios: one, ‘calibrated’ one-sector stochastic growth model with perfect competition; and two, several models of imperfect competition in the product market. Given the empirical comparisons among different models in the context of perfectly and imperfectly competitive product markets, the authors conclude that the predicted effects of an energy price increase on both real output and real wages increase significantly once an allowance for a modest degree of imperfect competition is made. Among different models of imperfect competition, the model involving implicit collusion between oligopolies explains the magnitude of the impact of oil price shocks on the real output and real wage in a more convincing manner.

In contrast to the above study of Rotemberg and Woodford (1996), Finn (2000) argues that the theory of perfect competition *per se* does not prevent the explanation of the effect of oil price increases in the economic fluctuations. In this study the author uses the same quarterly data-set of the US economy from 1948:2 to 1980:3 as that of Rotemberg and Woodford (1996) and employs the model of the theory of perfect competition. In the theory of perfect competition that the author considers, the oil price increase is treated as just like a negative technology shock in the production function to generate contraction in economic activities. The finding of this paper is similar to that of Rotemberg and Woodford (1996), the oil price shocks have contractionary effect on both real output (private value-added) and real wages.

Barsky and Kilian (2004a) compare the trends in different time-series data regarding the prices and export/import of crude oil and different U.S. macroeconomic aggregates from 1971:3 to 2003:12. This study tests the popular notion that oil prices are responsible for the US economic fluctuations like, recessions, periods of excessive inflation, reduced productivity growth, and lower economic growth. Through analysing the time-series data based on different international, specifically the US and Middle East, socio-political regimes the authors find that instead of

causality running from oil price to macroeconomic activities, the actual causality runs from macroeconomic variables to oil prices.

Some studies have introduced energy use as one variable of a vector of factors of production. Rasche and Tatom (1977) are probably the first to introduce energy use into the aggregate production function for the U.S. economy. They estimate an aggregate production function for the US between 1949 and 1975 using the following form of Cobb-Douglas production function,

$$Y = Ae^{rt} L^{\alpha} K^{\beta} E^{\gamma}$$

where  $Y$  is output,  $L$  is labour,  $K$  is capital,  $E$  is energy resources, and  $t$  is time.  $A$  is the scaling factor,  $r$  is the trend rate of growth of output due to technological change, and  $\alpha$ ,  $\beta$ ,  $\gamma$  are the output elasticities of the respective inputs. After estimating the above production function, the authors conclude that the new energy regime imposed in 1974 permanently reduces potential output by about four percent. The estimates further indicate that failure to account for energy prior to 1973 is not critical. However, serious inconsistencies arise when the sample period is extended to include recent years after 1973.

Based on a neoclassical aggregate capital-labour-energy (KLE) production technology Ghali and El-Sakka (2004) attempt to analyse the causal relationship between energy use and output growth in Canada. Employing an annual data set from 1961 to 1997 the authors develop a VEC model after performing multivariate cointegration test that indicates that energy enters significantly the cointegration space. The causality test finds that short-run causality runs from both directions between output growth and energy use. Thus, the results of this paper reject the neoclassical assumption that energy is neutral to growth. Consequently, the authors conclude that energy is a limiting factor to output growth in Canada.

Soytas and Sari (2006) examine the relationship between energy consumption and output in a three factor (capital, labour and energy, *i. e.* KLE) production function framework in G-7 countries. This paper employs multivariate cointegration, error correction models and generalized variance decompositions along with Granger causality test. The tests indicate different directions of causality for different countries. However, by employing a similar methodology Sari and Soytas (2007)

find that energy is a relatively more important input than labour and/or capital in some developing countries like, Indonesia, Iran, Malaysia, Pakistan, Singapore and Tunisia. Hence, in these countries neutrality of energy does not hold.

Most of the previous studies in this field perform bi-variate Granger causality test to ascertain the direction of causality. However, in one of the pioneering works in multivariate studies Stern (1993) questions the appropriateness of such bi-variate approach in the light of omitted variable problems. The traditional bi-variate causality tests may fail to identify additional channels of impact and can also lead to conflicting results<sup>9</sup>. Afterwards, multivariate studies in this field take two different dimensions: *demand-side* approach with energy consumption, GDP and prices; and *supply- or production-side* approach with energy consumption, GDP and labour. Examples of *demand-side* approach are Masih and Masih (1997) and Asafu-Adjaye (2000); while of *production-side* approach are Stern (1993), Stern (2000) and Oh and Lee (2004b), Ghali and El-Sakka (2004), Soytas and Sari (2006) and Sari and Soytas (2007)<sup>10</sup>. Ghali and El-Sakka (2004) has formalized the following generalized production function which has been employed by Soytas and Sari (2006) and Sari and Soytas (2007) afterwards:

$$Y = f(K_t, L_t, E_t)$$

where  $t$  is time trend.  $Y$  the real output,  $K$  the capital stock,  $L$  the total labour and  $E$  is the energy consumption.

The following conclusions can be drawn from the above discussions, (i) the mainstream theory of economic growth pays little attention to the contribution of energy in promoting economic growth; (ii) multivariate approaches are superior to bi-variate approach. Two main multivariate approaches are the *demand-side approach* and *supply-side approach*; (iii) multivariate studies on developing countries are not common.

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<sup>9</sup> Zachariadis (2007) also points out that one should be cautious in drawing any policy implication based on a bi-variate causality test on small samples.

<sup>10</sup> There is substantially more literature on both of these approaches. A detail discussion of these studies is presented in the next section. Moreover, there are some studies which analyses the substitution possibilities between the factors of production which are discussed in the next section of the chapter.

### **2.3 Energy Consumption and the Economy**

There is an impressive body of empirical literature on the relationship between energy consumption and economic growth (See Appendix Table 2.1). Research on this issue has primarily been aimed at providing significant policy guidelines in designing efficient energy conservation policies. The pioneering research in this area is by Kraft and Kraft (1978). Using Sims's (1972) test for causality, the authors find a uni-directional causality running from national product to energy consumption in the US over the period from 1947 to 1974. This finding suggests that energy conservation programs will not adversely affect economic growth. Following Kraft and Kraft (1978), research on this subject has flourished in the context of both developed and developing countries.

Some studies find that uni-directional causality runs from output to energy consumption. Following Kraft & Kraft (1978), Abosedra & Baghestani (1989) use the direct Granger causality test and find uni-directional causality from output to energy consumption using an extended data set on the US spanning from 1947 to 1987. Their test for causality differs from Sims's (1972) test for Granger causality. While Sims's test for Granger causality relies upon joint influence of the lagged variables as measured by the F-statistics, Abosedra & Baghestani consider the magnitude and significance of individual estimated coefficients on the lagged independent variables. Cheng and Lai (1997) analyse Taiwanese data on GDP, employment and energy consumption for the period 1955 to 1993. The Granger causality test finds that, without feedback, causality runs from energy consumption to employment and there is uni-directional causality from economic growth to energy consumption.

Employing cointegration and Granger causality test with Indian data from 1950-51 to 1996-97, Ghosh (2002) is unable to find any long-run co-integrating relationship between electricity consumption and economic growth. However, the Granger causality test indicates uni-directional causality running from economic growth to electricity consumption without any feedback effect. In respect to Pakistan, Aqeel and Butt (2001) also find a similar result that economic growth Granger causes energy consumption, to be more specific, petroleum consumption. In this study the

authors use data on both aggregate and disaggregate energy consumption, GDP, and employment from 1955 to 1996.

Narayan and Smyth (2005) study the Australian economy with the time-series data on per capita electricity consumption, per capita real GDP, and an index of manufacturing sector employment. In this paper they consider annual data from 1966 to 1999. Here, the authors find that electricity consumption, employment, and income are co-integrated and that in the long run there exists uni-directional causality running from both employment and income to electricity consumption.

Uni-directional causality from output to energy has also been found in many other studies. For example, Yang (2000a) examines the Taiwanese economy from 1954 to 1997 using time-series data on coal consumption and economic growth; Al-Iriani (2006) considers energy consumption and GDP data of 6 Gulf Cooperation Council (GCC) countries over the period from 1971 to 2002; Mozumder & Marathe (2007) analyse Bangladesh's data on electricity consumption and GDP from 1971 to 1999; Mehrara (2007) examines the energy consumption and economic growth data of 11 oil exporting countries from 1971 to 2002, Zamani (2007) investigates the link between aggregate GDP, industrial and agricultural value added, and consumption of Iran from 1967 to 2003.

Contrary to the above, some studies find that there is uni-directional causality running from energy consumption to output. Wolde-Rufael (2004) finds that over the period from 1952 to 1999 various forms of energy consumption namely, coal, coke, electricity and total energy consumption in Shanghai Granger cause GDP. In this study the author employs a modified version of Granger causality test due to Toda and Yamamoto (1995)<sup>11</sup>. Morimoto & Hope (2004) come up with a similar outcome on Sri Lankan data from 1960 to 1998 that electricity supply causes economic growth.

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<sup>11</sup> The distinctive feature of the Toda and Yamamoto (1995) approach is that the approach artificially augments the correct order of the vector auto-regression by the maximal order of integration. This technique fits a standard vector autoregressive model in the levels of the variables under consideration, and for this reason it minimizes the risks associated with the possibility of wrongly identifying the order of integration of the series. Moreover, the use of this approach ensures that the traditional test statistics for Granger causality have the standard asymptotic distribution where valid inference can be made.

Chen *et al.*(2007) use GDP and electric power consumption data of Asia's 10 newly industrialized countries (NICs) over the period from 1971 to 2001. In this study, they conduct both individual time-series and panel-data procedures and find mixed results. Uni-directional short-term causality from economic growth to electricity consumption is found when individual time-series data are used. However, panel-data analysis indicates the existence of bi-directional causality between the variables. Other studies that find uni-directional causality from energy consumption to income include Masih & Masih (1998), Stern (2000), Shiu & Lam (2004), Siddiqui (2004), Yoo (2005), Yuan *et al.*(2007) and Narayan & Singh (2007).

By contrast to the above mentioned studies indicating uni-directional causality, bi-directional causality is also found in some studies. Oh and Lee (2004a) analyse the Korean economy under a multi-variate framework consisting of capital, labour, energy and GDP. One salient feature of this study is that, in aggregating final energy consumption, the authors here use the log mean Divisia aggregation method instead of using simple British Thermal Unit (BTU) aggregation as this method does not reflect changes in the composition of energy input. Investigating annual data from 1970 to 1999 in the error-correction model, the authors find a long-run bi-directional causality between energy consumption and GDP.

Using similar econometric techniques, Glasure and Lee (1997) investigate the causality dynamics between GDP and energy consumption of South Korea and Singapore for the period of 1961 to 1990. For both the countries the error-correction models reveal that there is bi-directional causality between the variables. While standard Granger causality test finds no causal relationship between the variables for South Korea; with respect to Singapore the test finds uni-directional causality running from energy consumption to GDP.

Bi-directional causality between energy consumption and real GDP is also found by Yang (2000b) while he investigates Taiwan data from 1954 to 1997. In this study the author considers both aggregate and disaggregate categories of energy consumption and the variables included in the traditional Granger causality test are: real gross domestic product, total energy consumption, coal consumption, oil consumption, natural gas consumption, and electricity consumption. Jumbe (2004) also finds bi-directional causality between electricity consumption and GDP in Malawi from 1970

to 1999. In another study, Hondroyannis *et al.* (2002) investigate the dynamic relationship between energy consumption, real output and the price level of Greece for the period of 1960 to 1996. Based on an error-correction model the authors find that changes in both total energy consumption and industrial energy consumption are endogenous to inflation and economic growth. However, residential energy consumption remains a weakly exogenous variable.

Masih & Masih (1997) investigate the causal link between energy and output for Korea and Taiwan over the period from 1955 to 1991 and 1952 to 1992, respectively. This study concludes that there is bi-directional causal relationship between energy consumption and income for both of the countries. The variables that are considered in this study are total energy consumption, real income, and price level.

Soytas & Sari (2003) examine the causal relationship between energy consumption and GDP of G-7 countries along with 10 major emerging markets. In this study the authors employ cointegration and vector error correction models to analyse time-series data of the respective countries spanning from 1950 to 1990. There are three major findings of this paper. One, energy consumption Granger causes GDP in Turkey, France, Germany, and Japan making energy conservation programs difficult to implement. Two, there exists uni-directional causality running from GDP to energy consumption in Italy and Korea making energy conservation strategies more feasible for these countries. Three, bi-directional causality is found for Argentina.

There are some studies that also find mixed conclusions for different countries. While examining the energy-income relationship in India, Indonesia, the Philippines and Thailand, Asafu-Adjaye (2000) considers a tri-variate model comprised of energy, income, and prices. In this study, the author uses annual data covering the period of 1973 to 1995 for India and Indonesia, while for Thailand and the Philippines the sample period spans from 1971 to 1995. Based on Granger causality and error correction mechanisms, this paper outlines that, for India and Indonesia, a uni-directional Granger causality runs from energy to income in the short run. For Thailand and the Philippines, there exists bi-directional causality in the shorter time horizon. On the contrary, in the long run, uni-directional Granger causality runs from

energy and price level to income for India and Indonesia, while for Thailand and the Philippines, energy, income, and prices are mutually causal.

Chiou-Wei, Chen & Zhu (2008) examines the relationship between energy consumption and economic growth by using both linear and non-linear Granger causality tests for a sample of Asian newly industrialized countries along with the US. This study finds energy neutrality for Thailand, South Korea and the US, while there is a uni-directional causality running from economic growth to energy consumption for Philippines and Singapore. For Taiwan, Hong Kong, Malaysia and Indonesia causality is running from energy consumption to economic growth.

Salim, Rafiq & Hassan (2008) examines the short- and long-run causal relationship between energy consumption and output in six non-OECD Asian developing countries. This study finds a bi-directional causality between energy consumption and income in Malaysia, while there are a uni-directional causality from output to energy consumption in China and Thailand and from energy consumption to output in India and Pakistan. Bangladesh remains as an energy neutral economy confirming the fact that it is one of the lowest energy consuming countries in Asia. In a similar study Rafiq (2008) also finds mixed results for the major developing economies of Asia.

With the purpose of investigating the long-run causal relationship between electricity consumption and economic growth for seventeen African countries for the period from 1971 to 2001, Wolde-Rufael (2006) employs cointegration and Granger causality tests proposed by Pesaran *et al.* (2001)<sup>12</sup> and Toda and Yamamoto (1995), respectively. The countries analysed in this regard are: Algeria, Benin, Cameroon, Democratic Republic of Congo (Congo, DR.), Republic of Congo (Congo, Rep.), Egypt, Gabon, Ghana, Kenya, Morocco, Nigeria, Senegal, South Africa, Sudan, Tunisia, Zambia, and Zimbabwe. This study finds a long-run relationship and uni-directional causality running from per capita electricity to real per capita GDP for Benin only, while long-run relationships and uni-directional causality from GDP to

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<sup>12</sup> This newly introduced bounds test approach to cointegration testing technique is particularly attractive when the researcher is not sure whether the regressors are stationary or non-stationary, *i. e.* I(0) or I(1), or mutually co-integrated. Since the technique does not require knowledge of order of integration or cointegration ranks of the variables involved, it avoids the inherent limitations in testing for unit roots before testing for co-integrating relationships among variables.



electricity consumption are found for Cameroon, Nigeria, Zambia, and Zimbabwe. Both a long-run relationship and bi-directional causality between the series is present for Gabon and Morocco. Whereas a long-run relationship is found between the variables for the Congo, REP. and South Africa, there exists no causal relationship between the two time series. On the contrary, although no long-run relationship is found in Ghana, in Senegal uni-directional causality runs from GDP to electricity consumption. In Congo, Democratic Republic., and Tunisia causality runs from electricity consumption to GDP and in Egypt there is bi-directional causality. However, there is no evidence of a long-run relationship and causality for Algeria, Kenya, and Sudan. Afterwards, Wolde-Rufael (2009) again performed a similar multivariate analysis on seventeen African countries and for fifteen out of seventeen countries the neutrality hypothesis for energy-income relationship seems to be rejected. In another recent study on 11 Sub-Sahara African countries, Akinlo (2008) investigates the causal relationship between energy consumption and economic growth employing Autoregressive Distributed Lag (ARDL) bounds cointegrations test.

Masih and Masih (1996) study the energy consumption and growth relationship in six Asian Economies: India, Pakistan, Malaysia, Singapore, Indonesia and the Philippines. While the sample period for the Philippines is 1955 to 1991, for all the other countries annual data spanning from 1955 to 1990 is considered in bi-variate vector autoregressive and vector error correction models. Although energy consumption and economic growth for all the countries are integrated in the order of one, the long-run co-integrating relationship between these two variables is found only for three countries: India, Pakistan, and Indonesia. For these three countries, the bi-variate vector error-correction models indicate uni-directional causality from energy to income for India, uni-directional causality from income to energy for Indonesia, and bi-directional causality for Pakistan. However, for Pakistan the variance decompositions indicate that when post-sample periods are considered income leads energy consumption. For other countries where the variables are not co-integrated, that is, Malaysia, Singapore, and the Philippines, bi-variate vector autoregressive fails to suggest any significant relationship of causation between the variables.

Using simple correlation analysis Ferguson *et al.* (2000) examine the relationship between per capita electricity consumption and per capita GDP, and between total primary per capita energy supply and per capita GDP of over one hundred countries which constitute over 99% of the global economy. The study period for OECD countries span from 1960 to 1995 and from 1971 to 1995 for non-OECD countries. In this study, the authors find that the correlation between electricity use and wealth creation is greater for rich countries than for the global economy as a whole. Moreover, the correlations between electricity use and wealth creation is stronger than the correlation between aggregate energy use and wealth.

In a study relating to three Latin American countries namely, Brazil, Mexico and Venezuela, Cheng (1997) investigates the energy consumption-economic growth relationship with the Hsiao's version of Granger causality. In this study the author analyses GDP, energy consumption, and capital data of Mexico from 1949 to 1993, Venezuela from 1952 to 1993, and Brazil from 1963 to 1993. The causality test fails to find any type of causal relationship among the variables in Mexico and Venezuela, while there is uni-directional causality running from energy to economic growth in Brazil. The most surprising finding of this study is that, capital is found to negatively cause economic growth for both Mexico and Venezuela. However, the strength of this causation is weak.

With a different objective of not only just being able to find causal relationship between energy consumption and income, but also of comparing this relationship for New Zealand and Australia with four developing Asian economies, Fatai *et al.* (2004) use annual data from 1960 to 1999. This study considers GDP, coal, oil, gas, electricity and total final energy consumption and the Asian countries are: India, Indonesia, The Philippines, and Thailand. From the causality test for Australia and New Zealand, the authors find a uni-directional link from GDP to final energy consumption, industrial and commercial energy. Then the authors compare this result with the previous study of Asafu-Adjaye (2000) where the author find a uni-directional causality running from energy to income for both India and Indonesia, and bi-directional causality for Thailand and the Philippines. With this comparison, the authors conclude that energy conservation policy may be more feasible for

industrialized countries like New Zealand and Australia rather than for some developing Asian countries.

Although most of these studies find a significant causal link between energy and output, some earlier studies do not find any such relationship. For example, Yu and Hwang's (1984) study on the US data from 1947 to 1979, Stern's (1993) study on the US data from 1947 to 1990, and Yu and Jin's (1992) study on the US from 1974:1 to 1990:4.

In addition to the causality analysis, some studies examine whether the underlying time-series data have undergone any structural break. For example, Lee & Chang (2005) examine the energy-GDP relationship in Taiwan by considering both aggregate and disaggregate energy data. Data on real GDP, total energy consumption, coal consumption, oil consumption, gas consumption, and electricity consumption from 1954 to 2003 are used for this purpose. Using Zivot and Andrews's (1992) and Perron's (1997b) tests for structural break this study finds structural break in gas consumption data in 1960s. The causality test indicates bi-directional causality between GDP and both total energy consumption and coal consumption, and uni-directional causality running from oil consumption, gas consumption and electricity consumption to GDP.

Altinay and Karagol (2004) also perform tests for structural break by Zivot and Andrews (1992) and Perron (1989) in energy consumption and GDP data of Turkey from 1950 to 2000. Although the results from these two tests differ in detecting breakpoints, both of the tests reveal that the series are trend stationary with a structural break. Moreover, by using Hsiao's version of Granger causality technique the authors find no causal relationship between the variables once the series are detrended taking the breakpoints into consideration. In another similar study Altinay & Karagol (2005) find the existence of uni-directional causality running from electricity consumption to income, which in policy terms implies that energy conservation may be harmful for future economic growth in Turkey.

Narayan & Smyth (2008) extends panel data analysis in this field by employing Westerlund's (2006) cointegration test, which accommodates multiple structural breaks within the panel system. In this study the authors analyse the relationship

between energy consumption and GDP in G7 countries within a tri-variate model where the third variable included is capital formation. According to panel cointegration and Granger causality tests, the study finds that all the variables in the system are cointegrated and long-run Granger-causality runs from capital formation and energy consumption to real GDP, while the short-run causality runs from capital formation and energy consumption to real GDP. Some of the other studies in this field who employs panel-data analysis methods are Lee (2005), Al-Iriani (2006), Joyeux & Ripple (2007), Renuka Mahadevan & Asafu-Adjaye (2007), Lee & Chang (2007), Lee, Chang & Chen (2008), Apergis & Payne (2009) and Narayan & Smyth (2009).

Ang (2008) adds a new dimension in energy consumption and output relationship by including carbon emission as the third variable in his study of Malaysian economy. Through Granger causality test in the error correction framework the study finds that energy consumption and pollution are positively related to output in the long run. The study further finds that there is uni-directional causality running from economic growth to energy consumption growth in both the short run and the long run. Ang (2007) also performs a similar exercise for the French economy from 1960 to 2000. In this study the author finds uni-directional causal links from economic growth to growth in energy use and pollutant emission growth in the long run, while in the short run there is a uni-directional causality running from growth in energy use to output growth.

Halicioglu (2009) studies the Turkish economy to investigate the dynamic causal relationship between carbon emissions, energy consumption, income and foreign trade from 1960 to 2005. One of the most significant findings of this study is that income seems to be the most significant variable in explaining the carbon emissions in Turkey, which is followed by energy consumption and foreign trade. Karanfil (2008) also studies the Turkish energy consumption and economic growth relationship. However, in this study the author adds a new dimension in the energy economy relationship by analysing the impact of energy consumption on both recorded and unrecorded economy. The study finds find a uni-directional causality running from official GDP to energy consumption both in the long and short run. However, this study fails to detect any causality between the variables when the

unrecorded economy is added into the analysis. Other studies analysing the link between energy consumption and Turkish economic growth are, Lise & Monfort (2007), Soytas & Sari (2007), Erdal, Erdal & Esengun (2008) and Balat (2008).

Instead of analysing energy-economy relationship within the error correction mechanism, Narayan, Narayan & Prasad (2008) uses structural VAR analysis to investigate the reaction of real GDP to shocks in electricity consumption in G7 countries. This study finds that except for the US, electricity consumption has a significant positive effect on real GDP in the short run.

Pointing out the increased number of empirical studies on energy consumption and economy relationship, recently Karanfil (2009) questions the appropriateness of the policy implications proposed by studies considering small number of variables in a small sample by using conventional econometric methods. This thesis also identifies some of the limitations of the conventional studies investing energy-economy relationships and tries to make some significant improvements in the light of the limitations in its analysis of identifying the impact oil consumption on economic activities from both production and demand side.

Studies analysing the relationship between oil consumption and economic activities are limited in number. Zou and Chau (2006) examines the short- and long-run dynamics of the impact of oil consumption on economic growth in China from 1953 to 2002. While scrutinizing the predictability and long-run equilibrium relationship between oil consumption and economic growth, the authors use annual data that they analyse by both cointegration and Granger causality tests. Both short and long-run Granger causalities and elasticities are recovered in vector autoregressive (VAR) and in error-correction (EC) frameworks.

Zou and Chau (2006) split the sample period into two sub-periods: one, from 1953 to 1984 and the other, from 1984 to 2002, as they want to capture the dynamics of two different regimes in the economy. One, a centrally controlled planned economy and the other, market controlled economy “with Chinese characteristics.” They find a long-run equilibrium relationship between the variables in both sub-periods, while no long-run equilibrium is found for the entire sample period from 1953 to 2003. This study finds that GDP Granger causes oil consumption in the long-run, while in

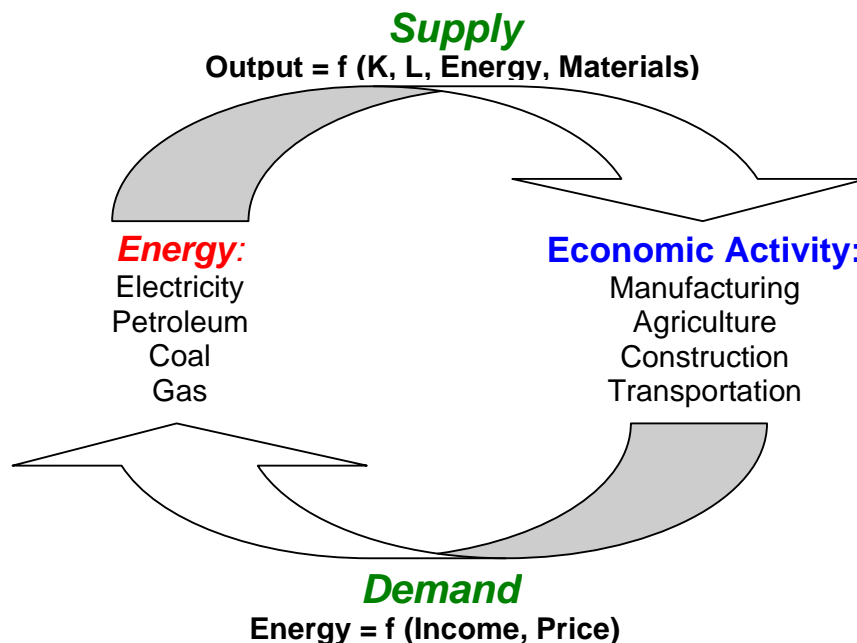
the short-run GDP does not have any predictability over oil consumption. On the contrary, this study finds the uni-directional causality running from oil consumption to economic growth both in the short and long run in China.

In a recent study on the Chinese economy, Yuan *et al.* (2008) also find a uni-directional causality running from oil consumption to GDP both in short and long run. In this study the authors analyse the causality dynamics between output growth and energy use in China at both aggregated total energy and disaggregated levels as coal, oil and electricity consumption within the production function framework.

From the above discussion some important points emerge. First, since 1970s, the relationship between energy consumption and economic growth has been widely discussed, with neither conclusive result nor persuasive explanations. This failure may arise from three different sources: (i) since they consider different data with different countries and time spans, the underlying economic circumstances may differ; (ii) they differ in the econometric methodologies employed; and (iii) there may be possible problems created by non-stationarity of data. Second, a typical question addressed by the previous literature is whether energy conservation can worsen the current trend in real GDP or not. Third, the approach of most of the earlier literature is to consider bi-variate methodology, with energy consumption and real GDP or GDP growth as the two studied variables. However, because of the omitted variable problems, recent studies in this field employ multivariate approaches. Two common multivariate approaches are: (i) the *supply-side* approach consisting of energy consumption, output, capital, and labour; (ii) the *demand-side* approach which includes energy prices or CPI in addition to energy consumption and output in their models (Figure 2.1, overleaf). Fourth, with respect to the *supply-side* approach, studies including oil consumption in the production function of developing economies are very limited. Fifth, none of the previous *demand-side* analysis in the context of developing countries includes both prices and carbon emission jointly in their models. Since pollutant emission is a major bi-product of the energy demand process, a complete *demand-side* analysis is expected to consider both of these variables in its model. Sixth, none of the previous studies in this field investigates energy conservation possibilities based on a combined analysis of both *supply-* and *demand-side* approaches.

Changes in the price and consumption of energy affect not only the demand for energy but also the rates of capital formation and labour utilization. These changes depend on the functional relationship between energy and the primary factor inputs. In particular, the empirical studies in this field reveal varying conclusions regarding whether capital and energy are complements or substitutes. Berndt and Wood (1979) use the US manufacturing data from 1947-71. This study finds that, while the Capital-Labour-Energy (KLE) translogarithmic specification and engineering specification indicate the presence of substitutability, the cost functions with Capital-Labour-Energy-Material (KLEM) translogarithmic specification indicate complementarity. Apostolakis (1990) analyses different literatures based on time-series and cross-sectional results regarding the substitutability or complementarity dichotomy. Apostolakis concludes that capital and energy act more as substitutes in the long-run and more as complements in the short-run.

**Figure 2.1 Causal Link between Energy and Economic Activity: Role of Energy on Demand Side and Supply Side**



Source: Chontanawat (2008)

Fronzel and Schmidt (2002) review the findings of previous literature regarding the energy-capital controversy and perform KLE and KLEM study for Germany from

1978 to 1990. This study finds that complementarity between energy and capital only occurs in cases where the cost share of energy is small. When materials are included, the cost share of both capital and energy are smaller. Thus, a finding of complementarity is more likely under this circumstance. Whereas, Thompson and Taylor (1995) argue that capital and energy are universally found to be substitutes when the Morishima elasticity of substitution is used in place of the more prominent Allen-Uzawa elasticities. However, Thompson (1997) and Frondel and Schmidt (2002) later indicate that the Morishima elasticity rarely finds any inputs to be complements.

Blackorby and Russell (1989) perform a comparison between Allen-Uzawa and Morishima elasticities. In this study the authors state that the elasticity of substitution concept, as originally conceived by Hicks, has nothing to do with the substitution/complement taxonomy. The discrimination should be made according to the sign of the cross-elasticity, which is necessarily the same as the sign of the Allen-Uzawa substitution elasticity.

Most of the above studies on energy-capital substitution or complementarity estimate elasticities at the industry level, to be more specific in manufacturing industry. Economy wide studies in this regard are very few. One such economy-wide study is Stern (1993). While examining the causal relationship between GDP and energy use for the period of 1947-1990 in the US, Stern (1993) finds energy and capital to be neither substitutes nor complements. Stern considers GDP, energy use, capital stock and employment in a multivariate vector auto-regressive (VAR) system.

Kaufmann and Azary-Lee (1991) show the importance of accounting for the physical interdependency between manufactured and natural capital. This study uses a standard production function to account for the indirect energy used elsewhere in the economy to produce the capital substituted for fuel in the US forest products sector. The authors find that from 1958 to 1984, the indirect energy costs of capital offset a significant portion of the direct fuel savings. Moreover, in some years, the indirect energy costs of capital are greater than the direct fuel savings, so the substitution possibilities are different at macro and micro levels.



It seems from the above literature that capital and energy are at best weak substitutes and possibly are complements. The degree of complementarity seemingly varies across industries and the level of aggregation considered. However, in a recent study Ma *et al.*(2008) investigates inter-factor and intra-fuel substitution possibilities in China. This study uses two-stage translog cost function approach into a panel data setup that covers 31 Chinese provinces' data from 1995 to 2004. The authors find that in China energy is substitutable with both capital and labour. Nevertheless, this study finds that there is a mixture of substitutability and complementarity between different fuel sources. Now the chapter continues with a discussion of narrower relationship between energy and economy by presenting some major studies regarding the impact of oil price shocks and/or oil price volatility on economic activities.

#### **2.4 Oil Price Shocks, Oil Price Volatility, and the Economy**

Oil price changes impact real economic activities on both the supply and demand side (Jimenez-Rodriguez & Sanchez 2005). The increase in oil price is reflected in a higher production cost that exerts adverse effects on supply (Brown & Yucel 1999). The higher production cost lowers the rate of return on investment, which affects investment demand negatively. Besides, increased volatility in oil price may affect investment by increasing uncertainty about future price movements.

Consumption demand is also influenced by the changes in oil price as it affects product price by changing production cost. Moreover, a rise in oil prices deteriorates the terms of trade for oil importing countries (Dohner 1981). As oil is directly linked to the production process, it can have a significant impact on inflation, employment and output. An oil price shock can increase inflation by increasing the cost of production. It also affects employment, as inflationary pressure may lead to a fall in demand and this, in turn, leads to a cut in production, which can create unemployment (Loungani 1986). The employment-oil price relationship holds true for not only industrial production, it is equally true for agricultural employment (Uri 1995). Oil price shocks also affect the monetary policy formulation of a country through its effect on inflation.

Previous research in this field mainly investigates two different aspects of the relationship between oil price and economic activities: the impact of oil price shocks

and the impact of oil price volatility. These two approaches differ in the way they incorporate oil price in their models. While the first approach takes oil prices at their levels, the second approach employs different volatility measures to capture the oil price uncertainty.

In response to two consecutive oil shocks in the early and late 1970s, a considerable number of studies have examined the impact of shocks to oil price levels on economic activities. Pioneering work by Hamilton in the early 1980s on the relationship between oil price and economic activities spurred researchers to look into the issue in greater detail. Hamilton (1983) analyses the behaviour of oil price and the output of the US economy over the period 1948 to 1981, and concludes that every US recession between the end of World War II and 1973 (except the 1960-61 recession) has been preceded, with a lag of around three-fourths of a year, by a dramatic increase in the price of crude petroleum. He further notes that post-1972 recessions in the US were mainly caused by OPEC's supply-oriented approach. In his subsequent works, Hamilton (1988, 1996) strengthens his conviction that there is an important correlation between oil shocks and recessions.

Since then a number of researchers have supported and extended Hamilton's results. Mork (1989) examines the relation between oil price change and GNP growth in the US with a more extended data set (1948-1988) to capture the effect of both upward and downward movements of oil price on output. Hamilton considers only large upward price movements and finds that there is a significant negative correlation between oil price increase and output. The major contribution of Mork's study is that it finds an asymmetric impact of oil prices on economic activities. In this study the author finds a negative correlation between oil price increases and the US macroeconomic performances, whereas the correlation with price decreases is significantly different and near to zero. In this paper the author uses a six-variable quarterly vector auto-regressive model consisting of real GNP growth, inflation, unemployment rate, wage inflation, import price inflation and real oil price changes.

Like Mork (1989), Jimenez-Rodriguez and Sanchez (2005) also try to capture the asymmetric impact of oil prices in some industrial countries by employing both linear and non-linear approaches within the multivariate VAR framework. Along with the linear VAR specification this study also takes three other non-linear

approaches: asymmetric, scaled and net specifications. The countries studied are the US, Japan, Canada, France, Italy, Germany, Norway and the UK. Here, Norway and UK are two net oil exporting countries. According to the empirical results, in Norway oil price increase affects positively on the GDP growth, while the increase in oil price has a negative impact in the UK's economic activity (indicating the presence of Dutch disease phenomena in the UK). Moreover, oil price shocks have the highest impact on the US economy, and when a non-linear specification is considered, a similarly strong impact is observed in the German, French, and Italian economies. As a whole, considering the asymmetric effects, oil price increases are found to exert an impact on GDP growth of a larger magnitude than that of oil price declines, with the latter being statistically insignificant in most of the instances. Farzanegan & Markwardt (2009) also find the asymmetric relationship between oil prices and Iranian economic activities. This study also finds 'Dutch Disease'<sup>13</sup> syndrome in the Iranian economy through significant real effective exchange rate appreciation.

Burbridge and Harrison (1984), using somewhat different methods and OECD (Organization of Economic Co-operation and Development) data, find mixed but overall reinforcing evidence of impact based on analysis of data from the US, Japan, Germany, the UK and Canada. Using data for the period of January 1961 to June 1982, the authors find that oil price increases have a sizeable negative impact on industrial production in the US and the UK, but the responses in other countries are small. This study also finds negative relationships between oil price shocks and macroeconomic indicators by using a comprehensive empirical model.

Gisser and Goodwin (1986) work on the US economy covering the period from 1961:1 to 1982:4. In this study, the authors estimate a St. Louis-type equation consisting of real GDP, the general price level, the rate of unemployment and real investment. They find crude oil prices to have a significant negative impact on output, even exceeding the impacts of monetary and fiscal policies. They also find that there is no structural break in oil price-output relationships after the OPEC

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<sup>13</sup> The term 'Dutch Disease' originated from the event of high revenue generation from the gas production in the Netherlands in 1960s. Despite of the increased revenue from the energy sector, the Netherlands experienced drastic fall in its economic growth. One reasoning behind such an event lies in the fact that the high revenue generated by gas discovery might have led to a sharp decline in the performance of the other sectors of the economy.

embargo in 1973, but they find that before 1973 inflation is strongly informative about future oil price and becomes less informative after that time.

Mork and Olsen (1994) examine the correlation between oil price and GDP in seven OECD countries (the US, Canada, Japan, West Germany, France, the UK and Norway) over the period from 1967:3 to 1992:4. They find a significant negative correlation between oil price increases and GDP in most of the countries studied. They estimate bi-variate correlations as well as partial correlations within a reduced-form macroeconomic model. The correlations with oil price increases are found to be negative and significant for most of the countries, but positive for Norway, whose oil-producing sector is large relative to the economy as a whole. The correlations with oil price decreases are mostly positive, but significant only for the US and Canada. Thus, they find evidence of asymmetric effects in most countries except Norway.

Cunado and Gracia (2005) also find evidence of the asymmetric effect of oil prices on economic activities. In this study, the authors examine the impact of oil price shocks on economic activity and inflation in six Asian countries, namely Japan, Singapore, South Korea, Malaysia, Thailand and the Philippines. Using quarterly data from 1975:1 to 2000:2, they find that oil prices have a significant impact on both economic growth and inflation, and this result is more significant when oil price is measured in local currencies. The nature of this relationship is short run as cointegration results fail to indicate any long-run relationship.

Cologni and Manera (2008) investigate the impact of oil prices on inflation and interest rates in a co-integrated VAR framework for G-7 countries. Using quarterly data for the period 1980:1 to 2003:4, they find that, except for Japan and the UK, oil prices significantly affect inflation, which is transmitted to the real economy by increasing interest rates. Impulse response function analysis suggests the existence of an instantaneous, temporary effect of oil price change on inflation. Jacquinot *et al.* (2009) also investigates the link between oil prices and inflation in the euro area by using Dynamic Stochastic General Equilibrium (DSGE) model. This study finds that changes in oil prices are of vital importance in understanding inflation in the short run. However, in the longer horizons the impact of oil prices on inflation is much more complex and depends on the initial shock.

Chen and Chen (2007) examine whether there is any long-run equilibrium relation between real oil prices and real exchange rates. Using the monthly panel data of G-7 countries over the period 1972:1 to 2005:10, they find a co-integrating relationship between real oil prices and real exchange rates. This paper is different from other studies in this field (for example Zhou 1995, Chaudhuri and Daniel 1998, Amano and Norden 1998) in that it assesses the role of real oil prices in predicting real exchange rates over long horizons. Panel predictive regression estimates suggest that real oil prices have significant forecasting power for real exchange rates.

Lardic and Mignon (2006) study the long-run equilibrium relationship between oil prices and GDP in twelve European countries using quarterly data spanning from 1970:1 to 2003:4. This study finds that the relationship between oil price and economic activities is asymmetric; that is, rising oil prices retard aggregate economic activity more than falling oil prices stimulate it. Their results show that, while the standard cointegration between the variables is rejected, there is asymmetric cointegration between oil prices and GDP in most of the participating European countries. This paper makes a significant contribution to the literature on the asymmetric impact of oil price on GDP and it differs from other studies, such as Mory (1993), in that it employs an asymmetric cointegration procedure to capture this asymmetric relation.

Using monthly data of the US, Canada and Japan during the period from 1970 to 2002, Huang *et al.* (2005) investigate the asymmetric relationship between oil price shocks and economic activities by applying the multivariate threshold model proposed by Tsay (1998). This study uses time-series data of the industrial production index, the interest rate, real oil price and real stock return, and concludes that countries differ in their ability to absorb shocks arising from oil price. The authors further state that there exists a threshold level of oil prices below which any changes in oil prices do not have any impact in any economy. Above the threshold level, a change in oil price and its volatility explains the model better than the real interest rate.

Instead of investigating the impact of oil price shocks on the US GDP, Huntington (2007) analyses the impact of the shock on real income which includes the US international purchasing power in it. The study finds that oil price shock reduces

income through its lagged effect on real output and the shock reduces real income immediately through its effect on an oil-importing economy's terms of trade.

Shiu-Sheng Chen (2009) investigates the oil price pass-through mechanism in 19 industrial countries from 1970:1 to 2006:4. With the introduction of a time-varying pass-through coefficient this study finds that the effects of oil shocks in inflation are declining. Therefore, the author suggests that measures like, the appreciation of domestic currencies, a more active monetary policy and trade openness might be the causes of this decline.

Being consistent with the previous literature<sup>14</sup> which provides evidence of a non-linear relationship between GDP growth and oil-price changes in the US, Jimenez-Rodriguez R (2009) questions the appropriateness of non-linear transformation techniques employed in the literature. The author further suggests that scaled oil price increase (SOPI) specification used by Lee, Ni & Ratti (1995) seems to be most appropriate among all the non-linear specifications used in this regard. However, Gronwald (2008) performs a similar study on the non-linear relationship between oil-price shocks and the US economy and in this study the author proposes a standard VAR framework with the Markov switching based oil-price specifications. Furthermore, by using Hamilton's (2001) parametric approach Dayong Zhang (2008) also confirms the existence of a non-linear relationship between oil price shocks and the Japanese economic growth.

Jbir & Zouari-Ghorbel (2009) add a new dimension in the oil shock and economy relationship by including government subsidy on oil prices. In this paper the authors study the Tunisian economy from 1993:01 to 2007:03. Employing both linear and non-linear specification in a VAR method, this study finds that oil price shocks does not directly affect the economy rather the impact is indirect and transmitted to the economy through government's spending.

From all the previous studies discussed above, the basic inference that can be drawn is that the world price of oil has considerable impact on the real activities of an economy, especially in the US. While most of the studies concentrate on

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<sup>14</sup> Previous literature finding evidence for non-linear relationship between the US GDP growth and oil-price change include Mork (1989), Lee, Ni & Ratti (1995), Hamilton (1996), Hooker (1996) and Hamilton (2003).

investigating the impact of oil prices on economic activities using macro-level data, some studies also consider industry-level data to ascertain the impact of oil price shocks.

Keane and Prasad (1996) identify the impact of oil prices on labour economy by studying the US employment and real wages at both the aggregate and industry levels. This study employs panel-data econometric techniques to analyse a panel containing twelve US surveys over the period from 1966 to 1981. The empirical study finds that oil price increases have substantial negative impact in virtually all sectors of the economy with varying magnitudes for different industries. In most industries, oil price increase contributes to real wage decline for all workers. However, unskilled workers are found to be the greatest sufferers. With respect to employment, this study finds that, like wages, oil price increases reduce employment in the short run. While in the long run the increase has positive impact on employment. This long-run increase can be an indicator of the existence of a substitution effect between energy and labour in the US aggregate production function.

Lee and Ni (2002) also investigate the dynamic effect of oil price shocks by adding industry-level variables along with macro-variables in their VAR model. With the sample of monthly US industry-level data, the study concludes that for industries that have a large cost share of oil, like petroleum refinery and industrial chemicals, oil price shocks mainly reduce supply. For many other industries, most importantly for the automobile industry, oil price shocks mainly reduce demand. The findings predominantly reinforce the theory that increased operating cost of durable goods and heightened uncertainty are the key reasons for oil price shocks to induce recession.

Bohi (1991) investigates the industry-level data of four industrial countries: Germany, Japan, the United Kingdom and the United States. This study tests the connection between the significance of energy consumption in production and the behaviour of selected industry activity variables by using simple bi-variate correlation. Here, the author analyses the industry-specific correlation between industrial production and employment in two periods of oil shocks: 1973-1975 and 1978-1980. This study fails to find any similarity in the effect on industrial

production and employment across industries in these four countries between the two recessions. Furthermore, the author does not find any consistent relationship between industry activity and energy intensity by industry, which indicates the inability of both the wage rigidity hypothesis and the capital obsolescence hypothesis to explain the impact of energy price shocks on macroeconomic behaviour.

Jimenez-Rodriguez (2008) investigates the impact of oil price shocks on six OECD countries from 1975:1 to 1998:2. This study finds that the patterns of responses to oil shocks by the industrial output for the European monetary union (EMU) countries in the sample (France, Germany, Italy and Spain) are diverse, while the patterns are highly similar for the UK and the US indicating a cross-country difference in industrial structure in EMU countries.

In addition to the above studies concentrating on the impact of oil price shocks on macroeconomic performance of different countries, there exists a number of studies that scrutinize the impact of such shocks on stock market activities, too. Some major papers focusing on analysing stock market implications of oil price rise are: Jones and Kaul (1996), Huang *et al.* (1996), Sadorsky (1999), Papapetrou (2001), Park & Ratti (2008) and Cong *et al.* (2008).

Jones and Kaul (1996) use quarterly data on four countries: the US, Canada, Japan and the UK from 1947 to 1991 and find that oil prices do have impact on stock returns of these markets. On the contrary, Huang *et al.* (1996) finds no evidence of a relationship between daily oil futures prices and daily US aggregate stock returns from 1979 to 1990. Using vector auto-regressive (VAR) technique, the study finds that, regardless of some evidences for oil future returns leading some individual oil company stock returns, there is no evidence that suggests oil futures returns have any impact on broad-based market indices like the S&P 500.

Using monthly data on the US industrial production, interest rates, real oil prices and real stock returns from 1947:1 to 1996:4, Sadorsky (1999) concludes that both oil prices and oil price volatility play imperative roles in affecting real stock returns. Vector auto-regressive technique along with impulse responses indicate oil prices have significant impact on economic activities, while the impact channel does not run in the opposite direction.



Within the framework of five variables (oil prices, real stock prices, interest rates, industrial production and employment) in a VAR model, Papapetrou (2001) studies Greek economy with the monthly data from 1989:1 to 1996:6. In this study the author concludes that, in Greece, oil prices play an important role in affecting both employment and industrial production (economic activity, thereof). According to the impulse response functions oil prices are also vital in explaining stock price changes. Park & Ratti (2008) also find statistically significant impact of oil price shocks on real stock returns in the US and 13 European countries. However, Cong *et al.* (2008) finds that for most of the Chinese stock indices oil price shocks do not show statistically significant impact on real stock returns, except for manufacturing indexes and some oil companies.

In contrast to the above studies that analyse the impact of oil price shocks, papers investigating the impact of oil price volatility on the economies are very limited and have their origin in the increase of oil price volatility from the mid-1980s. Lee, *et al.* (1995) find that oil price changes have a substantial impact on economic activities (notably GNP and unemployment) only when prices are relatively stable, rather than highly volatile or erratic. This indicates a weaker empirical relationship between oil prices and economic activities in the US since the remarkable increase in oil price volatility. In this study the authors utilize a generalized auto-regressive conditional heteroskedasticity (GARCH) model to construct the conditional variation in oil prices.

Ferderer (1996) analyses the US data spanning from 1970:01 to 1990:12 to see whether the relation between oil price volatility and macroeconomic performance is significant. In this study, the oil price volatility is measured by the simple standard deviation. Oil price volatility is found to contain significant independent information that helps forecast industrial production growth. The vector auto-regressive (VAR) framework is utilized to analyse the impact of both oil price shocks and oil price volatility on variables like industrial production growth, federal funds rate and non-borrowed reserves. Evidence is found that oil market disruptions have impact on the economy through both sectoral shocks and uncertainty channels. Further, monetary tightening in response to oil price increase partially explains the output-oil price correlation and the Federal Reserve reacts to oil price increases as much as it

responds to oil price decreases. The paper concludes that sectoral shocks and uncertainty channels offer a partial solution to the asymmetry puzzle between oil price and output.

Using the measure of realized volatility constructed from daily crude oil future prices traded on the NYMEX (New York Mercantile Exchange), Guo and Kliesen (2005) find that over the period 1984-2004 oil price volatility has a significant effect on various key US macroeconomic indicators, such as fixed investment, consumption, employment, and the unemployment rate. The findings suggest that changes in oil prices are less significant than the uncertainty about future prices. They also find that standard macroeconomic variables do not forecast realized oil price volatility, which indicates that the variance of future oil prices reflect independent stochastic disturbances. They conclude that this is mainly driven by exogenous events, like significant terrorist attacks and military conflicts in the Middle East.

Rafiq, Salim & Bloch (2009) investigates the impact of oil price volatility on key macroeconomic variables in Thailand by using vector auto-regression systems. The variables used for this purpose are oil price volatility, GDP growth, investment, unemployment, inflation, interest rate, trade balance and budget deficit of Thailand for the period of 1993:1 to 2006:4. The oil price volatility data is constructed using the realized volatility measure. Since the structural break test indicates breaks during the Asian financial crisis, this study employs two different VAR systems, one for the whole period and the other for the period after the crisis. For the whole time period, the causality test along with impulse response functions and variance decomposition tests indicate that oil price volatility has significant impact on unemployment and investment. However, the empirical analysis for the post-crisis period shows that the impact of oil price volatility is transmitted to the budget deficit.

Some observations can be made from the above discussion on the relationship between oil prices and/or volatility and the economy. Firstly, there is some evidence that oil price shocks have important impact on aggregate macroeconomic indicators, such as GDP, interest rates, investment, inflation, unemployment and exchange rates. Secondly, the evidence generally suggest that impact of oil price changes on the economy is asymmetric; that is, the negative impact of oil price increases is larger

than the positive impact of oil price decreases. Finally, there have been a few academic endeavours made to analyse the impact of oil price volatility per se on economic activities and, more importantly, such studies are conducted almost exclusively in the context of developed countries, especially the US.

## 2.5 Summary

This chapter reviews the literature, both theoretical and empirical, regarding the energy-economy relationship. For this purpose, it first discusses neoclassical growth and real business cycle literature concerning the role of energy. It finds that, the mainstream theory of economic growth pays little attention to the contribution of energy and other natural resources in promoting and facilitating growth. This chapter also contains an extensive discussion of the empirical literature analysing the link between energy consumption and output. From the review of these studies, a few important gaps are identified: (i) studies analysing the oil consumption-output relationship in developing countries based on the *production-* and/or *supply-side* approach are very limited; (ii) complete *demand-side* studies including both oil price and carbon emission in developing countries are non-existent; (iii) none of the previous studies on developing economies suggests conservation policies based on a combined analysis of both *supply-* and *demand-side* approaches.

This chapter, further, explores empirical literature identifying the impact of oil price shocks and oil price volatility on economic activities. Based on a comprehensive literature review in this respect, two important gaps are found. One, studies analysing the impact of oil price volatility on economic activities are very limited. Two, studies of this type in the context of developing economies are non-existent.

This thesis centres around filling these gaps identified above and addresses the issues with the application of the recent advances in time-series econometrics. The next chapter discusses the techniques that are used to deal with these issues in the context of developing economies.

## Appendix to Chapter 2

**Appendix Table 2.1: Summary of Major Literature Regarding Energy Consumption and the Economy**

Study	Countries studied (Period)	Variables used	Method	Finding(s)
Abosedra and Baghestani (1989)	US (1947-1987)	GNP and energy consumption	Cointegration, Granger causality	GNP causes energy consumption.
Akinlo (2008)	11 sub-Saharan African countries (1980-2003)	GDP and energy consumption	Autoregressive distributed lag (ARDL) bounds test, Granger causality test and error correction model (ECM)	Bi-directional causality between energy consumption and economic growth in Gambia, Ghana and Senegal, uni-directional causality from GDP growth to energy consumption in Sudan and Zimbabwe and no causal relationship in Cameroon, Cote D'Ivoire, Nigeria, Kenya and Togo.
Ang (2007)	France (1960-2000)	GDP, carbon emissions and energy consumption	Cointegration, Granger causality and error correction	Uni-directional causality from output growth to growth in energy consumption in the long run and uni-directional causality from growth of energy use to output growth, uni-directional causality from output growth to pollutant emissions

*Continued*

Study	Countries studied (Period)	Variables used	Method	Finding(s)
Asafu-Adjaye (2000)	India (1973-1995), Indonesia (1973-1995), Philippine (1971-1995), and Thailand (1971-1995)	Income, energy consumption and energy prices	Cointegration, Granger causality based on ECM	Bi-directional causality in Philippine and Thailand; unidirectional causality (energy causes income) in India and Indonesia.
Akarca and Long (1980)	US (1950-1968, 1970)	GNP and energy consumption	Sims' technique	No causal relation
Aqeel and Butt (2001)	Pakistan (1955-1996)	GDP and total energy consumption	Cointegration and causality	GDP causes energy consumption
Chang and Wong (2001)	Singapore (1975-1995)	GDP and energy consumption	Cointegration, Granger causality	GDP causes energy consumption
Cheng (1995)	US (1947-1990)	GNP and energy consumption	Cointegration and causality	No causal relationship
Cheng and Lai (1997)	Taiwan (1954-1993)	GDP and energy consumption	Granger causality	GDP causes energy consumption

*Continued*

Study	Countries studied (Period)	Variables used	Method	Finding(s)
Cheng (1999)	India (1972-1997)	GDP and energy consumption	Cointegration and Granger causality	GDP causes energy consumption
Chiou-Wei, Chen and Zhu (2008)	22 OECD countries (1960-2001)	Per capita GDP, per capita total net capital stock, energy consumption per capita	Panel cointegration, panel causality and panel vector error correction	Bi-directional causality among energy consumption, the capital stock and GDP growth
Fatai <i>et al.</i> (2004)	New Zealand (1960-1999)	Employment, total energy consumption (also disaggregated in oil, electricity and gas) and GDP	Granger causality, Toda and Yamamoto's Autoregressive distributed lag (ARDL) technique	No causal relationship (long-run) between total energy consumption and real GDP; real GDP causes oil and electricity consumption
Glasure and Lee (1997)	South Korea and Singapore (1961-1990)	GDP and Energy Consumption	Cointegration and Granger causality	No causal relation for South Korea; GDP causes energy consumption in Singapore

*Continued*

Study	Countries studied (Period)	Variables used	Method	Finding(s)
Ghali and El-Sakka (2004)	Canada (1961-1997)	GDP and energy consumption	Cointegration, Granger causality	Bi-directional causality
Halicioglu (2009)	Turkey (1960-2005)	GDP, foreign trade, carbon emission and energy consumption	Bounds test to cointegration procedure, Granger causality	Bi-directional causality between carbon emissions and commercial energy consumption and bi-directional causality between carbon emissions and income
Jumbe (2004)	Malawi (1970-1999)	GDP, agriculture GDP. Non-agriculture GDP and electricity consumption	Cointegration, Granger causality and error correction	Bi-directional causality from Granger causality test; GDP causes electricity consumption from error correction model
Karanfil (2008)	Turkey (1970-2005)	Energy consumption, total GDP taking into account the unrecorded economy and real official GDP	Cointegration, Granger causality and error correction	Uni-directional causality from official GDP to energy consumption both in Short run and long run, no causality between energy consumption and total GDP including unrecorded economic activities
Kraft and Kraft (1978)	USA (1947-1974)	GNP and gross energy input (GEI)	Sim's technique	GNP causes GEI

*Continued*

Study			Countries studied (Period)	Variables used	Method			Finding(s)
Masih and (1996)	Masih		India (1955-1990), Pakistan & Philippines (1955-1990), Indonesia & Singapore (1960- 1990)	Income and energy consumption	Cointegration, causality and decomposition	Granger vector		No causal relations for Malaysia, Singapore and Philippine; bi-directional causality in Pakistan; energy consumption causes real income in India; real income causes energy consumption in Indonesia
Masih and (1997)	Masih		Korea (1955-1991) and Taiwan (1952-1992)	Income consumption energy prices	Energy and Cointegration, vector error correction, variance decomposition and impulse response function			Bi-directional causality
Morimoto and (2004)	Hope		Sri Lanka (1960-1998)	GDP and electricity production	Granger causality			Electricity production causes GDP
Mozumder and Marathe (2007)			Bangladesh (1971-1999)	Per capita GDP and per capita electricity consumption	Cointegration, vector error correction			Uni-directional causality from per capita GDP to per capita electricity consumption

*Continued*



Study	Countries studied (Period)	Variables used	Method	Finding(s)
Narayan and Smyth (2005)	Australia (1966-1999)	Per capita GDP and electricity consumption, manufacturing sector employment index	Cointegration, Granger causality and error correction	Long run uni-directional causality from both employment and income to electricity consumption
Oh and Lee (2004)	Korea (1970-1999)	GDP and electricity consumption	Granger causality, error correction	Bi-directional causality (long-run); electricity consumption causes GDP (short-run)
Salim, Rafiq and Hassan (2008)	Bangladesh, China, India, Malaysia, Pakistan and Thailand (1980-2005)	GDP, consumer price index and energy consumption	Cointegration, Granger causality, error correction, variance decomposition and impulse responses functions	Bi-directional causality between energy consumption and income in Malaysia, uni-directional causality from output to energy consumption in China and Thailand and uni-directional causality from energy consumption to output in India and Pakistan.
Soytas and Sari (2003)	Argentina (1950-1990), Italy (1950-1992), Korea (1953-1991), Turkey & France (1950-1992), Germany (1950-1992), Japan (1950-1992)	Per capita GDP and Energy consumption	Cointegration and Granger causality	Bi-directional causality (in Argentina) and uni-directional causality (GDP causes energy consumption in Italy and Korea and energy consumption causes GDP in Turkey, France, Germany and Japan)

*Continued*

Study	Countries studied (Period)	Variables used	Method	Finding(s)
Stern (1993)	US (1947-1990)	GDP, gross energy use, adjusted (for hanging fuel consumption) final energy use	Granger causality	No causality between GDP and gross energy use; adjusted (for hanging fuel consumption) final energy use causes GDP
Wolde-Rufael (2004)	Shanghai (1952-1999)	GDP, total and disaggregated energy consumption	Granger causality	Energy consumption (total and disaggregated) to GDP
Yang (2000)	Taiwan (1954-1997)	GDP and electricity consumption	Granger causality	Electricity consumption causes real GDP
Yu and Hwang (1984)	US (1947-1979)	GNP and total energy consumption	Sim's technique	No causal relationship
Yu and Jin (1992)	US (1974-1990)	GNP and total energy consumption, industrial production index of manufacturing and total energy consumption	Cointegration and Granger causality	No causal relationship (long-run)

# Chapter 3

## Oil and Economic Activities: An Analytical Framework

### 3.1 Introduction

As discussed in the previous chapter, empirical studies of the association between energy consumption and economic activities are not new. Among them, bi-variate studies suffer from omitted variable problems, while the multivariate studies differ in their approaches. One group takes a *supply-side approach* by assuming an energy inclusive Cobb-Douglas-type production function. Another group adopts a *demand-side approach* by including output, energy consumption and CPI (as there is no one aggregate price for energy, CPI is used as a proxy) in their models. Since this thesis is concerned with analysing the impact of oil consumption and oil price volatility on economic activities, the study considers oil consumption in both approaches.

As far as *demand-side approach* is concerned, the inclusion of oil consumption instead of aggregate energy consumption gives this study a unique advantage of considering oil prices in the model instead of including CPI as a proxy. Furthermore, this study performs a comprehensive *demand-side* analysis by analysing the relationship among output, oil consumption, carbon emission and oil prices in a two-step process. Regarding the *supply-side approach*, instead of considering aggregate energy consumption in the production function framework as the previous studies, this thesis considers oil consumption.

Previous research of the linkage between oil price and economy mainly investigates two different aspects of the relationship between oil price and economic activities: the impact of oil price shock and the impact of oil price volatility. These two approaches differ in the way they incorporate oil price in their model. While the first approach takes oil prices at their levels, the second approach employs different volatility measures to capture the oil price uncertainty.

Studies investigating the impact of oil price shocks on economies are numerous. However, studies analysing the impact of oil price volatility on economic activities

are very limited. Research concerning the impact of oil price volatility in the context of developing countries is very limited. This is partly due to the lack of reliable data and partly due to the less historical dependence of these countries on oil. However, since these countries are presently experiencing increased demand for energy, a through investigation of the impact of oil price variability on these economies is warranted. This thesis aims to analyse the impact of oil price volatility on different macroeconomic variables of six developing countries of Asia.

In this setting, this research intends to fill the above mentioned gaps in the energy economics literature though adopting recent developments in time-series econometric techniques. This chapter can be divided into two broad sections. First, the theoretical settings are identified for the impact of oil consumption based on both supply- and demand-side approaches and oil price volatility on economic activities. Second, a discussion of the time-series econometric techniques employed to achieve the objectives of this thesis is presented.

### **3.2 Theoretical Settings**

This section explores the theoretical framework used in this study to identify the relationship between oil consumption and oil price volatility and economic activities in developing economies. For this purpose, this section first presents the *supply-side approach* of analysing the impact of oil consumption on output, followed by the *demand-side* approach to further investigate the impact of oil consumption. The section ends with identifying the impact of oil price volatility on economic activities for the concerned countries.

#### *3.2.1 Impact of oil consumption on output: the supply-side approach*

The concept of aggregate production function plays a key role in the field of economic studies regarding growth and development. Throughout the neoclassical literature of economic growth the concept has been extensively used to identify the sources of economic development and to assess the contribution of different inputs in accelerating growth. Both the neoclassical production functions introduced by Cobb and Douglas (1928) and further developed by Tinbergen (1942), popularly known as Cobb-Douglas production function, and the function presented by Arrow *et al.* (1961), subsequently called the Constant Elasticity of Substitution (CES), assume constant returns to scale. Both these production functions have been

extensively investigated in both theoretical and empirical economics literature. However, the Cobb-Douglas-type production function remains the most popular instrument for finding relationships between energy and economic variables because of two important reasons. One reason is the simplicity of the Cobb-Douglas production function from an estimation point of view. Secondly, it seems to fit with most economic data.

In the first part of the empirical analysis, this thesis examines the relationship between oil consumption and output in a three factor (capital, labour and oil consumption) production function framework. This thesis follows the spirit similar to Ghali and El-Sakka (2004), Soytas and Sari (2006) and Sari and Soytas (2007). However, this study extends the approach further by analysing the contribution of oil consumption on the total factor productivity of developing economies. The theoretical underpinning is elaborated below.

Weitzman (1970) formalizes the aggregate production function algebraically in a general form as:

$$Y_t = A_t f(K_t, L_t) \quad (3.1)$$

where  $Y_t$  indicates aggregate output at time  $t$ ,  $K_t$  is the flow of services provided by the existing capital stock rather than the capital stock itself,  $L_t$  is the labour employed in production,  $A_t$  is the level of technology, which is also the measure of total factor productivity, and  $f(.)$  is the function describing the connection between the variables  $K$  and  $L$ .

The aggregate production function, as presented in equation (3.1) above, commonly used in early empirical works assumes a Cobb-Douglas functional form that has constant returns to scale. Thus, equation (3.1) becomes:

$$Y_t = A_t K_t^\alpha L_t^\beta \varepsilon_t, \quad \alpha + \beta = 1 \quad (3.2)$$

where  $\alpha$  and  $\beta$  measure the elasticity of output with respect to capital and labour, respectively. Each of the elasticities is assumed to be constant and lying between zero and unity. The parameter  $A$  may be regarded as a technology parameter.  $\varepsilon_t$  is the stochastic disturbance term.

This thesis investigates the contribution of oil consumption to output of developing economies. With the help of recent developments in time-series econometrics, the *supply-side* impact of oil consumption (OC) on output will be investigated through the following *oil inclusive production function*:

$$Y_t = A_t K_t^\alpha L_t^\beta OC^\gamma \varepsilon_t \quad (3.3)$$

where  $\gamma$  measure the elasticity of output with respect to oil consumption.

### 3.2.2 Impact of oil consumption on output: the demand-side approach

Previous literature concerning the *demand-side* analysis mainly focuses on ascertaining the impact on energy consumption of economic activities. As mentioned earlier, most of these studies adopted a tri-variate framework consisting of energy consumption, income and CPI. Here, CPI is used as a proxy of energy prices. Since this study focuses on the impact on oil consumption, the inclusion of oil consumption in the model opens up a unique opportunity to incorporate the actual price of the commodity, *i. e.* oil price. Furthermore, demand for oil consumption and output determine the level of pollutant emissions in the environment. Thus, a complete *demand-side* analysis should take into account this dynamic relationship between oil consumption, output, oil price and CO<sub>2</sub> emissions.

This study estimates two different *demand-side* equations. The first one analyses the relationship between oil consumption and output within the framework presented in the following equation:

$$OC = F(Y, P) \quad (3.4)$$

where,  $OC$  is oil consumption,  $Y$  is output and  $P$  is oil prices.

The second equation estimated for the purpose of analysing the dynamic relationship among carbon emissions, output and oil consumption is as follows:

$$CO_2 = F(Y, OC) \quad (3.5)$$

where  $CO_2$  is carbon emission. This study analyses Equation 3.4 and 3.5 to investigate both long- and short-run relationships among output, oil consumption and pollutant emission.

### 3.2.3 Oil price volatility and the economy

It is now well established in both empirical and theoretical literature that oil price shocks exert adverse impacts on different macroeconomic indicators through raising production and operational costs. Alternatively, large oil price changes, either increases or decreases, *i.e.* volatility; may affect the economy adversely because they delay business investment by raising uncertainty or by inducing costly sectoral resource reallocation.

Bernanke (1983) offers a theoretical explanation of the uncertainty channel by demonstrating that, when the firms experience increased uncertainty about the future price of oil then it is optimal for them to postpone irreversible investment expenditures. When a firm is confronted with a choice of whether to add energy-efficient or energy-inefficient capital, increased uncertainty born by oil price volatility raises the option value associated with waiting to invest. As the firm waits for more updated information, it forgoes returns obtained by making an early commitment, but the chances of making the right investment decision increase. Thus, as the level of oil price volatility increases, the option value rises and the incentive to investment declines (Ferderer 1996). The downward trend in investment incentives ultimately transmits to different sectors of the economy.

Hamilton (1988) discusses the sectoral resource allocation channel. In this study by constructing a multi-sector model, the author demonstrates that relative price shocks can lead to a reduction in aggregate employment by inducing workers of the adversely affected sectors to remain unemployed while waiting for the conditions to improve in their own sector rather than moving to other positively affected sectors. Lilien (1982) also show that aggregate unemployment rises when relative price shocks becomes more variable.

This study analyses the impact of oil price volatility on developing economies within the following framework:

$$X = F(OPV) \tag{3.6}$$

where  $X$  is a matrix of two macroeconomic indicators, namely, GDP growth and inflation, on which the impact of oil price volatility is ascertained and  $OPV$  is oil price volatility.

Oil price volatility is constructed through the application of realized volatility measures. The method employed in constructing the volatility measure is discussed later in the data section of this thesis.

For the purpose of fulfilling the objectives of this thesis different time-series econometric and panel data analysis techniques are used. The following section discusses all the methods that are employed in the empirical analysis of this study.

### **3.3 Time-Series Analysis**

This section discusses the time-series and panel-data econometric procedures to be used in this thesis. However, since time-series econometric techniques are the dominant methods to be employed in this research, the main focus is the time-series analysis while panel-data techniques are discussed wherever necessary. A brief discussion about the time-series properties of the data is followed by discussion of causality testing procedures. An overview of impulse response functions and variance decomposition ends the section.

#### *3.3.1 Time-series properties*

In order to avoid model misspecification and misleading results, it is imperative to investigate the time-series properties of the data. Thus, the tests for integration (unit-root tests) and cointegration are warranted at the beginning of any empirical analysis involving time-series data. The most widely used unit root tests are Augmented Dickey-Fuller (*ADF*) and Phillips-Perron (*PP*) tests. However, these standard tests may not be appropriate when the series contains structural breaks (Salim & Bloch 2007). To account for such structural breaks Perron (1997) develops a procedure that allows endogenous break points in the series under consideration.

Engle and Granger (1987) suggest that a vector of non-stationary time series, which may be stationary only after differencing, may have one or more stationary linear combinations without differencing. If that is the case, the variables are said to have a cointegrated relationship. If the variables are non-stationary and not co-integrated,



the estimation result of a regression model gives rise to what is called ‘spurious regression’ (C. W. J Granger & Newbold 1974).

The traditional OLS regression approach to identify cointegration cannot be applied where the equation contains more than two variables and there is a possibility of having multiple cointegrating relationships. In that case VAR based cointegration testing is appropriate. This thesis uses the Johansen (1988) and Johansen and Juselius (1990) maximum likelihood estimation (MLE) procedures to test for cointegration.

### 3.3.1.1 Stationary and non-stationary time series

A time-series process,  $y_t$ , for  $t = 1, 2, \dots, \infty$ , is stationary if,

$$E(y_t) = \mu. \quad \forall t \quad (3.7)$$

$$E(y_t - \mu)(y_t - \mu) = \sigma^2. \quad \forall t \quad (3.8)$$

$$E(y_t - \mu)(y_{t-j} - \mu) = \gamma_j. \quad \forall t \text{ and any } j \quad (3.9)$$

Thus, a stationary process should have a constant mean, a constant variance and a constant auto-covariance structure.

However, many economic time series are non-stationary and do not follow the above conditions. A non-stationary time series can be represented by the following equation:

$$y_t = y_{t-1} + \varepsilon_t. \quad (3.10)$$

where  $\varepsilon_t$  is a white-noise process, *i.e.*:

$$E(\varepsilon_t) = 0. \quad \forall t \quad (3.11)$$

$$E(\varepsilon_t^2) = \sigma^2. \quad \forall t \quad (3.12)$$

$$E(\varepsilon_t \varepsilon_r) = \begin{cases} \sigma^2 & \text{if } t=r \\ 0 & \text{otherwise} \end{cases} \quad \forall t \text{ and any } r \quad (3.13)$$

Equation (3.10) is a non-stationary stochastic process and is also termed ‘random walk’. Non-stationarity is usually characterized by two different models. The first one is *random walk model with drift*:

$$y_t = \mu + y_{t-1} + \varepsilon_t. \quad \forall t \quad (3.14)$$

And the second one is *trend-stationary process*:

$$y_t = \alpha + \beta t + \varepsilon_t. \quad \forall t \quad (3.15)$$

Equation (3.14) and equation (3.15) are also known as *stochastic non-stationarity* and *deterministic non-stationarity*, respectively.

In case of deterministic non-stationarity detrending is required, while in case of stochastic non-stationarity differencing is needed to reach stationarity. Thus, with a little simplification, equation (3.14) can be transformed into a stationary process as follows:

$$y_t = \mu + y_{t-1} + \varepsilon_t$$

$$y_t - y_{t-1} = \mu + \varepsilon_t$$

$$(1 - L)y_t = \mu + \varepsilon_t. \quad (3.16)$$

$$\Delta y_t = \mu + \varepsilon_t. \quad (3.17)$$

where  $\Delta y$  follows a stationary process. Hence, the non-stationary variable,  $y_t$  has to be ‘differenced once’ to transform it to a stationary one. And this is why the  $y_t$  is also known as a *unit root process*. In other words, the name *unit root* comes from the fact that the characteristic polynomial of equation (3.18) has a root equal to 1. Furthermore,  $y_t$  is also termed as a  $I(1)$  variable or integrated of order 1 as it requires a first difference to transform the variable from non-stationary to stationary.

In some of the instances there may also be a mixed stochastic-deterministic trend process of the following form:

$$y_t = \alpha + \beta t + y_{t-1} + \varepsilon_t. \quad (3.18)$$

### 3.3.1.2 Tests for unit root, correct functional form and structural break

Estimating a linear regression model with non-stationary variables usually leads to a high  $t$ -ratio and an  $R^2$  being close to 1. The results typically indicate a significant relationship among the variables. However, it is not the case here as it is a consequence of explosive variance due to the presence of unit roots in the variable under consideration and it is not related to the strength of relationship among the variables. This is the reasoning behind what is popularly known as *spurious regression* in the econometric literature. For this reason prior to use any time-series data for estimation and any meaningful empirical analysis, tests for stationarity are warranted. There have been a number of tests for unit-root process proposed in the literature. This part discusses some of the popular tests in the empirical literature.

*Dickey-Fuller (DF) test:* The early and pioneering work on testing for a unit root in time series is done by Dickey and Fuller (Fuller 1976, Dickey and Fuller 1979). The basic objective of the test is to examine the null hypothesis that  $\phi_1 = 0$  against the alternative  $\phi_1 < 0$  in

$$\Delta y_t = \phi_0 + \phi_1 y_{t-1} + \varepsilon_t. \quad (3.19)$$

In the above equation, if the null cannot be rejected, then  $\phi_1 = 0$  and thus,

$$\Delta y_t = \phi_0 + \varepsilon_t$$

$$y_t - y_{t-1} = \phi_0 + \varepsilon_t$$

$$y_t = \phi_0 + y_{t-1} + \varepsilon_t$$

which supports the presence of unit root in  $y_t$ . On the other hand, if the null can be rejected, then  $\phi_1 < 0$ , hence,

$$\Delta y_t = \phi_0 + \phi_1 y_{t-1} + \varepsilon_t$$

$$y_t - y_{t-1} = \phi_0 + \phi_1 y_{t-1} + \varepsilon_t$$

$$y_t = \phi_0 + (1 + \phi_1) y_{t-1} + \varepsilon_t$$

Since  $\phi_1 < 0$ , this implies  $(1 + \phi_1) < 1$  and hence,  $y_t$  does not contain unit root.

*Augmented Dickey-Fuller (ADF) test:* The DF test assumes that the error term,  $\varepsilon_t$  in the equation (3.19) to be independently, identically distributed (iid). Thus, the presence of serial correlation may affect the test statistic and its underlying distribution. To avoid this shortcoming, an extension to the DF test, the Augmented Dickey Fuller (ADF) test is proposed to accommodate the possible presence of time trend and serial correlation in the error terms. The ADF regression is as follows:

$$\Delta y_t = \alpha + \beta y_{t-1} + \gamma t + \sum_{j=1}^J \delta_j \Delta y_{t-j} + \varepsilon_t. \quad (3.20)$$

where the role of each of the terms in the regression above can be viewed as below:

$$\Delta y_t = \underbrace{\alpha + \beta y_{t-1}}_{\text{original DF component}} + \underbrace{\gamma t}_{\text{time trend}} + \sum_{j=1}^J \underbrace{\delta_j \Delta y_{t-j}}_{\text{serial correlation}} + \varepsilon_t.$$

The ADF test works identically to the original DF test with two additional components, namely the trend component and the lag component. The functions of the trend and lag components are to accommodate the effect of a time trend and of serial correlation in the error term, respectively.

*Phillips-Perron (PP) test:* The Phillips-Perron test is another extension to the original Dickey Fuller test. It uses the original DF equation (3.19) as the basis of the test statistic. However, to accommodate the potential serial correlation and heteroscedasticity it uses non-parametric methods. According to some econometric literature, because of this approach, the PP test has more power than the DF and the ADF tests.

Two critical assumptions that are inherent in the estimation of equation (3.20) are that the logarithmic transformation of the variables is appropriate and there are no structural breaks in the trend functions. Granger and Hallman (1991) and Frances and McAleer (1998) argue that the tests for unit root are sensitive to non-linear transformation. They demonstrate that the ADF test on the log form of a variable often report stationarity; whereas when the same variable in its level form is tested

for unit root it is found to be non-stationary. Thus, prior to testing for unit root it is required that a test for appropriateness of logarithmic transformation is carried out.

Frances and McAleer (1998) investigate the impacts of non-linear transformations on the ADF regression within the class of Box-Cox models and propose a test for correct functional form by employing the following equation:

$$\Delta y_t = \phi^* y_{t-1} + \phi_1^* \Delta y_{t-1} + \phi_2^* \Delta y_{t-2} + \dots + \phi_{t-(p-1)}^* \Delta y_{t-(p-1)} + \phi_p (\Delta y_{t-1})^2 + \varepsilon_t. \quad (3.21)$$

The test is employed by examining the significance of  $\phi_p$  in the above equation. Should the additional variable be statistically significant, the ADF regression is inappropriately transformed and does not yield a valid inference in testing for a single unit root in  $y_t$ . This study will employ the above approach to test for single unit root and non-linear transformation.

Perron (1989) argues that many macroeconomic time series can be characterised as stationary fluctuations around deterministic trend function if allowance is made for a possible change in slope and intercept. Thus, the standard ADF and PP tests for stationarity may not be appropriate when a series contains structural breaks. A number of authors point out this limitation of conventional unit root tests (for example Perron (1989, 1997); Zivot and Andrews (1992); Salim and Bloch (2007) and so forth). To account for such structural breaks this study will employ Perron (1997) test for unknown structural break.

Perron (1997) develops a procedure that allows endogenous break points in series under consideration. The following regression (Perron 1997) is used here to examine the stationarity of time series allowing for unknown structural breaks:

$$y_t = \mu + \beta t + \gamma DT_t^* + \alpha y_{t-1} + \sum_{j=1}^k c_j \Delta y_{t-j} + e_t. \quad (3.22)$$

where  $DT_t^*$  is a dummy variable and  $DT_t^* = 1(t > T_b)(t - T_b)$ . Here  $T_b$  indicates break point(s). The break point is estimated by OLS for  $T_b = 2, \dots, T-1$ , thus,  $(T-2)$  regressions are estimated and the break point is obtained by the minimum  $t$  statistic on the coefficient of the autoregressive variable ( $t_\alpha$ ).

### 3.3.2 Lag length selection criteria

The first step of conducting the cointegration test is to select the correct order of the VAR model. The appropriate lag order,  $k$ , is chosen carefully by a combination of multivariate Schwarz (1978) Bayesian Criterion (SBC), multivariate Hannan and Quinn (1979) Criterion (HQC), Akaike Information Criterion (AIC), Log Likelihood (LL) and a battery of multivariate diagnostic tests. The methods applied in this study for selecting the appropriate lag length are:

- (i) Minimising a selection criterion, for example  $AIC = n \ln(\hat{\sigma}^2) + 2k$ , and  $SBC = n \ln(\hat{\sigma}^2) + \ln(T)k$ , where  $k$  is the number of augmenting lags;
- (ii) Using a variety of  $k$  values to look for the robustness of the ADF test;
- (iii) Selecting the smallest  $k$  such that the errors are approximately white noise;
- (iv) Choosing  $k = T^{1/3}$ , for example if the sample size  $T = 64$ , then  $k = 4$ .

Different software packages employ different methods for determining the value of  $k$ . This study is very flexible in the lag selection since the nature of the data being used for this analysis can also play a very important role.

### 3.3.3 Vector autoregressive (VAR) models, cointegration, and vector error correction models (VECM)

Vector autoregressive (VAR) models, popularized by Sims (1980), are hybrids between the univariate time-series models and the simultaneous equation models. In a VAR model, no distinction is made between endogenous and exogenous variables, *i.e.* all the variables are treated as endogenous. In order to implement the Johansen (1988) technique of cointegration in the latter part, the econometric model that underlies the following general unrestricted VAR(p) model for the  $q$  series is presented as below:

$$X_t = \mu + \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + \dots + \Pi_p X_{t-p} + \phi D_t + \varepsilon_t. \quad (3.23)$$

where,

$X_t$  = a vector of  $q$  variables

$D_t$  = a vector of deterministic terms such as (centered) seasonal and trend dummies

$\Pi_i$  = ( $q \times q$ ) matrices of parameters where  $i = 1, 2, \dots, p$

$\mu$  = ( $q \times 1$ ) vector of constants

$\varepsilon_t$  is a white noise ‘well behaved’ random disturbance term with positive definite covariance matrix  $\Omega$ . Two major reasons for the popularity of this model is its flexibility or ease of generalization and the compactness with which the notation can be expressed (Brooks 2002). Nevertheless, when the variables in the model are integrated, then it is wise to perform tests for cointegration.

Campbell and Perron (1991) states that there are both ‘pitfalls’ and ‘opportunities’ for the macroeconomic researcher when dealing with non-stationary data. Perhaps the major opportunities for the applied economists stem from the development of the test for cointegration. Granger<sup>15</sup> proposes the following definition of cointegration:

Let  $y_{it} \sim I(1) \forall i = 1, 2, \dots, k$  and let  $y_t = (y_{1t}, y_{2t}, \dots, y_{kt})'$ .  $y_t$  is said to be cointegrated if there is a vector  $\beta = (\beta_1, \beta_2, \dots, \beta_k)'$  such that

$$\beta'y_t \sim I(0).$$

Thus, the definition essentially states that if there is a linear combination of a set of  $I(1)$  variables such that the result is  $I(0)$  then the set of  $I(1)$  variables to be cointegrated and they possess a long-run equilibrium relationship.

Three main tests for cointegration are usually employed in empirical literature : (i) two-step test by Engle and Granger (1987), (ii) the maximum likelihood based test by Johansen (1988, 1991) and Johansen and Juselius (1990) and (iii) the residual based test by Gregory and Hansen (1996). Among all these methods, Johansen’s approach is probably the most popular applied test in the literature today. One of the reasons behind the popularity is that the Johansen (Johansen (1988, 1991) and Johansen and Juselius (1990)) test allow estimation and testing of all the cointegrating vectors that exist among a set of time series and the tests are based on the error-correction representation of the VAR model. Along with different significance tests for various restrictions this study employs Johansen (1988, 1991) and Johansen and Juselius (1990) maximum likelihood estimator procedure for determining cointegration.

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<sup>15</sup> Because of his contributions to time-series econometrics, especially his invention of the idea of cointegration, Clive Granger was awarded ‘The Sveriges Riksbank Prize in Economic Science in Memory of Alfred Nobel’ (popularly known as the Nobel Prize in Economics) in 2003, shared with his former PhD student, Robert Engle who was awarded the prize for another innovation of his, the ARCH model.

Stock (1987) proposes the property of ‘super consistency’ of ordinary least squares (OLS) estimates of cointegrating vectors. Stock argues that in the case of cointegrated non-stationary series, the OLS estimates of the cointegrating vector(s) are not only consistent but they also converge on their true parameter values much faster than in the stationary case. The proof of such consistency does not require the assumption that the regressors be uncorrelated with the white noise error term. In fact, the estimates remain ‘super consistent’ while any of the variables in the cointegrating vector is employed as the dependent variable. However, most of the classical assumptions underlying general linear model are not essential in order for OLS or maximum likelihood estimates of the cointegrating vector to have desirable properties. This is important since errors in variables and simultaneity; both of which would normally be a cause of concern in the data set employed for any analysis would not affect the desirable properties of the estimates. Furthermore, as the cointegration approach focuses on long-run relationships, problems linked with variations in factor utilization and autocorrelation do not arise.

In contrast to the above property of ‘super consistency’ in OLS estimates, Banerjee *et al.*(1986) demonstrates that there may be significant small-sample biases in such OLS estimates of the cointegrating vectors. Hendry and Mizon (1990) argue that the traditional DF and ADF tests generally suffer from parameter instability. Furthermore, while analysing the asymptotic properties of residual based tests Philips and Ouliaris (1990) states the limiting distributions for the DF and ADF tests are not well defined, suggesting that the power of these tests is low. Perhaps more damaging is the possibility that for a given set of variables there may exist more than one long-run relationship, *i.e.* there may be multiple cointegrating vectors. OLS estimates of the cointegrating vector cannot identify multiple long-run relationships or test for the number of cointegrating vectors. In addition, the residual based tests for cointegration are insufficient and can lead to contradictory results, especially when the model consists of more than two  $I(1)$  variables.

As mentioned earlier, Johansen (1988, 1991) and Johansen and Juselius (1990) maximum likelihood estimator procedure offers a cointegration estimation methodology that overcomes most of the drawbacks of the Engle and Ganger (1987) two-step method. Johansen’s technique is based on maximum likelihood estimates of



multiple cointegrating vectors in a given set of variables and provides two likelihood ratio tests for the number of cointegrating vectors. The method provides a unified framework for estimating and testing of cointegrating relations in the context of vector autoregressive (VAR) models.

Many economic time-series are non-stationary at levels but stationary in first differences. Systems such as the above vector autoregressive (VAR) representation in equation (3.19) can be written in the conventional first-difference form as below:

$$\Delta X_t = \mu + \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \dots + \Gamma_p \Delta X_{t-p+1} + \Pi X_{t-p} + \phi D_t + \varepsilon_t. \quad (3.24)$$

where:

$$\Gamma_i = -Iq + \Pi_1 + \Pi_2 + \dots + \Pi_i \text{ for } i = 1, 2, \dots, p-1 \text{ and}$$

$$\Pi = -Iq + \Pi_1 + \Pi_2 + \dots + \Pi_p.$$

$\Pi$  is a ( $q \times q$ ) matrix which contains information about the long-run equilibrium relations among the series, and the rank of  $\Pi$  gives the number of cointegrating relationships among the variables in the data vector. Assuming each variable in a six variable system (i.e.  $X$  has 6 dimensions) has 2 lags, i.e.  $p = 2$ , then

$$X_t = \mu + \Pi_1 X_{t-1} + \Pi_2 X_{t-2} + \varepsilon_t. \quad (3.25)$$

where,

$$\Pi_1 = \begin{bmatrix} \pi_{11} & \pi_{12} & \pi_{13} & \pi_{14} & \pi_{15} & \pi_{16} \\ \pi_{21} & \pi_{22} & \pi_{23} & \pi_{24} & \pi_{25} & \pi_{26} \\ \pi_{31} & \pi_{32} & \pi_{33} & \pi_{34} & \pi_{35} & \pi_{36} \\ \pi_{41} & \pi_{42} & \pi_{43} & \pi_{44} & \pi_{45} & \pi_{46} \\ \pi_{51} & \pi_{52} & \pi_{53} & \pi_{54} & \pi_{55} & \pi_{56} \\ \pi_{61} & \pi_{62} & \pi_{63} & \pi_{64} & \pi_{65} & \pi_{66} \end{bmatrix} \text{ and } \Pi_2 = \begin{bmatrix} \pi_{17} & \pi_{18} & \pi_{19} & \pi_{110} & \pi_{111} & \pi_{112} \\ \pi_{27} & \pi_{28} & \pi_{29} & \pi_{210} & \pi_{211} & \pi_{212} \\ \pi_{37} & \pi_{38} & \pi_{39} & \pi_{310} & \pi_{311} & \pi_{312} \\ \pi_{47} & \pi_{48} & \pi_{49} & \pi_{410} & \pi_{411} & \pi_{412} \\ \pi_{57} & \pi_{58} & \pi_{59} & \pi_{510} & \pi_{511} & \pi_{512} \\ \pi_{67} & \pi_{68} & \pi_{69} & \pi_{610} & \pi_{611} & \pi_{612} \end{bmatrix}$$

With the help of simple algebra equation (3.25) can be transformed into vector error correction model counterpart to the VAR model as follows:

$$\Delta X_t = \mu + \Gamma \Delta X_{t-1} + \Pi X_{t-2} + \varepsilon_t. \quad (3.26)$$

where,

$$\Gamma = -I + \Pi_1 \text{ and } \Pi = -I + \Pi_1 + \Pi_2.$$

The  $\Gamma$  matrix for the first differenced variables,  $\Delta X_{t-1}$ , contains the contemporaneous short-run adjustment parameters, while the  $\Pi$  parameter matrix for the levels variables  $X_{t-p}$  contains the information about the long-run equilibrium relationship between the variables in the data vector. The rank of  $\Pi$  indicates the number of distinct cointegrating vectors. In this regard, there are three cases to be discussed:

(a) If the rank ( $\Pi$ ) = 0, this implies that  $\Pi$  is a null matrix and (3.30) reduces to:

$$\Delta X_t = \Gamma \Delta X_{t-1} + \mu + \varepsilon_t. \quad (3.27)$$

which is a VAR(1) model in first differences. Thus, since variables in the vector  $X$  are each  $I(1)$ ,  $\Delta X$  is  $I(0)$  and there is no cointegration. For the general VAR model [*i.e.* equation (3.24) with ( $q$  and  $p$ ) > 2], if rank ( $\Pi$ ) = 0, then the model reduces to a general VAR ( $p-1$ ) model in first differences as follows:

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \dots + \Gamma_{p-1} \Delta X_{t-p+1} + \mu + \varepsilon_t. \quad (3.28)$$

(b) If the rank ( $\Pi$ ) =  $q$ , which occurs only if the vector  $X$  is stationary contradicts the assumption that (the variables in  $X$ )  $\sim I(1)$ . In this case  $\Delta X$  is over differenced and the correct specification is a VAR ( $p$ ) model in levels, as in equation (3.25), rather than in first differences as in above.

(c) If  $0 < [\text{rank}(\Pi) = r] < q$ , this implies that there are  $r$  cointegrating vectors. For example in equation (3.22) if the maximum rank ( $\Pi$ ) =  $r$ , cointegration occurs and  $\Pi$  can be decomposed into the product of two  $q$  by  $r$  matrices  $\alpha$  and  $\beta$  such that  $\Pi = \alpha\beta'$ . Since the  $\beta$  matrix contains the long-run equilibrium parameters (the  $r$  cointegrating vectors), then  $\beta' X_{t-p}$  comprises the  $r$  error correction terms which are

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<sup>16</sup> Franses (1998), Brooks (2002) and Edners (2004) can be consulted for further clarification.

stationary, even though  $X_t$  itself is non-stationary. The parameters in the  $\alpha$  matrix measure the speed at which  $\Delta X_t$  adjusts to the lagged error correction terms  $\beta' X_{t-p}$ . That is, it gives the weights with which the cointegrating vectors enter each equation of the system.

To determine the number of cointegrating vectors,  $r$ , Johansen and Juselius (1990) describe two likelihood ratio tests, namely maximum eigenvalue test and trace test. In the maximum eigenvalue test the null hypothesis is that there are at most  $r$  cointegrating vectors against the alternative of  $r+1$  cointegrating vectors. In the trace test which is based on the trace of the stochastic matrix, the null hypothesis is that there are at most  $r$  cointegrating vectors against the alternative hypothesis that there are  $r$  or more cointegrating vectors. Johansen's procedure is a sequential test. The maximum eigenvalue test is generally considered to be more powerful because the alternative hypothesis is equality. These tests can also be used to determine if a single variable is stationary by including only that variable in  $\Delta X_t$ .

According to Johansen (1988) the likelihood ratio tests have asymptotic distributions that are a function of only the difference between the number of variables and the number of cointegrating vectors. Thus, in contrast with the DF and ADF tests, the Johansen likelihood ratio tests have well-defined limiting distributions. Moreover, Johansen and Juselius (1990) present a methodology for testing hypotheses about the estimated coefficients of the cointegrating vectors based on likelihood ratio tests with standard chi-squared distributions.

In addition to the test of cointegration among variables this study performs Granger causality tests, impulse response functions and variance decomposition analyses. These techniques are used to capture the dynamic interrelationships among the variables and the following part of this section offers a brief discussion of these methods.

### *3.3.4 The Granger causality test, impulse response functions, and variance decomposition*

This study intends to capture both the short-run and long-run dynamic interrelations among different variables. To be more specific, this study intends to find out the causal relationships between different macroeconomic indicators and oil

consumption, oil price shocks and volatility. It will examine the response of each of the indicators to a unit standard error shock to consumption and prices as well as the proportion of factor error variances of the macroeconomic variables caused by innovation of oil consumption and oil price and volatility included in different VAR models. To achieve these multiple objectives study employs Granger causality tests, impulse response functions and variance decompositions analyses.

#### 3.3.4.1 Granger causality test

Causality remains one of the most important relationships between two variables in the time-series econometrics literature. Standard correlational analysis, such as regression analysis, does not provide any information about causality. The basic concept of Granger causality is discussed below.

If there are two time series  $\{y_{it}\}_{i=1}^{\infty}$ , for  $i = 1, 2$ , let  $I_t$  be the information sets containing the past information of  $y_{it}$  for  $i = 1, 2$  up to  $t$  and  $I_t = I_{1t} \cup I_{2t}$ , then  $y_{2t}$  is said to cause  $y_{1t}$  if

$$\Pr(y_{1t}|I_{1t}) \neq \Pr(y_{1t}|I_t). \quad (3.30)$$

The idea behind the causality test essentially, is to investigate the contribution of additional information from the past values of  $y_{2t}$ . If there is no causal relationship between  $y_{1t}$  and  $y_{2t}$ , then the addition of the information from  $y_{2t}$  will not change the probability structure of  $y_{1t}$  and that means  $\Pr(y_{1t}|I_{1t-1}) = \Pr(y_{1t}|I_{t-1})$ . However, if two variables do share a causal relationship then equation (3.30) holds and if there is bi-directional exists then  $\Pr(y_{2t}|I_{2t-1}) \neq \Pr(y_{2t}|I_{t-1})$ . Thus, testing

$$H_0 : \Pr(y_{1t}|I_{1t-1}) = \Pr(y_{1t}|I_{t-1})$$

$$H_1 : \Pr(y_{1t}|I_{1t-1}) \neq \Pr(y_{1t}|I_{t-1})$$

is equivalent to testing whether  $y_{2t}$  causes  $y_{1t}$ ; and testing

$$H_0 : \Pr(y_{2t}|I_{2t-1}) = \Pr(y_{2t}|I_{t-1})$$

$$H_1 : \Pr(y_{2t}|I_{2t-1}) \neq \Pr(y_{2t}|I_{t-1})$$

is equivalent to testing whether  $y_{1t}$  causes  $y_{2t}$ .

Since testing the above hypothesis is difficult as it requires several conditional probability densities, Granger proposes to restrict the causality test to only the first moment (conditional mean) of the random variables. That is to test:

$$H_0 : E(y_{1t} | I_{1t-1}) = E(y_{1t} | I_{t-1})$$

$$H_1 : E(y_{1t} | I_{1t-1}) \neq E(y_{1t} | I_{t-1})$$

and

$$H_0 : E(y_{2t} | I_{2t-1}) = E(y_{2t} | I_{t-1})$$

$$H_1 : E(y_{2t} | I_{2t-1}) \neq E(y_{2t} | I_{t-1})$$

To understand the mechanism in the vector autoregressive (VAR) framework, a general three-equation VAR (p) model of the following form can be considered:

$$\begin{bmatrix} x_{1t} \\ x_{2t} \\ x_{3t} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \end{bmatrix} + \begin{bmatrix} A_{11}(L) & A_{12}(L) & A_{13}(L) \\ A_{21}(L) & A_{22}(L) & A_{23}(L) \\ A_{31}(L) & A_{32}(L) & A_{33}(L) \end{bmatrix} \begin{bmatrix} x_{1t-1} \\ x_{2t-1} \\ x_{3t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \end{bmatrix}. \quad (3.31)$$

where:

$\mu_i$  = a matrix of deterministic terms (intercept, trend, dummies variables etc) in the  $i^{\text{th}}$  equation, for  $i=1,2,3$ .

$A_{ij}$  = polynomials in the lag operator  $L$ , with individual parameters denoted by  $a_{ij}(1)$  for the first lag on the  $j^{\text{th}}$  variable in the  $i^{\text{th}}$  equation,  $a_{ij}(2)$  for the second lag, ...,  $a_{ij}(p)$  for the final lag, and

$e_{ij}$  = vectors of white-noise error terms that are usually contemporaneously

correlated, *i.e.*  $\sum_e$  (sum of the error terms) is usually non-diagonal.

Granger (1969) offers an optional definition of causality that is based on the notion of predictability. Suppose, for example, that the values for the variable  $y_{1t}$  can be predicted using two different information sets namely:

$$\Omega^1_{t-1} = [(L)y_{1t-i} ; (L)y_{2t-i}] \quad (3.32)$$

$$\Omega^2_{t-1} = [(L)y_{1t-i} ; (L)y_{2t-i} ; (L)y_{3t-1}]. \quad (3.33)$$

According to Granger, if the mean square error (MSE) of the prediction using  $\Omega^2_{t-1}$  is less than the MSE from using  $\Omega^1_{t-1}$ , then  $y_3$  Granger causes  $y_l$ . A formal procedure for testing Granger causality based on the preceding trivariate VAR (p) model is as follows:

$H_0: a_{13}(1) = a_{13}(2) = \dots = a_{13}(p) = 0$ , *i.e.*  $y_3$  does not Granger cause  $y_l$

$H_1$ : Not  $H_0$ , *i.e.*  $y_3$  does Granger cause  $y_l$ .

Since individual  $e_{it}$  error terms are assumed to be white noise, and since each individual set of restrictions involves parameters drawn from only one equation, the restrictions in  $H_0$  can be tested with the usual F-test.

A test of related null hypothesis is that  $y_3$  does not Granger cause either of the other two variables, that is  $y_3$  should not even be in the VAR model at all. The null hypothesis for this block exogeneity (block Granger causality) test is in terms of parameter restrictions:

$H_0: a_{13(1)} = a_{13(2)} = \dots = a_{13(p)}$  and  $a_{23(1)} = a_{23(2)} = \dots = a_{23(p)} = 0$ .

In this case,  $H_0$  involves cross-equation restrictions and can be tested with a likelihood-ratio test. The equations are estimated separately using OLS to obtain the unrestricted RSS, then the restrictions imposed and the models are re-estimated to obtain the restricted RSS. Thus, evaluation of the significance of variables in the context of a VAR model almost invariably occurs on the basis of joint F-tests on all the lags of a particular variable in an equation, rather than by examination of the individual coefficient estimates.

However, if the variables of the models are cointegrated, instead of using a VAR based standard Granger causality test, a vector error correction model (VECM) should be estimated. Following Engle and Granger(1987) and Granger (1969), a VEC representation of the following form can be formulated:

$$\Delta y_t = \alpha_1 + \sum_{i=1}^l \beta_{li} \Delta k_{t-1} + \sum_{i=1}^m \gamma_{li} \Delta y_{t-1} + \sum_{i=1}^n \delta_{li} \Delta l_{t-1} + \sum_{i=1}^p \lambda_{li} \Delta o_{t-1} + \sum_{i=1}^r \xi_{li} ECT_{t-1} + \varepsilon_{it} \quad (3.34)$$

$$\Delta k_t = \alpha_2 + \sum_{i=1}^l \beta_{2i} \Delta k_{t-1} + \sum_{i=1}^m \gamma_{2i} \Delta y_{t-1} + \sum_{i=1}^n \delta_{2i} \Delta l_{t-1} + \sum_{i=1}^p \lambda_{2i} \Delta o_{t-1} + \sum_{i=1}^r \xi_{2i} ECT_{t-1} + \varepsilon_{2t}. \quad (3.35)$$

$$\Delta l_t = \alpha_3 + \sum_{i=1}^l \beta_{3i} \Delta k_{t-1} + \sum_{i=1}^m \gamma_{3i} \Delta y_{t-1} + \sum_{i=1}^n \delta_{3i} \Delta l_{t-1} + \sum_{i=1}^p \lambda_{3i} \Delta o_{t-1} + \sum_{i=1}^r \xi_{3i} ECT_{t-1} + \varepsilon_{3t}. \quad (3.36)$$

$$\Delta o_t = \alpha_4 + \sum_{i=1}^l \beta_{4i} \Delta k_{t-1} + \sum_{i=1}^m \gamma_{4i} \Delta y_{t-1} + \sum_{i=1}^n \delta_{4i} \Delta l_{t-1} + \sum_{i=1}^p \lambda_{4i} \Delta o_{t-1} + \sum_{i=1}^r \xi_{4i} ECT_{t-1} + \varepsilon_{4t}. \quad (3.37)$$

where  $y_t$ ,  $k_t$ ,  $l_t$  and  $o_t$  are output, capital, labour and oil consumption (*i.e.* VECM representation of the energy inclusive production function in equation 3.3).  $ECT$  refers to the error-correction term(s) derived from the long-run cointegrating relationship via the Johansen likelihood method, and  $\varepsilon_{i,t}$ 's are serially uncorrelated random error terms with mean zero.

Through the error correction term (ECT), the model opens up an additional channel of causality which is traditionally ignored by the standard Granger (1969) and Sims (1972) testing procedures (Masih & Masih 1997). Sources of causality can be identified through the statistical significance of: (i) the lagged ECTs ( $\xi$ 's) by a t-test; (ii) a joint test applied to the significance of the sum of lags of each explanatory variables ( $\beta$ 's,  $\gamma$ 's,  $\delta$ 's and  $\lambda$ 's) in turn, by joint  $F$  or Wald  $\chi^2$  test (weak or short-run Granger causality); or (iii) a joint test of the terms in (i) and (ii) by a Wald  $F$  or  $\chi^2$  test (strong or long-run Granger causality). It is worth to note that this thesis uses the concept of causality in the *predictive* rather than *deterministic* sense. It is based on the notion that 'X causes Y' is simply the abbreviated expression of the fact that 'X contains useful information for predicting Y' (Diebold 2004). Thus, the causality results presented here are interpreted in the Granger sense.

According to Brooks (2002) the  $F$ -test results of Granger causality are not, by construction, able to explain the sign of the relationship or how long these effects require to take place. In other words,  $F$ -test results will not reveal whether changes in the value of a given variable have positive or negative effects on other variables in the system or how long it would take for the effect of that variable to work through the system. According to Brooks (2002), such information will, however, be given by examination of the VAR's impulse responses and variance decompositions. Thus,

this thesis employs impulse response functions and variance decomposition techniques and they are discussed as follows.

### 3.3.4.2 Impulse response functions (IRF) and variance decompositions (VDC)

Impulse response functions trace out the responsiveness of the dependent variable in the VAR system to a unit shock in error terms. For each variable from each equation, a unit shock is applied to the error term and the effects upon the VAR over time are noted. If there are  $x$  variables in the VAR system, then a total of  $x^2$  impulse responses could be generated (Brooks 2002).

One limitation with the Granger-causality test is that the results are valid within the sample, which is useful in detecting exogeneity or endogeneity of the dependent variable in the sample period, but is unable to deduce the degree of exogeneity of the variables beyond the sample period (Narayan and Smyth 2005). To examine this issue the variance decomposition technique is employed. Unlike impulse responses, a shock to the  $i$ -th variable not only directly affects the  $i$ -th variable, but it also transmitted to all of the other endogenous variables through the dynamic (lag) structure of the VAR. Variance decomposition separates the variation in an endogenous variable into the component shocks to the VAR. Thus, variance decomposition provides information about the relative importance of each random innovation affecting the variables in the VAR. Sims (1980) notes that, if a variable is truly exogenous with respect to other variables in the system, own innovations will explain all of the variables forecast error variance.

To understand the concepts, the moving average representation of a bivariate equation is given below:

$$\begin{bmatrix} X_t \\ Z_t \end{bmatrix} = \begin{bmatrix} \bar{X} \\ \bar{Z} \end{bmatrix} + \sum_{i=0}^{\infty} \begin{bmatrix} \phi_{11}(i) & \phi_{12}(i) \\ \phi_{21}(i) & \phi_{22}(i) \end{bmatrix} \begin{bmatrix} \varepsilon_{1,t-i} \\ \varepsilon_{2,t-i} \end{bmatrix} \quad (3.38)$$

The above equation is the vector moving average (VMA) ( $\infty$ ) representation that provides the basis for developing one of the main sets of analytical tools for impulse response functions and forecast error variance decomposition (Enders 2004). In this

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<sup>17</sup> For detail discussion Enders (1995, p. 273-280) can be consulted.



equation, each  $\phi_{jk}(i)$  parameter may be used to generate the quantitative effects of  $\varepsilon_{1t}$  and  $\varepsilon_{2t}$  shocks on the entire time paths of the  $\{X_t\}$  and  $\{Z_t\}$ , series. Normally, each  $\phi_{jk}(i)$  parameter is interpreted as the time-specific partial derivative of the VMA ( $\infty$ ) function. Thus, the matrix  $\phi_i$  has the interpretation:

$$\phi_{jk}(i) = \frac{\partial y_{ji}}{\partial \varepsilon_{kt}}. \quad (3.39)$$

which measures the numerical change in the  $j^{\text{th}}$  variable in period  $i$  resulting from a unit shock to the  $k^{\text{th}}$  variable in the present period,  $t$ .

Enders (2004) indicates that accumulating  $\phi_{jk}(i)$  impact multipliers up to period  $m$  gives the period multipliers for period  $m$ . Furthermore, the author offers an example that the accumulated sum of effects of the unit shock (impulse) to  $\varepsilon_{zt}$  on the  $\{X_t\}$  series is given by:

$$\Psi_{12} = \phi_{12}(0) + \phi_{12}(1) + \phi_{12}(2) + \dots + \phi_{12}(m) = \sum_{i=0}^m \phi_{12}(i). \quad (3.40)$$

Finally, letting  $m \rightarrow \infty$ , the long-run multipliers can be obtained. Given the assumption that  $\{y_t\} \sim I(0)$ , it follows that for all  $j$  and  $k$ ,

$$\sum_{i=0}^{\infty} \phi_{12}(i) \text{ is finite.}$$

As mentioned earlier, each  $\phi_{jk}(i)$  parameter of the impulse response function is intended to be a measure of the change in the  $j^{\text{th}}$  variable induced by a unit shock (impulse) to the  $\varepsilon_{kt}$  disturbance term, with the values of all other  $\varepsilon_{lt}$ ,  $l = 1, 2, \dots, n$  and  $l \neq j$ , terms held constant. For a bivariate VAR (1) model,  $\phi_{jk}(i)$  can be meaningfully interpreted as the partial derivative of the VMA ( $\infty$ ) model only if  $\varepsilon_1$  or  $\varepsilon_2$  remains constant when  $\varepsilon_{t1}$  or  $\varepsilon_{t2}$  is shocked. This requires that

$$\text{Cov}(\varepsilon_{t1}, \varepsilon_{t2}) = 0.$$

In general, however, this will not be the case. Orthogonal impulse response functions (IRF) by orthogonalising the  $\{\varepsilon_t\}$  terms through Choleski decomposition then needs to be created. For any real symmetric positive definite matrix such as  $\sum_{\varepsilon}$ , it can be shown that there exists a unique lower triangle matrix  $C$  with ‘1s’ along the main diagonal and a unique diagonal matrix  $D$  with positive elements on the main diagonal satisfying:  $\sum_{\varepsilon} = \mathbf{C}\mathbf{D}\mathbf{C}'$  which implies that  $\mathbf{C}^{-1}\sum_{\varepsilon}\mathbf{C}'^{-1} = \mathbf{D}$ . The implication of this result is that once the appropriate numerical values for the elements of the matrix  $C$  are known (*i.e.* estimated), they can be used to construct an  $(n \times 1)$  vector of transformed errors:  $\varepsilon_t^* = \mathbf{C}^{-1}\varepsilon_t$  that are uncorrelated with each other.

Enders (2004) shows that the impulse responses in a linear AR(1) model  $y_t = \rho y_{t-1} + \varepsilon_t$  are

$$y_t = \sum_{i=0}^{\alpha} \rho^i \varepsilon_{t-i} \quad (3.41)$$

Thus, the effect of a one-unit shock on  $y_t$  is 1, the effect of the shock on  $y_{t+1}$  is predicted to be  $\rho$ . Here  $\rho = \partial y_{t+1} / \partial \varepsilon_t = \partial y_t / \partial \varepsilon_{t-1}$ . Furthermore, the effect of the shock in  $y_{t+2}$  period is predicted to be  $\rho^2$ , and so forth.

This thesis employs the *generalized* impulse response functions and *generalized* forecast variance decomposition techniques because these techniques overcome some of the shortcomings of the standard approach of Sims (1980). As indicated in Lutkepohl (1991), the traditional VAR models and innovation accounting techniques are subject to the orthogonality critique, which implies that the results may differ depending on the ordering of the variables in the system (Ewing, Sari & Soytas 2007). Thus, this thesis applies *generalized* versions of both these tests due to Koop *et al* (1996) and Pesaran and Shin (1998). These approaches resolve the ordering problem of the standard techniques so the results are not sensitive to the ordering of the variables in the VAR system.

As mentioned earlier, the technique of forecast error variance decomposition indicates what proportion of the variation in a variable can be explained by the changes in each of the variables in the same VAR model. Innovations to an

individual variable can exert impact on its ‘own’ changes as well as on the changes of the other variables. The relative importance of these effects can be identified through the employment of the forecast error variance decomposition (VDC) technique. Thus, the VDC may well be referred to as an out-of-sample causality test.

Following Koop *et al.*(1996), Pesaran and Pesaran (1997), Pesaran and Shin (1998) and Sari and Soytas (2007) the following VAR representation for  $g_t$  can be considered for illustration<sup>18</sup>:

$$g_t = M[\phi_1 g_{t-1} + \phi_2 g_{t-2} + \dots + \phi_p g_{t-p}] + \varepsilon_t. \quad (3.42)$$

where  $g_t$  is an  $m \times 1$  vector of jointly determined endogenous variables,  $\phi_1$  through  $\phi_p$  are  $m \times m$  matrices of coefficients to be estimated.  $M$  represents a vector of constant,  $t$  is linear time trend, while  $\varepsilon_t$  is an  $m \times 1$  vector of well behaved white noise disturbances with covariance  $\sum = \sigma_{ij}$ . The generalized impulse response of  $g_{t+n}$  with respect to a unit shock to  $j$ -th variable at time  $i$  is denoted by  $(S_n \sum e_j)(\sigma_{ij})^{-1}$ , where  $S_n = \phi_1 S_{n-1} + \phi_2 S_{n-2} + \dots + \phi_p S_{n-p}$ , here  $n = 1, 2, \dots$ ,  $S_0 = I$ ,  $S_n = 0$  for  $n < 0$ , and  $e_j$  is  $m \times 1$  selection vector with unity as its  $j$ -th element and zero elsewhere<sup>19</sup>. Therefore, *generalized* error variance decompositions can be computed by

$$\frac{\sigma_{ij}^{-1} \sum_{l=0}^n (e'_i S_l \sum e_j)^2}{\sum_{l=0}^n (e'_i S_l \sum B S'_l e_i)^2}. \quad (3.43)$$

The generalized VAR produces an expression that is invariant of the ordering of variables or any other priori restrictions on the variance-covariance matrix of the reduced form residuals. Likewise, the generalized VAR does not attempt to recover any structural shocks (Elyasiani, Kocagil & Mansur 2007). Instead, the genelaralized version of the analysis describes how the system behaves after a particular historical shock, taking into account the correlation among the shocks. Since the historical

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<sup>18</sup> Hamilton (1994) can be consulted for greater technical details of the generalized approaches.

<sup>19</sup> See Pesaran, MH & Shin (1998) for derivation of the triangular orthogonalization and generalized IRF procedures.

shocks are not orthogonal, the sum of forecast error variance decompositions does not add up to 100% (Soytas & Sari, 2007 and Dua, 2008)<sup>20</sup>.

Essentially, this study employs *generalized* impulse responses and *generalized* variance decompositions techniques since these approaches resolve most of the drawbacks of Sim's conventional approach.

*A note to panel data analysis:* This study employs simple panel-data estimation in the models for oil consumption-output relationship. Least square estimation with three different effect specification scenarios is employed in this respect. The first one is without any specification at all. In the second one, cross-section fixed effect is used. The third one employs both cross-section and time fixed effects.

### 3.4 Summary

This chapter presents a brief discussion about the theoretical framework and econometric methodology to be employed in the empirical analysis part of the thesis. In the theoretical section, several equations regarding oil inclusive production function (*supply-side approach*) are presented, followed by a brief overview of the methods for identifying the impact of oil consumption based on *demand-side approach* and oil price volatility on economic activities. The econometric methodology section elaborates the time-series econometrics and panel-data analysis approaches that will be employed to achieve the objectives (borne by the theoretical framework) of the thesis. The next chapter offers an extensive empirical analysis of the *supply-side approach* to identify the impact of oil consumption in the overall production process of six developing countries of Asia.

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<sup>20</sup> Consult Yang, Min & Li (2003), Yang, Kolari & Min (2003), Wang, Kutan & Yang (2005) and Darrat & Zhong (2005) for further descriptions and recent applications of generalized variance decomposition technique. An alternative technique is introduced by Swanson & Granger (1997) and can be applied for testing structural models based on over-identifying restrictions and data-determining ordering of errors. Afterwards, Bessler & Yang (2003) employ this technique to investigate the causal structure among innovations in international stock markets. This approach also avoids the sensitivity of the results to the ordering of the variables.

# Chapter 4

## **Empirical Analysis on Oil Consumption and Output: A Production Function Approach**

### **4.1 Introduction**

This chapter builds upon identifying the causal link between oil consumption and output within the production function framework presented on Equation 3.3 in Chapter 3. As stated in the last two chapters, none of the previous studies in this field analyse the importance of oil consumption on income in some of the concerned countries. This study is an attempt to investigate the causal relationship between these two variables by using a multivariate production-function framework. Time-series econometric techniques presented in Chapter 3 are employed to identify the causal link between oil consumption and output in individual countries. Further the panel data method is employed across countries to identify the significance of oil consumption in production.

The causality link between energy consumption and output informs the policy implications for energy conservation. Furthermore, since oil is one of the major sources of carbon emission, policy inferences can be made through the analysis of causal link between oil consumption and output. Thus, if causality is running from oil consumption to output, then oil conservation policy may harm economic growth. Under such circumstances, concerned countries may choose to invest in technology that discovers and makes alternative energy sources economically feasible. In the meantime they can initiate two-fold policies that mitigate carbon emissions, for instance increasing energy efficiency and decreasing energy intensity via substituting in cleaner (*i.e.* natural gas, solar and wind energy) sources for fossil fuels like oil and coal. On the contrary, if there is uni-directional causality running in the opposite direction. *i.e.* output to oil consumption, then decreasing domestic oil consumption and encouraging oil conservation may become the key action in reducing domestic emissions in these countries. Finally, in case of a bi-directional causality a carefully crafted mixture of alternative policy actions may be required.

This thesis gives more emphasis to the use of country-specific case studies rather than cross-sectional study since empirical analyses conducted at the aggregate level

are unable to capture and account for the diversity and complexity of the economic environment and histories of each individual country. Thus, any inference drawn from cross-sectional studies offer only a general insight of how the variables are broadly related, and hence offers a little guidance to policy formulation. In this backdrop, a country-specific in-depth study appears to be more appropriate in order to find a deeper answer for the issue in question.

In the light of these possible policy implications, this chapter investigates the relationship between oil consumption and output for the concerned countries within a multivariate production function framework. The next section describes the data and data sources, followed by a discussion of the unit root and cointegration test results. The following section performs the Granger causality tests in a vector error correction (VEC) framework and generalized impulse responses and variance decompositions are employed (as out-of-sample causality tests). A simple panel-data estimation taking all these countries together is presented, afterwards followed by the Chapter summary.

## **4.2 Data**

Annual data on output, labour, capital and oil consumption are used in the empirical analysis. Time spans for the data of China, India, Indonesia, Malaysia, Philippines and Thailand are 1977 to 2007, 1980 to 2007, 1979 to 2007, 1980 to 2007, 1970 to 2007 and 1971 to 2007, respectively. The rationale behind selecting these periods is the availability of data. For all the countries, output and capital are represented by constant GDP and constant gross fixed gross capital formation. Constant gross domestic product, constant fixed gross capital formation data are collected from the World Bank's World Tables of December 2007 which is available from dxttime data series 2432 written by EconData released on 20 December 2007 in the EconData compact disk. The base year for both of these constant series is 2000.

Mahadevan (2004) argues that the Cobb-Douglas production function is conventionally interpreted as a relationship between the flow of output and the flow of inputs' services. However, as there are no data available on the flow of capital services the easiest option is to assume that capital flows are proportional to net capital stock after depreciation. Furthermore, another important aspect of capital measurement is valuation of capital input given by the rental price of capital.

Thus, this study assumes that capital flows are proportional to gross investment in capital goods. Another option could be to use the perpetual inventory method. One of the major limitations of this method is that the usual Perpetual Inventory Method (PIM) assumes that the rate of depreciation is constant in different category of capital assets and across industries. However, the depreciation rate varies significantly for different categories of capital assets. For example, it is logically inappropriate to assume that the rate of depreciation in computer assets is the same as those of machinery, building and other capital assets. This study argues that in long-run equilibrium the gross investment in capital is proportional to long-run net capital stock. In the long-run equilibrium, all variables, irrespective of proxies of measurement, eventually converge. This study uses the gross investment in fixed capital goods as a proxy for measuring capital rather than the net capital stock. Hence, data on gross fixed gross capital formation are used as proxies for measuring fixed capital variable.

For all the countries, except India and Malaysia, the labour data represent general level of employment in thousand units. The general level of employment data are collected from LABORSTA Labour Statistics Database, an online publication of International Labour Organization (ILO), which is available on <http://www.ilo.org/stat/lang--en/index.htm>. For India and Malaysia the labour data are labour force data available in dxtime data series 2432 written by EconData released on 20 December 2007 in the EconData compact disk.

Oil consumption data is collected from Statistical Review of World Energy, 2008 published by British Petroleum (BP), which is available on <http://www.bp.com>. Consumption figures are in million tonnes and include inland demand plus international aviation and marine bunkers and refinery fuel and loss. All the variables are transformed into their logarithmic form before estimation. Graphical representation of all series is given below in Figure 4.1 (overleaf).

From the graphs of four variables for individual countries it can be inferred that for Indonesia, Malaysia and Thailand there are spikes around the period of Asian financial crisis, *i.e.* from 1997-mid 1998. In addition to that, all the variables seem to be non-stationary at levels. Summary statistics of all the variables are offered in Appendix Table 4.1. The simple correlation analysis indicates that output and oil

consumption are significantly correlated for all the countries, except for China and Philippines. Oil consumption is also significantly correlated with capital and labour for most of the countries. Prior to identifying causality among the variables, an investigation of time-series properties of the data is warranted and the following section discusses these properties.

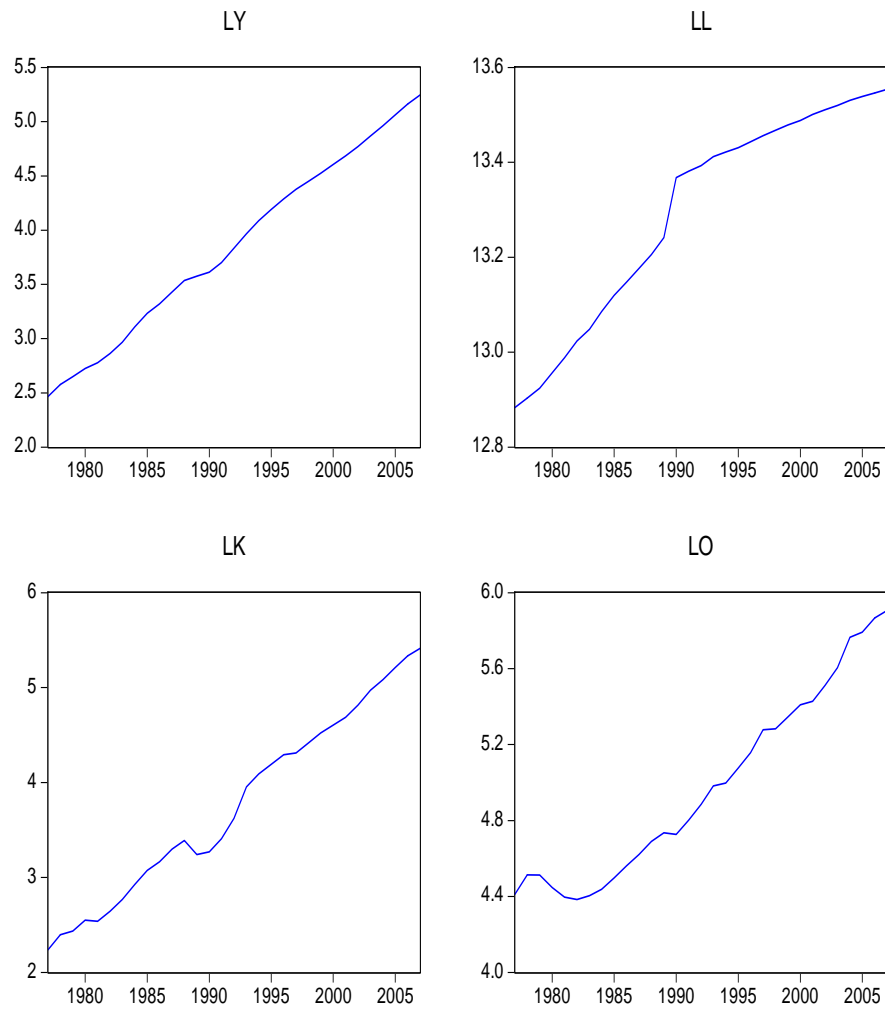
### **4.3 Time-Series Properties of Data**

Prior to carrying out unit root tests for the variables, this section first tests for the appropriateness of the logarithmic transformation of the non-linear equation (3.3) for each of the variables. For the ADF auxiliary equation in each variable, the study tests for the hypothesis that  $H_0: \phi_p = 0$  (in equation 3.25), which implies appropriate logarithmic transformation versus the alternative of  $H_a: \phi_p \neq 0$ , which indicates inappropriate logarithmic transformation. The results of the logarithmic transformation test are presented in Table 4.1.

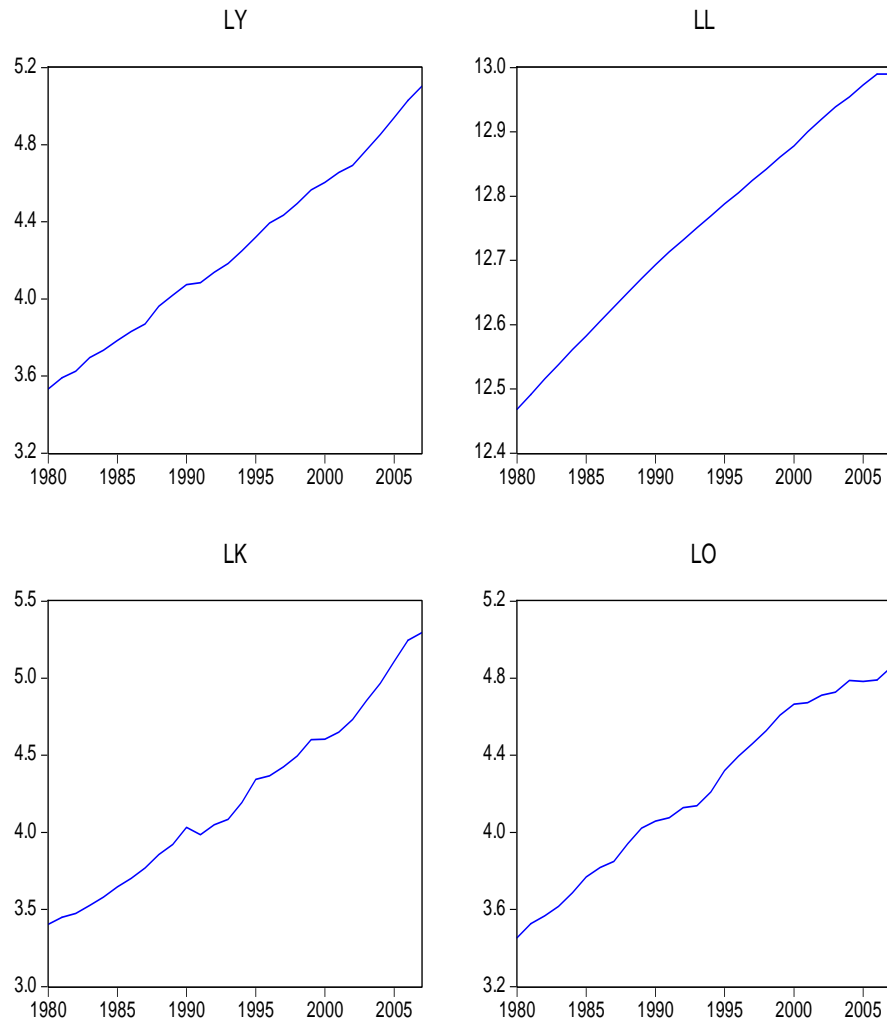


**Figure 4.1: Variables Used in This Chapter**

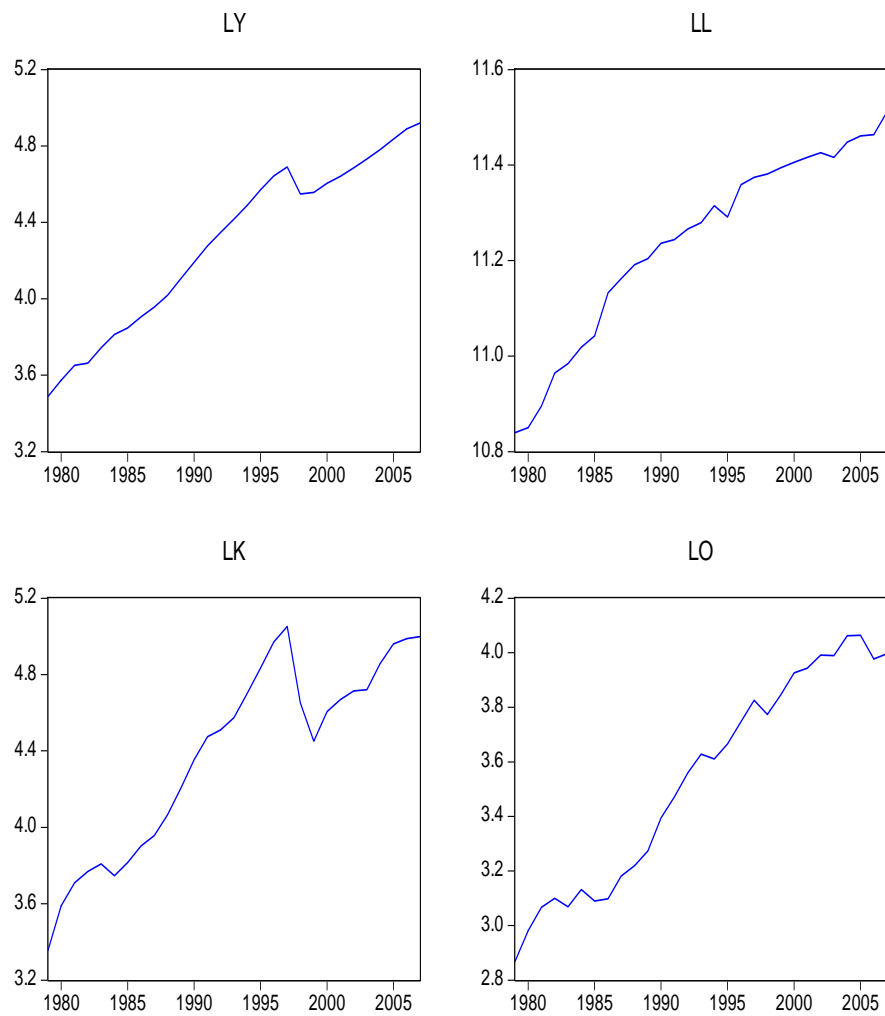
**a. China**



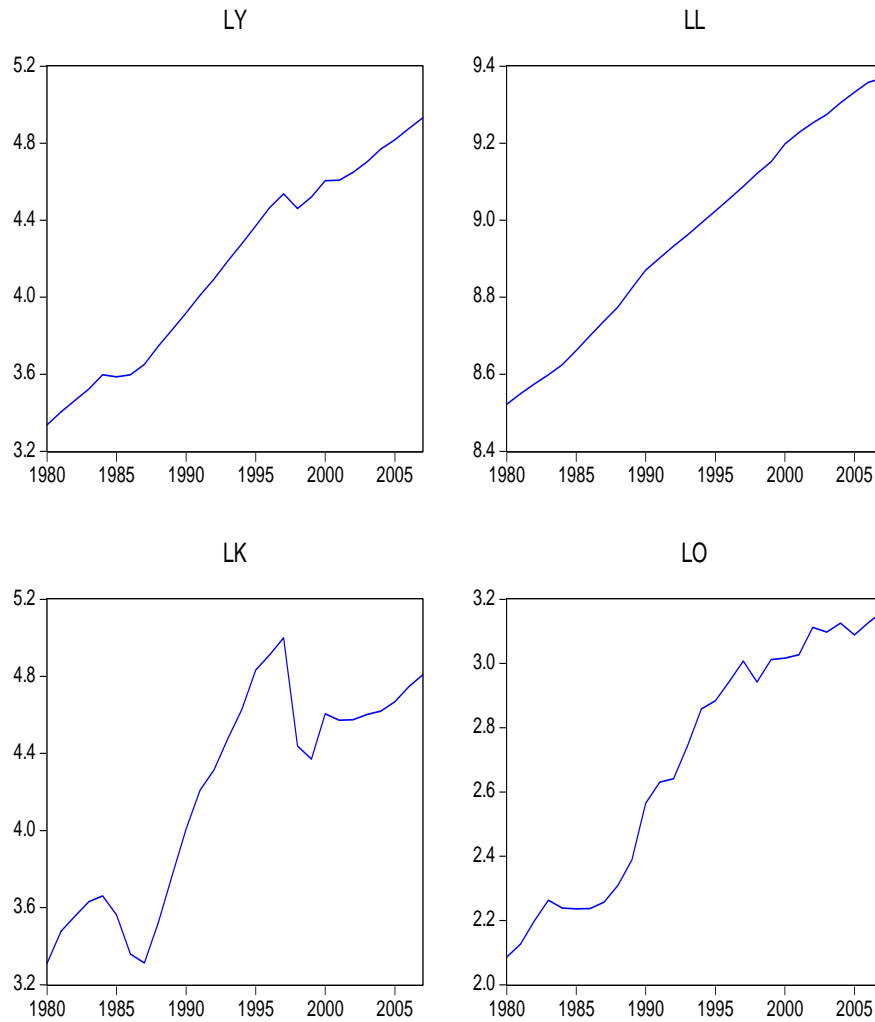
## b. India



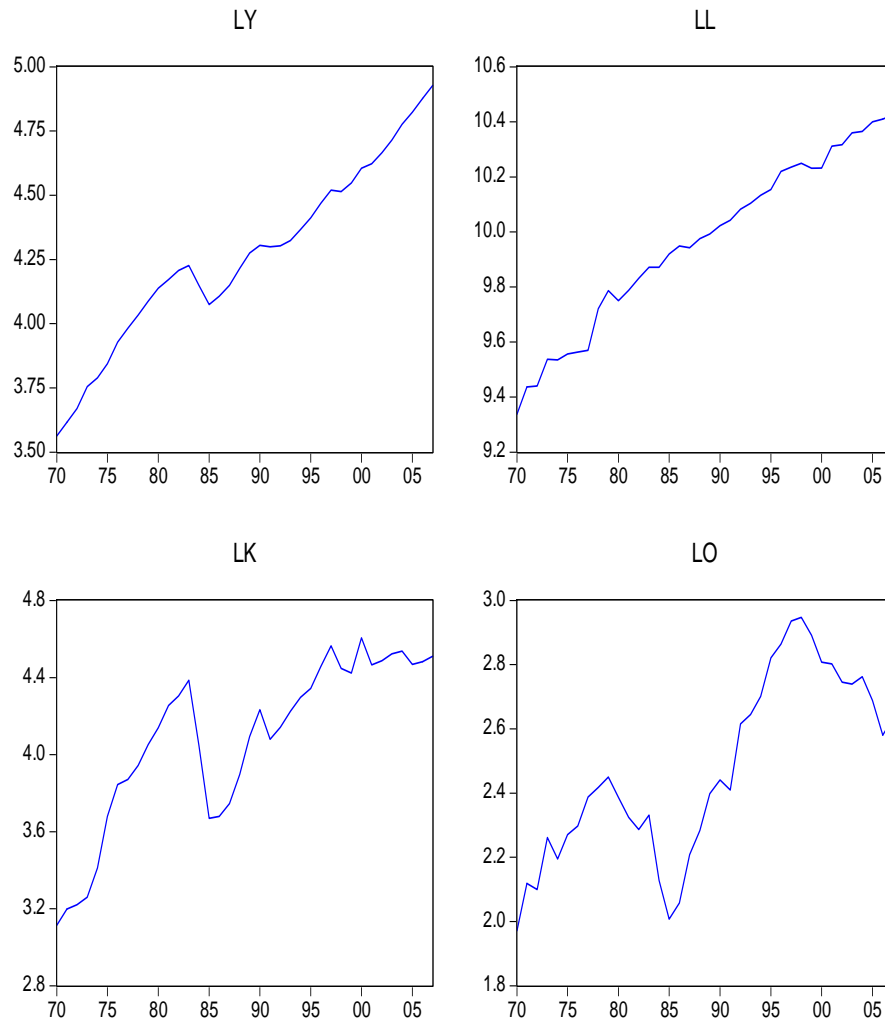
**c. Indonesia**



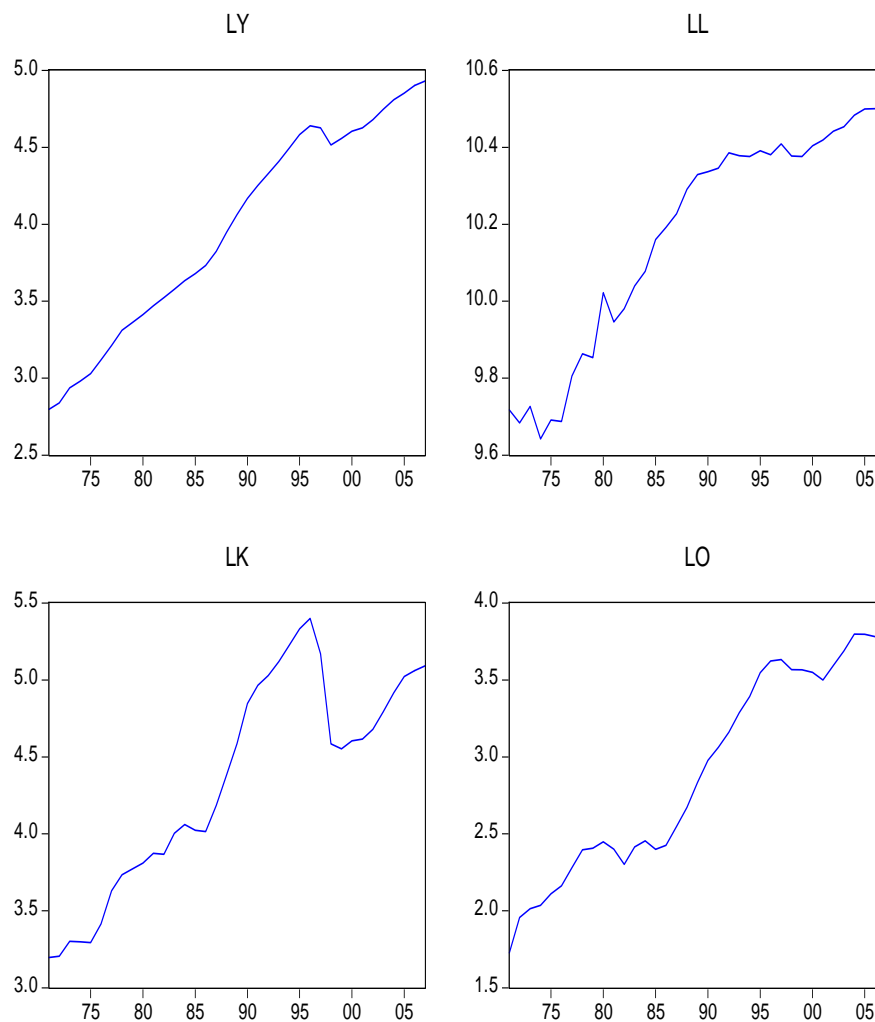
#### d. Malaysia



**e. Philippines**



## f. Thailand



Note: LY, LL, LK and LO stands for log of output, labour, capital and oil consumption.

**Table 4.1: Test of Non-Linear Logarithmic Transformation of Output, Labour, Capital, and Oil Consumption**

Country	Series	$\hat{\phi}_4$	S. E.	$T(\hat{\phi}_4)$	Prob. ( $\hat{\phi}_4$ )	$\bar{R}^2$	Country	Series	$\hat{\phi}_4$	S. E.	$T(\hat{\phi}_4)$	Prob. ( $\hat{\phi}_4$ )	$\bar{R}^2$
China	LY	-5.382	4.155	-1.295	0.209	0.204	India	LY	9.169	6.209	1.477	0.156	0.232
	LL	0.0467	0.168	0.277	0.785	0.322		LL	-112.770	168.488	-0.669	0.511	0.255
	LK	0.654	1.049	0.624	0.539	0.042		LK	-1.939	3.728	-0.520	0.609	0.413
	LO	-0.149	0.156	-0.958	0.349	0.309		LO	5.249	7.456	0.701	0.491	0.356
Indonesia	LY	3.464	2.972	1.166	0.257	0.207	Malaysia	LY	6.666	4.263	1.564	0.134	0.002
	LL	0.178	0.187	0.943	0.357	0.108		LL	21.895	128.384	0.171	0.866	0.127
	LK	-0.181	1.235	-0.147	0.885	0.069		LK	1.024	0.773	1.325	0.201	0.013
	LO	2.636	4.044	0.632	0.522	0.146		LO	2.204	2.992	0.737	0.470	0.051
Philippines	LY	-0.577	2.719	-0.212	0.834	0.236	Thailand	LY	-1.746	2.629	-0.664	0.512	0.413
	LL	-0.242	0.149	-1.638	0.112	0.172		LL	-1.776	1.697	-1.047	0.304	0.096
	LK	-0.405	0.819	-0.495	0.624	0.044		LK	-2.757	1.942	-1.421	0.162	0.2788
	LO	-0.861	1.409	-0.611	0.546	0.063		LO	0.116	0.163	0.709	0.484	0.228

Note: Ordinary least square estimation. Dependent variables are DLY, DLL, DLK and DLO. Lags order 3 is chosen for each of the equation.

It is apparent from Table 4.1 (opposite) that all of the variables for all the individual countries do not reject the null hypothesis  $\phi_4 = 0$  in equation 3.25. Hence, the test results indicate that the natural logarithmic transformation of equation 3.3 is appropriate for testing for a single unit root. The following sub-section discusses the results of unit root and structural break tests.

#### *4.3.1 Unit root and Perron's structural break tests*

This study performs three different unit root tests, namely Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS). The results of these tests are presented in Appendix Tables 4.2, 4.3 and 4.4, respectively. As mentioned in Chapter 3, the null hypotheses for both ADF and PP tests are that the series has a unit root. According to the results of both of the unit root tests the null hypotheses cannot be rejected; *i.e.* all the series for all the countries have unit root at their levels, while all these variables are stationary at their first differences. For further clarification KPSS unit root test is undertaken as this test has the null that the series is stationary. For all the variables in respect of all countries the null cannot be accepted, thus the results of this test further confirm that all these variables are non-stationary at their levels.

The graphical representation of the variables reveals some spikes in the concerned variables for some countries during the time of Asian financial crisis and the traditional unit root test cannot be relied upon if the underlying series contains structural break(s). Therefore, this study uses Perron's (1997) unit root test, which allows for a structural break and the test results are summarized in Table 4.2 (overleaf)<sup>21</sup>.

The Perron test results provide further evidence of the existence of unit roots in all series of different countries when breaks are allowed. However, for output and capital series of Indonesia the test reveals the existence of structural break in 1996, *i.e.* after this period the series experiences structural change. Hence, given the unavailability of long data series that could have permitted the study to divide the series; this study uses a dummy variable in the estimation process for Indonesia to deal with this change in overall structure. Prior to the break date the dummy takes

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<sup>21</sup> Perron (1997) is a unit root test which allows for multiple structural breaks. However, none of the tests identify more than one break point. The reason may be the test is not of high power.



the value of 0, while after the break date the dummy takes 1. For all the other countries when the underlying series is found non-stationary, the selected value of  $T_b$  no longer yields a consistent estimate of the break point (Perron 1997). Therefore, it may be concluded that the underlying data are non-stationary at levels but stationary at their first differences.

**Table 4.2: Perron Innovational Outlier Model with Change in Both Intercept and Slope for LY, LL, LK, and LO**

Country	Series	$T$	$T_b$	$k^1$	$t_{\hat{\beta}}$	$t_{\hat{\theta}}$	$t_{\hat{\gamma}}$	$t_{\hat{\delta}}$	$\hat{\alpha}$	$t_{\alpha}$	Inference
China	LY	13	1989	0	2.29	1.67	-1.32	-3.01	0.732	-2.288	NS
	LL	13	1989	0	3.93	3.63	-4.17	3.39	0.522	-3.741	NS
	LK	15	1991	0	2.73	0.38	1.34	-0.89	0.498	-3.169	NS
	LO	26	2002	0	2.43	1.52	-1.47	-0.98	0.846	-1.845	NS
India	LY	21	2000	0	3.26	-3.32	3.46	1.18	0.431	-3.228	NS
	LL	25	2004	0	1.54	8.42	-8.59	-4.60	0.920	-1.831	NS
	LK	19	1998	0	4.14	-4.09	4.17	2.79	0.383	-4.027	NS
	LO	14	1993	0	1.93	3.35	-2.20	-1.71	0.712	-2.389	NS
Indonesia	LY	18	1996	0	6.34	0.24	-2.40	5.89	0.390	-6.228**	S
	LL	13	1991	0	3.03	2.63	-2.80	-0.50	0.237	-3.254	NS
	LK	18	1996	0	5.27	-1.44	-0.48	5.11	0.401	-5.468***	S
	LO	13	1991	0	1.74	1.76	-1.04	-0.04	0.637	-1.761	NS
Malaysia	LY	13	1992	0	2.54	2.27	-2.16	-0.39	0.597	-2.273	NS
	LL	19	1998	0	2.35	3.65	-3.87	-1.69	0.709	-2.312	NS
	LK	17	1996	0	2.77	-0.94	-0.05	2.37	0.692	-2.425	NS
	LO	13	1992	0	2.64	2.67	-2.52	-0.39	0.597	-2.472	NS
Philippines	LY	13	1992	0	4.33	-2.29	-2.14	3.60	0.557	-4.986	NS
	LL	13	1982	0	4.45	3.21	-3.13	0.36	0.138	-4.956	NS
	LK	13	1982	0	3.55	0.75	-2.74	2.81	0.496	-4.288	NS
	LO	16	1985	0	-3.06	1.20	1.51	-1.21	0.912	-1.139	NS
Thailand	LY	16	1986	0	2.65	3.70	-2.49	-1.56	0.765	-3.138	NS
	LL	16	1986	0	5.25	4.69	-5.09	-1.17	0.306	-4.852	NS
	LK	26	1996	0	4.98	-2.79	0.95	2.61	0.571	-4.794	NS
	LO	16	1986	0	-0.24	1.68	1.11	-1.22	0.807	-2.509	NS

**Note:** 1%, 5% and 10% critical values are -6.32, -5.59 and -5.29, respectively (Perron, 1997). The optimal lag length is determined by Akaike Information Criterion ( $AIC$ ) with  $k_{\max} = 10$ . NS stands for Non-stationary at levels. LY, LL, LK and LO stand for log of GDP, labour, capital and oil consumption, respectively. \*, \*\*, and \*\*\* indicate significant at 1%, 5%, and 10% level respectively.

The above unit root tests show that all the variables of all the concerned countries are found to be I(1) process. At this stage, tests for cointegration among the variables are

required as these tests enable the study to make inferences about the long-run relationships. The following section identifies cointegrating relationships among the variables.

#### **4.4 Cointegration Test for Variables**

In order to carry out the cointegration test, the order of the VAR model is to be selected first. This is done by the application of the usual selection criteria, namely the Akaike Information Criterion (AIC), Schwarz Bayesian Criterion (SBC) and Log Likelihood (LL). In selecting the optimum lag length, maximum lag lengths for all the countries except Indonesia are selected as four. However, the Indonesian VAR model includes a dummy variable, so the maximum lag length the estimation process is able to give is three given the size of the data available.

This study accepts the optimum lag lengths provided by AIC criterion. The optimum lag lengths suggested by the AIC criterion for China, India, Indonesia, Malaysia, Philippines and Thailand are 4, 4, 3, 4, 2 and 4, respectively<sup>22</sup>. Once the lag lengths are selected, it is appropriate to perform the cointegration tests for the variables. This study adopts Johansen cointegration test for this purpose and the results for different countries are presented in Table 4.3 (overleaf).

Both the maximum eigenvalues and trace statistics are reported in Table 4.3 (overleaf), where  $r$  denotes the number of cointegrating vectors. The null hypothesis of the maximum eigenvalue test is that there are at most  $r$  cointegrating vectors against the alternative of  $r+1$  cointegrating vectors. The null hypothesis of the trace test is that there are at most  $r$  cointegrating vectors against the alternative of  $r \geq 1$  cointegrating vectors.

It is worth to note that the cointegration test is a sequential test. Thus, for China as the null of at most 2 cointegrating vector is rejected whereas the null of at most 3 cannot be rejected at 10% level in case of both the maximum eigenvalue and trace statistics, the results indicate that there are at most 3 cointegrating relationship among the four variables in the system. In the same way it can be inferred that for all the countries except Philippines there exist at most 3 cointegrating vectors among the variables. In case of Philippines there is at most one cointegrating vector among output, labour, capital and oil consumption.

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<sup>22</sup> Results not reported due to space limitation. However, results will be provided upon request.

**Table 4.3: Johansen's Test for Multiple Cointegrating Relationships and Tests of Restrictions on Cointegrating Vector(s) [Intercept, no Trend<sup>23</sup>]**

Country	Null Hypothesis	Optimal lag Used in VAR	Max eigenvalue	Trace Stat.
China	$r = 0$	4	82.413**	131.239**
	$r \leq 1$		29.314**	48.826**
	$r \leq 2$		15.323***	19.512***
	$r \leq 3$		7.189	7.189
India	$r = 0$	4	55.201**	102.262**
	$r \leq 1$		24.298**	47.060**
	$r \leq 2$		14.444*	22.762**
	$r \leq 3$		8.318	7.318
Indonesia	$r = 0$	3	93.710**	193.389**
	$r \leq 1$		60.188**	99.679**
	$r \leq 2$		21.510***	39.491**
	$r \leq 3$		3.547	3.547
Malaysia	$r = 0$	4	31.865**	75.391**
	$r \leq 1$		21.257***	43.526**
	$r \leq 2$		15.571***	22.268**
	$r \leq 3$		6.698	6.698
Philippines	$r = 0$	2	26.216**	53.443**
	$r \leq 1$		16.698	27.227
	$r \leq 2$		6.664	10.529
	$r \leq 3$		3.865	3.865
Thailand	$r = 0$	4	49.838**	94.406**
	$r \leq 1$		25.454**	44.567**
	$r \leq 2$		16.602***	19.113***
	$r \leq 3$		5.511	5.510

Note: Cointegration with restricted intercepts and no trends in the VAR. Variables included in the cointegrating vector are LY, LL, LK, LO and intercept.  $r$  indicates number of cointegrations. The optimal lag length of VAR is selected by Akaike Information Criterion. Critical values are based on Johansen and Juselius (1990). \*, \*\*, and \*\*\* indicate significant at 1%, 5%, and 10% level respectively.

<sup>23</sup> Following Ang (2007) and Akinlo (2008) this thesis adapts cointegration tests based on intercept, no trend.

Evidence of cointegration implies the existence of both short-run and long-run causality. However, it does not indicate the direction of the causal relationship. Hence, to shed light on the direction of causality, this study estimates the error correction models (ECM) to perform causality tests and the results are reported in Table 4.4 (overleaf).

#### **4.5 The Granger Causality Tests**

The results of this section are based on the methodology presented in sub-section 3.3.4.1 of the previous chapter. According to the causality analysis both short- and long-run causality is captured for individual countries. In addition to this, the methodology can also indicate which of the variables in the system takes the burden to restore long-run equilibrium relationship. According to Table 4.4 the significance of the Wald  $\chi^2$ -statistics in the short-run effects indicates short-run causality, while the long-run causality is indicated by the significance of the Joint Wald  $\chi^2$ -statistics where all the error correction terms are allowed for. For example, in the first equation for china (the equation for output), none of the short-run  $\chi^2$ -statistics is significant. Hence in this equation none of the three variables causes output in the short-run, while the significance of Joint Wald  $\chi^2$ -statistics for oil consumption means in the long-run oil consumption Granger causes output. Furthermore, the significance of one of the three error correction terms implies that output in China adjusts actively to restore the long-run equilibrium relationship within the system.

The results for China imply uni-directional causality from oil consumption to output in the long run. This finding is consistent with Yuan *et al.* (2008), where the authors find uni-directional causality running from oil consumption to GDP in China. However, there exists bi-directional causality between labour and capital both in the short and the long run. Output and oil consumption Granger cause capital in short and long run. Labour and capital also cause oil consumption both in the short run and the long run. The results further indicate that all the variables in the system adjust to restore the long-run equilibrium relationship whenever there is a deviation from the equilibrium cointegrating relationship.

For India, bi-directional Granger causality exists between oil consumption and output both in the short run and the long run. There is uni-directional causality running from capital to labour in both short and long run. Oil consumption also

Granger causes capital in short and long run, while labour causes oil consumption in the long run. Only output and labour appear to bear the burden of adjustment towards the long-run equilibrium in response to a short-run deviation.

As far as causality between output and oil consumption is concerned, the results from Indonesia are similar to that of India, *i.e.* bi-directional causality is present both in the short and the long run. Labour Granger causes output and oil consumption both in short and long run, while both capital and oil consumption cause labour in both short and long run. Both in the short run and the long run, output Granger causes capital. All the variables in the system except capital seem to actively participate in restoring the equilibrium relationship.

**Table 4.4: Temporal Causality Test Results Based on Parsimonious Vector Error Correction Models (VECM)**

Equation	Short-run effects				Sources of causation						
	$\Delta LY$	$\Delta LL$	$\Delta LK$	$\Delta LO$	$ECT_{1,t-1}$	$ECT_{1,t-2}$	$ETC_{1,t-3}$	$ETC, \Delta LY$	$ETC, \Delta LL$	$ETC, \Delta LK$	$ETC, \Delta LO$
	Wald $\chi^2$ -statistics				$t$ -ratio			Joint Wald $\chi^2$ -statistics			
China											
$\Delta LY$	-	1.723	0.419	2.186	-1.068	-1.461	-2.477**	-	1.432	0.069	2.925***
$\Delta LL$	0.497	-	3.578**	0.321	3.409*	0.358	-0.472	0.305	-	3.012***	0.111
$\Delta LK$	2.967***	4.152*	-	4.439**	-0.067	-2.591**	-1.767	3.287***	4.075**	-	5.152**
$\Delta LO$	2.549	8.316*	3.101***	-	-4.223*	-3.239*	0.801	1.852	7.563*	5.086**	-
India											
$\Delta LY$	-	0.049	0.006	3.211***	0.977	0.795	-2.382**	-	0.048	0.002	2.995***
$\Delta LL$	0.428	-	3.646***	0.183	-1.178	2.919**	-1.541	0.417	-	3.773***	0.211
$\Delta LK$	0.017	0.053	-	4.729**	-0.594	0.202	-1.168	0.010	0.052	-	4.855**
$\Delta LO$	3.305***	0.097	0.371	-	-0.519	-0.744	1.528	3.298***	3.099***	0.375	-
Indonesia											
$\Delta LY$	-	4.638**	0.175	11.899*	-6.897*	2.315**	-0.522	-	5.543**	1.063	13.732*
$\Delta LL$	0.394	-	6.452**	3.792***	3.254*	4.515*	-0.252	0.404	-	10.682*	6.401**
$\Delta LK$	7.439*	2.545	-	0.583	-0.042	1.722	-1.424	6.130**	2.409	-	0.544
$\Delta LO$	5.968**	14.354*	5.805**	-	-2.707**	2.836**	-3.049*	7.012*	14.848*	3.308***	-

Equation	Short-run effects				Sources of causation						
	$\Delta LY$	$\Delta LL$	$\Delta LK$	$\Delta LO$	$ECT_{1, t-1}$	$ECT_{1, t-2}$	$ETC_{1, t-3}$	$ETC, \Delta LY$	$ETC, \Delta LL$	$ETC, \Delta LK$	$ETC, \Delta LO$
	Wald $\chi^2$ -statistics				$t$ -ratio			Joint Wald $\chi^2$ -statistics			
Malaysia											
$\Delta LY$	-	4.716**	6.366**	5.853**	0.314	-3.247**	1.195	-	4.665**	7.329*	6.057**
$\Delta LL$	2.568	-	0.519	0.739	1.991***	-0.117	-0.329	2.477	-	0.294	0.695
$\Delta LK$	1.780	3.556***	-	2.709	1.206	-2.582**	1.809	1.708	3.483***	-	3.044***
$\Delta LO$	0.783	0.039	4.189**	-	0.146	-1.068	2.212***	0.789	0.032	3.757***	-
Philippines											
$\Delta LY$	-	0.221	3.667***	0.195	-0.955			-	0.073	4.222**	0.414
$\Delta LL$	1.080	-	1.635	0.707	2.738**			3.421***	1.080	-	1.635
$\Delta LK$	5.357**	0.024	-	0.007	-1.636			5.339**	0.250	-	0.174
$\Delta LO$	6.155**	0.053	0.268	-	-2.628**			5.605**	0.619	2.333	-
Thailand											
$\Delta LY$	-	3.303***	0.005	0.228	-0.336	1.488	2.831**	-	2.615	0.299	0.015
$\Delta LL$	0.003	-	1.126	2.372	0.337	4.066*	-0.935	0.011	-	0.111	2.871***
$\Delta LK$	2.958***	2.700	-	0.131	-1.632	1.457	2.383**	3.319***	2.351	-	0.025
$\Delta LO$	20.010*	9.429*	11.311*	-	-3.979*	1.653	1.351	20.793*	9.775*	8.268*	-

**Note:** The vector error correction model (VECM) is based on an optimally determined (Akaike Information Criterion) lag structure (Appendix Table 4.6) and a constant. \*, \*\*, and \*\*\*\* indicate significant at 1%, 5%, and 10% level respectively.

The results indicate uni-directional causality running from oil consumption to output in both the short and long run in Malaysia. Regarding the causality between labour and capital there is uni-directional causality running from labour to capital in both short and long run. Both labour and capital Granger cause output, while only capital causes oil consumption in the short and long run. All of the variables adjust to restore the long-run equilibrium relationship.

The direction of causality is from GDP to oil consumption in both Philippines and Thailand in short and long run. However, there is no evidence of any causality between labour and capital for either of these countries. In Philippines, there is a bi-directional Granger causality between capital and output in the short and long run. In Philippines, both labour and oil consumption actively participate in the adjustment process of restoring the long-run equilibrium relationship among the variables. For Thailand, short-run causality runs from labour to output, while output causes capital in both short and long run. Both capital and labour strongly Granger cause oil consumption in both the short and the long run. All the variables hold the burden of adjusting toward long-run equilibrium throughout the system.

In summary, short-run causality runs from output to oil consumption in Philippines and Thailand; from oil consumption to output in Malaysia; and both ways in India and Indonesia. The only country in which the study fails to identify short-run causality between output and oil consumption is China. However, in the long run, the analysis uncovers causality in all countries. In two countries, namely India and Indonesia, there is evidence of a bi-directional causality, suggesting that these countries may benefit from integrating oil consumption and economic policies in the long run. In China and Malaysia, the long-run causality is running from oil consumption to output. This result may be suggesting that the long-run economic growth in these countries may be heavily relying on oil use but not vice versa. Whereas, for Philippines and Thailand, the study finds a uni-directional causality running from output to oil consumption.

The Granger causality tests fail to explain the sign relationship among the variables or how long these effects are persistent on each other. In other words, the  $\chi^2$  or  $F$ -test results do not reveal whether the change in any given variable has a positive or



negative impact in other variables in the system. Neither do the test statistics indicate how long it would take for the effect of a particular variable to work through the system.

The Granger causality is a within sample test and can only be employed to discern the plausible Granger exogeneity or endogeneity of each of the variables in the sample period. It is unable to ascertain the degree of exogeneity of the variables beyond the sample period. The impulse response functions and forecast error variance decomposition provide such information and the findings from these tests are discussed in the next section.

#### **4.6 Generalized Impulse Response Functions and Generalized Forecast Error Variance Decomposition**

This section investigates the interrelationships between oil consumption and output within the framework of a production function. To be more specific, this section examines how each of the variables, namely output, labour, capital or oil consumption respond to a unit standard error (S.E.) shock in another factor of production in the system and determines the proportion of the forecast error variance of each of the variables due to innovations of each of the other variables at different forecast horizon. Unlike orthogonalized impulse response functions and variance decompositions, the generalized versions of these tests are not sensitive to ordering of the variables. Thus, the generalized impulse response functions and generalized variance decomposition are used in this study. However, since this thesis is primarily concerned with the relationship between oil consumption and output, this section mainly discusses the responses and explanatory powers of these two variables.

The generalized impulse response functions trace out responsiveness of the dependent variables in the VAR to shocks to each of the variables. For each variable from each equation separately, a unit shock is applied to the error, and the effects upon the VAR system over time are noted (Brooks 2002). The results of the impulse response functions are presented in Figure 4.2 (overleaf).

For China a unit standard error (S.E.) shock in output has minimal impact on oil consumption; the response from output to a one S.E. shock in oil consumption is initially negative and is increasing persistently into the long run. This finding

confirms the possibility of out of sample uni-directional causality from oil consumption to output.

In case of India, as the time passes oil consumption responds negatively to a unit standard error shock to output and the shock seems to have persistent effect on oil consumption in the future. The response from output to a one S.E. shock in oil consumption does not die in the future as well and as can be expected the response is positive. This also confirms the findings from causality test that for India there is a bi-directional causality between oil consumption and output.

For Indonesia the findings from impulse response function are similar to that of India. Here the response from output and oil consumption to a unit S. E. shock in oil consumption and output, respectively, are also persistent into the future indicating a bi-directional causality between the two variables.

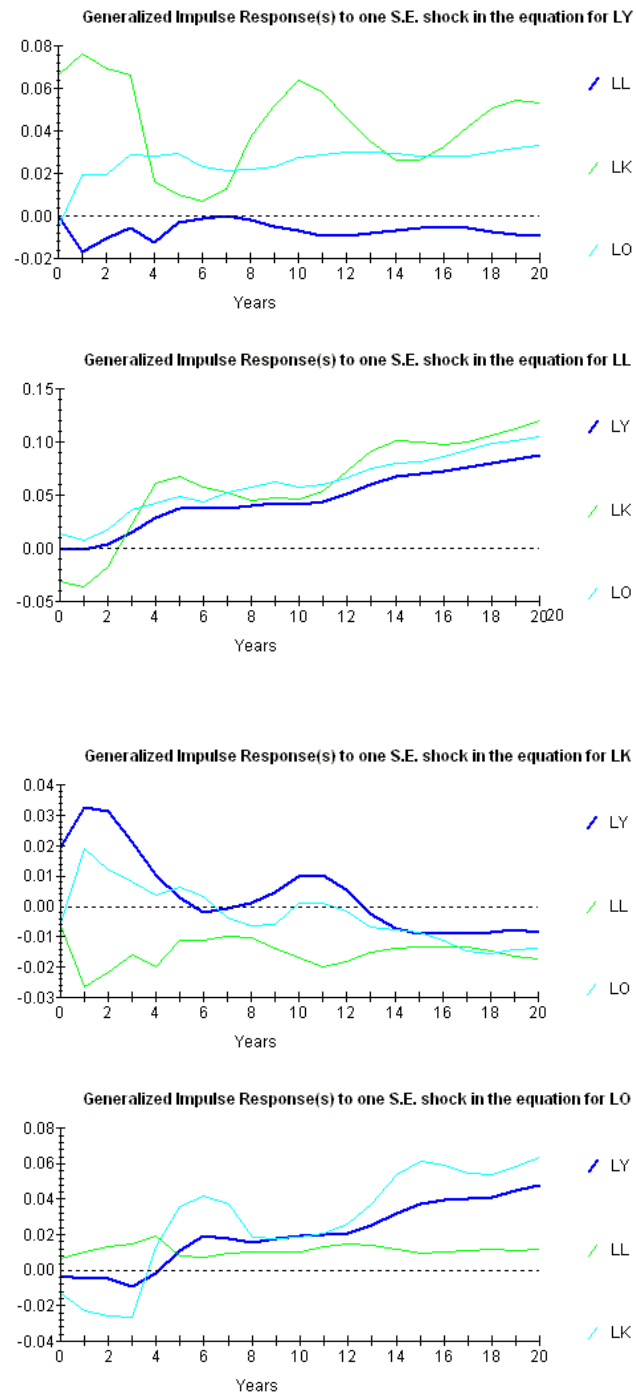
In Malaysia the response from oil consumption to a unit standard error shock to output is very minimal and dies down just after three years. On the other side, the response from output to one S. E. shock in oil consumption is also horizontal at a 5% level. However, the effect does not die down, rather it continues persistently into the future. This indicates a uni-directional causality running from oil consumption to output even after the sample horizon.

The findings from Philippines indicate that in response to a one standard error shock in output oil consumption goes up by more than 5% after second year and it remains at that same level into the future. The response from output to the shock in oil consumption is also increasing in the course of time.

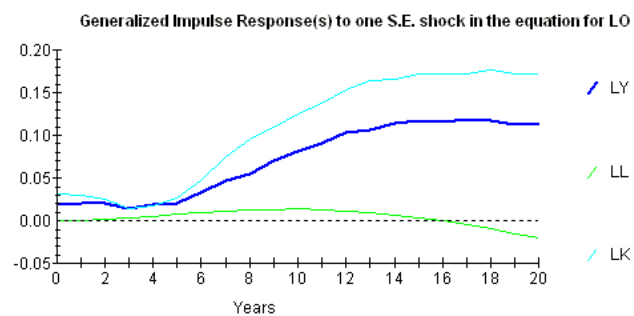
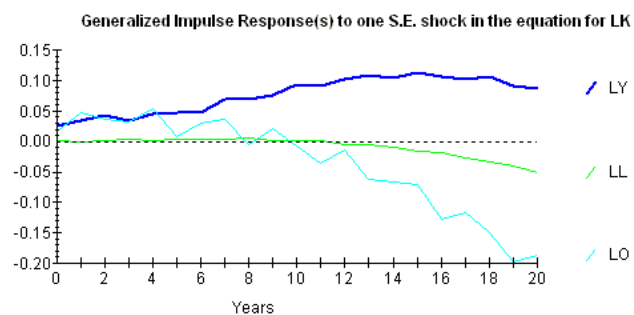
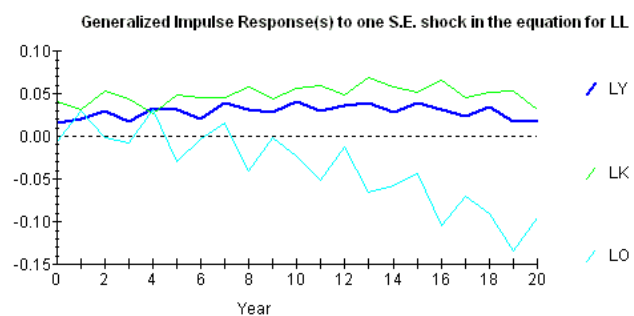
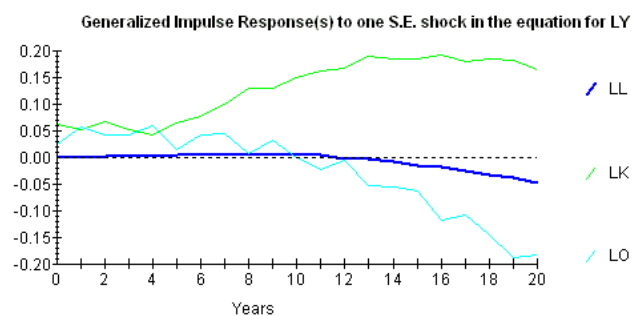
The Thai results also confirm that in this country uni-directional causality is running from output to oil consumption even after the sample period. Just after three years, the response from oil consumption to a unit standard error shock in output drastically falls down to less than  $-5\%$  and persists in the future. The response from output to unit S. E. shock in oil consumption is very minimal and almost horizontal into the future implying that there is a uni-directional causality from income to oil consumption in Thailand. Thus, with a few exceptions the results from impulse response functions also confirm the identified directions of causality for different countries.

**Figure 4.2: Findings from Generalized Impulse Response Function**

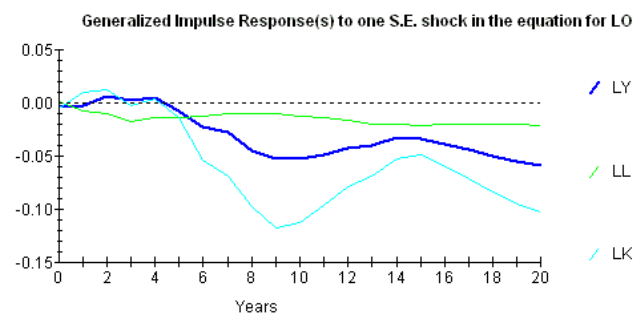
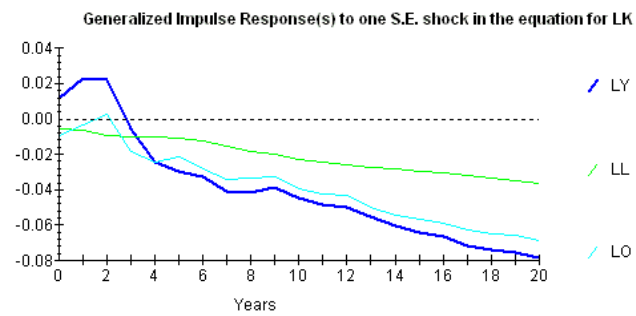
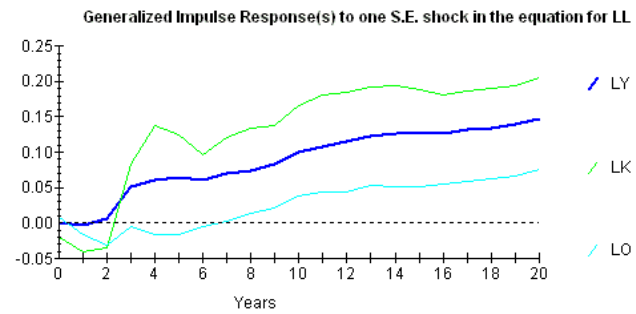
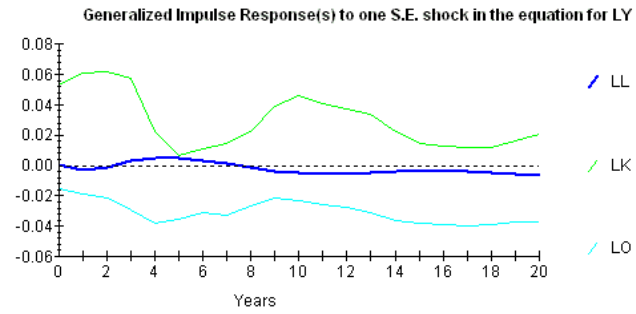
**a. China**



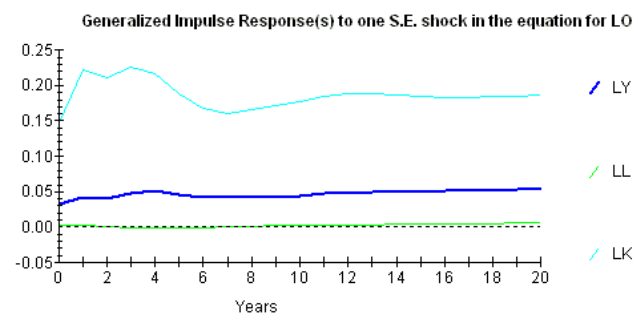
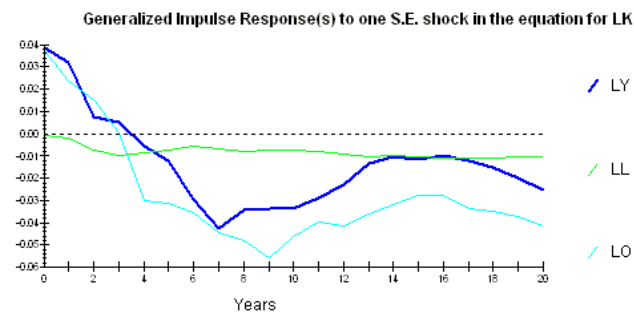
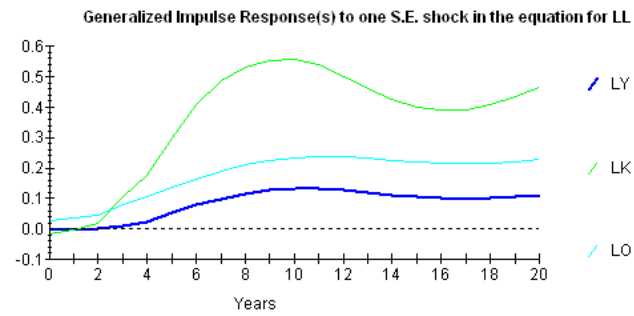
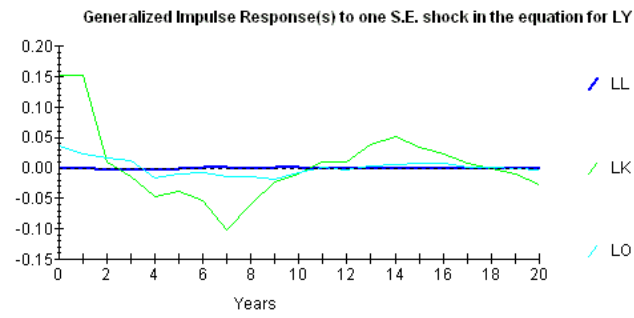
## b. India



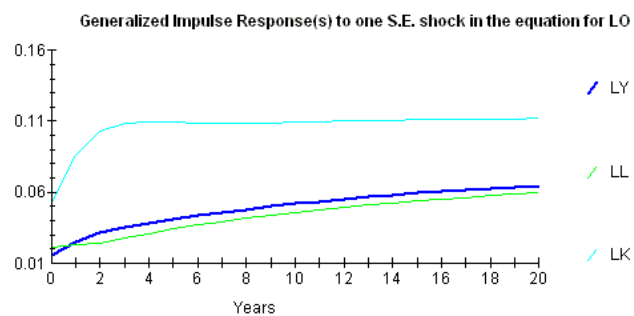
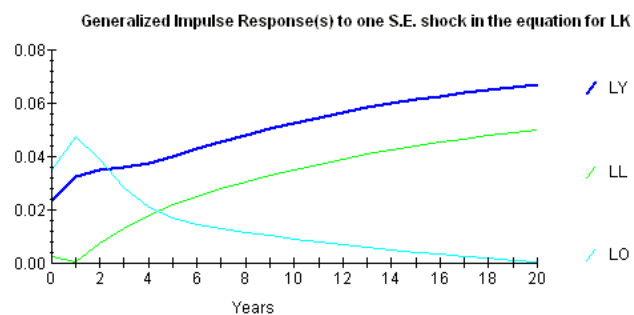
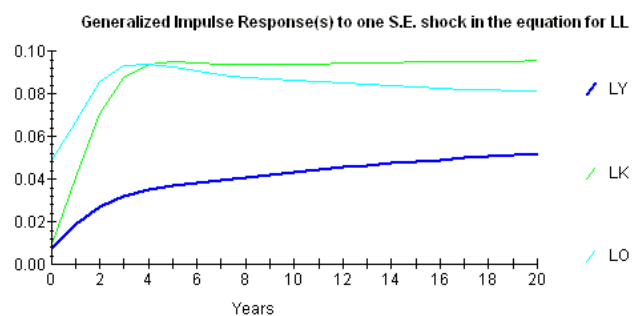
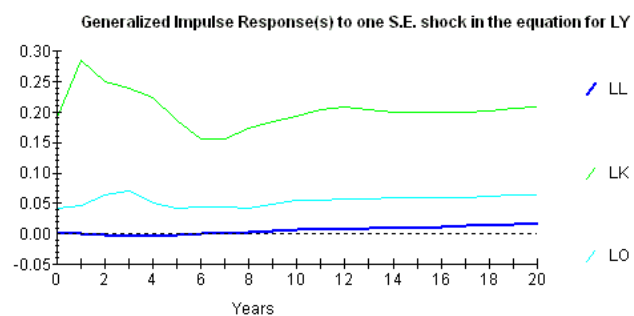
### c. Indonesia



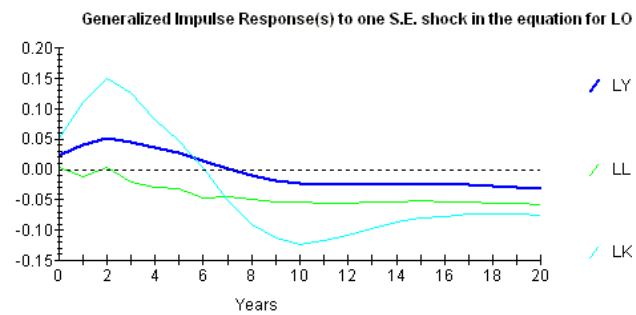
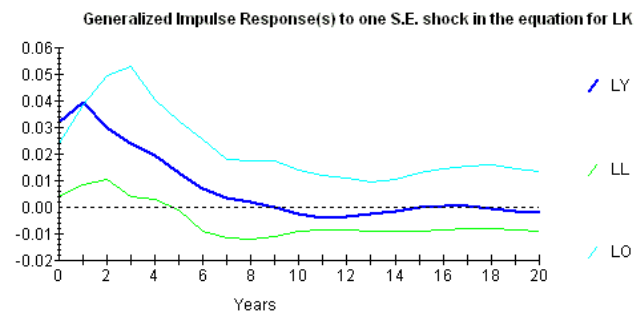
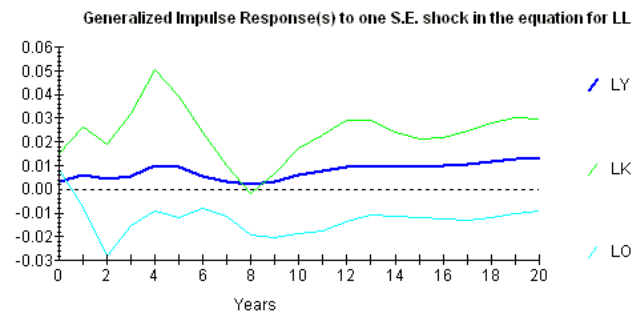
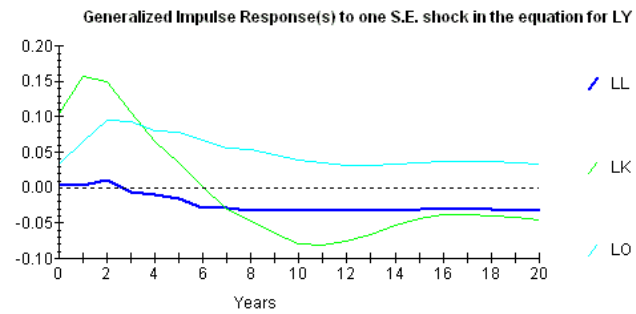
#### d. Malaysia



## e. Philippines



## f. Thailand





Variance decomposition gives the proportions of the movement in the dependent variables that are due to their ‘own’ shocks, versus shocks to the other variables. The results of variance decomposition over a period of 20-year time horizon for different countries are presented in Table 4.5 (overleaf). Results for most of the countries are similar to the outcomes of causality analysis. Some of the significant findings are as follows.

The results for China indicate that after five years, 67% of the variation in the forecast error for GDP is explained by its own innovations, while at the end of twenty years, this drops to only 21.2%. About 2.9% of variation in the forecast error for GDP is explained by innovations of oil consumption, while at the end of 20 years about 28.4% of the variation in the forecast error for GDP is explained by the innovations of oil consumption. As the results suggest, the explanatory power of oil consumption in the variation of GDP increases over time, indicating the existence of long-run causality running from oil consumption to GDP in China.

The results for India suggest that after five years, 90.7% of the variation in the forecast error for output is explained by its own innovations, while at the end of twenty years horizon, this is still 85.9%. After five years about 22.3% of the forecast error variance for output is explained by oil consumptions, which increases by 73.1% at the end of twenty years. On the other hand, after five years, 79.3% variations in forecast error of oil consumption is explained by its own innovations, while at the end of twenty years only 29.2% of the variation is explained by its own innovation. Innovations in output explain about 60.9% variation in oil consumption after five years, while after twenty years, 74.5% variation in oil consumption is explained by the innovations in output. These results are also consistent with the finding of temporal causality that in India bi-directional causality exists between income and oil consumption.

**Table 4.5: Findings from Generalized Forecast Error Variance Decomposition**

**a. China**

Years	Variance Decomposition of LY				Variance Decomposition of LL				Variance Decomposition of LK				Variance Decomposition of LO			
	LY	LL	LK	LO	LY	LL	LK	LO	LY	LL	LK	LO	LY	LL	LK	LO
1	0.992	0.043	0.791	0.016	0.249	0.682	0.651	0.139	0.778	0.172	0.989	0.051	0.215	0.132	0.201	0.691
5	0.670	0.274	0.339	0.029	0.151	0.791	0.508	0.257	0.580	0.336	0.586	0.103	0.292	0.347	0.258	0.236
10	0.438	0.417	0.157	0.194	0.105	0.842	0.439	0.234	0.501	0.426	0.401	0.137	0.199	0.402	0.324	0.240
15	0.302	0.555	0.079	0.236	0.108	0.842	0.449	0.254	0.351	0.473	0.434	0.163	0.164	0.459	0.315	0.244
20	0.212	0.642	0.046	0.284	0.110	0.842	0.458	0.258	0.269	0.485	0.438	0.191	0.126	0.504	0.316	0.259

**b. India**

Years	Variance Decomposition of LY				Variance Decomposition of LL				Variance Decomposition of LK				Variance Decomposition of LO			
	LY	LL	LK	LO	LY	LL	LK	LO	LY	LL	LK	LO	LY	LL	LK	LO
1	0.970	0.321	0.934	0.362	0.306	0.946	0.353	0.044	0.908	0.357	0.973	0.258	0.736	0.183	0.509	0.709
5	0.907	0.409	0.957	0.223	0.545	0.187	0.341	0.744	0.839	0.437	0.944	0.155	0.609	0.153	0.419	0.793
10	0.940	0.232	0.869	0.490	0.282	0.099	0.118	0.879	0.923	0.231	0.862	0.485	0.482	0.156	0.310	0.799
15	0.899	0.133	0.766	0.659	0.217	0.306	0.234	0.526	0.906	0.144	0.787	0.633	0.454	0.303	0.434	0.501
20	0.859	0.096	0.703	0.731	0.642	0.409	0.746	0.219	0.885	0.112	0.744	0.692	0.745	0.361	0.797	0.292

**c. Indonesia**

Years	Variance Decomposition of LY				Variance Decomposition of LL				Variance Decomposition of LK				Variance Decomposition of LO			
	LY	LL	LK	LO	LY	LL	LK	LO	LY	LL	LK	LO	LY	LL	LK	LO
1	0.910	0.009	0.863	0.192	0.027	0.867	0.178	0.058	0.611	0.186	0.973	0.035	0.159	0.087	0.027	0.839
5	0.899	0.598	0.177	0.357	0.017	0.737	0.129	0.046	0.493	0.309	0.269	0.030	0.361	0.139	0.118	0.568
10	0.729	0.663	0.192	0.318	0.008	0.790	0.161	0.041	0.494	0.271	0.150	0.036	0.412	0.199	0.354	0.389
15	0.712	0.692	0.182	0.416	0.008	0.796	0.211	0.025	0.455	0.332	0.111	0.019	0.327	0.392	0.469	0.315
20	0.709	0.698	0.205	0.415	0.007	0.801	0.219	0.021	0.437	0.353	0.119	0.013	0.280	0.492	0.538	0.227

#### d. Malaysia

Years	Variance Decomposition of LY				Variance Decomposition of LL				Variance Decomposition of LK				Variance Decomposition of LO			
	LY	LL	LK	LO	LY	LL	LK	LO	LY	LL	LK	LO	LY	LL	LK	LO
1	0.949	0.003	0.894	0.425	0.005	0.966	0.016	0.191	0.826	0.004	0.954	0.521	0.283	0.299	0.311	0.968
5	0.387	0.501	0.393	0.213	0.005	0.864	0.058	0.187	0.244	0.644	0.329	0.229	0.053	0.514	0.383	0.360
10	0.047	0.408	0.207	0.388	0.002	0.852	0.036	0.244	0.038	0.799	0.091	0.243	0.011	0.537	0.349	0.277
15	0.024	0.407	0.262	0.359	0.001	0.852	0.035	0.248	0.023	0.795	0.055	0.305	0.006	0.526	0.334	0.305
20	0.018	0.420	0.252	0.366	0.009	0.848	0.034	0.254	0.018	0.808	0.048	0.306	0.004	0.529	0.330	0.309

#### e. Philippines

Years	Variance Decomposition of LY				Variance Decomposition of LL				Variance Decomposition of LK				Variance Decomposition of LO			
	LY	LL	LK	LO	LY	LL	LK	LO	LY	LL	LK	LO	LY	LL	LK	LO
1	0.962	0.092	0.360	0.197	0.089	0.948	0.003	0.397	0.683	0.037	0.946	0.213	0.372	0.395	0.201	0.931
5	0.845	0.112	0.168	0.148	0.561	0.502	0.084	0.359	0.859	0.157	0.696	0.273	0.337	0.584	0.095	0.795
10	0.818	0.193	0.104	0.117	0.733	0.252	0.105	0.244	0.893	0.186	0.619	0.282	0.349	0.448	0.059	0.779
15	0.809	0.282	0.073	0.097	0.766	0.179	0.105	0.198	0.907	0.194	0.589	0.283	0.489	0.373	0.044	0.776
20	0.803	0.276	0.018	0.011	0.776	0.147	0.105	0.176	0.915	0.197	0.573	0.283	0.449	0.379	0.034	0.746

#### f. Thailand

Years	Variance Decomposition of LY				Variance Decomposition of LL				Variance Decomposition of LK				Variance Decomposition of LO			
	LY	LL	LK	LO	LY	LL	LK	LO	LY	LL	LK	LO	LY	LL	LK	LO
1	0.975	0.106	0.497	0.281	0.041	0.822	0.091	0.032	0.858	0.018	0.872	0.174	0.309	0.248	0.114	0.479
5	0.576	0.212	0.147	0.279	0.038	0.362	0.251	0.267	0.617	0.036	0.539	0.289	0.190	0.192	0.141	0.411
10	0.428	0.367	0.125	0.258	0.018	0.182	0.206	0.415	0.342	0.083	0.325	0.421	0.121	0.165	0.221	0.356
15	0.239	0.388	0.177	0.207	0.012	0.145	0.252	0.388	0.199	0.078	0.309	0.399	0.118	0.166	0.223	0.342
20	0.174	0.405	0.215	0.169	0.009	0.139	0.259	0.358	0.168	0.088	0.319	0.383	0.120	0.165	0.219	0.336

Note: All the figures are estimates rounded to three decimal places.

In Indonesia 89.9% of the variation in the forecast error for output is explained by its own innovations after five years, while at the end of 20 years, this is 70.9%. After five years 35.7% of the variation in the forecast error for income is explained by innovations of oil consumption and after twenty years 41.5% of the forecast error variation in output is explained by the innovations in oil consumption. With respect to the forecast error variations in oil consumption, after five years 56.8% of the variation is explained by its own innovations, whereas at the end of twenty years only 22.7% is explained by its own innovations. After five years innovations in output explains 36.1% of the forecast error variations in oil consumptions and after twenty years the explanation from output is 28.0%. These results also confirm the existent of a bi-directional causality between output and oil consumption in Indonesia.

Results for Malaysia suggest that after five years, only 38.7% forecast error variation in output is explained by its own innovations and the figure falls down to 1.8% at the end of twenty years. After five years 21.3% forecast error variation in output is explained by innovations in oil consumption, which rises up to 36.6% at the end of twenty years. Thus, according to the forecast error variance decomposition findings for Malaysia, a uni-directional causality running from oil consumption to output is also a possibility even in the out-of-sample horizon.

In Philippines, after five years, 79.5% of the variation in the forecast error for oil consumption is explained by its own innovations, while at the end of twenty years the forecast error variance for output explained by its own innovations is 74.6%. After five years, about 33.7% of the variation in the forecast error for oil consumption is explained by innovations in output, whereas by the end of twenty years, about 44.9% of the variation in the forecast error for oil consumption is explained by innovations in output. This is also indicative to the existence of uni-directional causality running from output to oil consumption in Philippines.

The results reported for Thailand indicate that after five years, 41.1% of the variation in the forecast error for oil consumption is explained by its own innovations, while at the end of twenty years, this is only 33.6%. After five years about 19.0% of the variation in the forecast error for oil consumption is explained by innovations of output. By the end of the twenty years, about 12.0% of the variation in the forecast

error for oil consumption is explained by innovations of output, indicating the existence of a uni-directional causality running from output to oil consumption in case of the Thai economy.

Thus, the results of both generalized impulse response function and forecast error variance decomposition are consistent with the outcome of the causality tests. From the time-series econometric analysis it is unveiled that for all the concerned economies output and oil consumption are closely tied in the long-run. None of the economies seems to be oil neutral. Hence, the study intends to investigate the importance of oil consumption in the production process of the region as a whole. A simple panel data analysis is performed in this regard and the results are reported in the following section.

#### **4.7 Panel Data Analysis**

For the purpose of analysing the impact of oil consumption in the production function for the whole region, a simple panel data analysis is undertaken<sup>24</sup>. The oil inclusive production function in Equation 3.3 is estimated within three different effect specifications. Under the first scenario neither the country nor time effect is implemented. In the second scenario only country effect is included, while the third scenario includes both country and time effects. The results of this estimation are provided in Table 4.6 (overleaf).

According to the results, oil consumption seems to be highly significant in both the models with country effect and both the time and country effects within the panel system. The coefficients of output with respect to oil consumption in the second and third specifications are 0.3452 and 0.2214, respectively. Furthermore, the *F*-statistics for all the models are highly significant. Hence, the simple panel-data analysis also confirms that oil consumption plays a significant role in the production process of this whole region providing further justification for this study.

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<sup>24</sup> If the data is from the same country the approach would have been appropriate. However, to get a first approximation about the importance of oil consumption in the production process of this whole region the author has made such an extreme assumption of data from similar countries.

**Table 4.6: Panel Data Analysis**

Variable(s)	Effect Specifications		
	1	2	3
Intercept	0.7048*	-6.3947*	-1.5021
LL	0.0103	0.6887*	0.2629***
LK	0.7814*	0.4100*	0.4758*
LO	0.0218	0.3452*	0.2214*
Effects:			
Time fixed effect	none	none	yes
Country effect	none	yes	yes
$R^2$	0.8505	0.9675	0.9792
Adjusted $R^2$	0.8477	0.9658	0.9737
F-statistics	310.9192*	590.9119*	177.4193*
Number of observations	168	168	168

Note: Dependent variable is LY. Ordinary least square estimates. \*, \*\*, and \*\*\*\* indicate significant at 1%, 5%, and 10% level respectively LY, LL, LK and LO denotes log of output, labour, capital and oil consumption.

## 4.8 Summary

This chapter investigates the relationship between oil consumption and output in a production function framework by utilizing annual data of six Asian developing countries. The study uncovers both short-run and long-run causality between oil use and output in these countries. In India and Indonesia, causality seems to run from both ways in both the short run and long run. In China and Malaysia causality is running from oil consumption to output in the long-run, while for China there is no evidence of causal relationship in the short run. The long-run causality direction in China is consistent with the findings of Yuan *et al.* (2008). For Malaysia this uni-directional causality from oil consumption to output also exist in the short-run. In both the Philippines and Thailand, a uni-directional causality runs from output to oil consumption, indicating that they may contribute to the fight against global warming directly implementing oil conservation measures. For China and Malaysia, they can

initiate technological improvements and mitigation policies, while for India and Indonesia a balanced combination of alternative policies seem to be appropriate.

According to the simple panel-data analysis since oil plays a significant role in the production process in the whole region, policy makers of these countries should be cautious in designing energy conservation policies so as not to interfere with the economic growth goals (Lee 2005), and should pursue sustainable oil supply in developing economic growth strategies. Another implication of the close link between oil consumption and economic growth in the long run may be that to achieve sustainable growth the countries may need to rely more on renewable energy sources to ensure uninterrupted energy supply as traditional energy sources like oil become scarcer.

The following chapter looks into the energy conservation and greenhouse gas emission issues in a greater detail as it looks at the oil consumption and output relationship in a model where both oil prices and carbon emission are included.

## Appendix to Chapter 4

**Appendix Table 4.1: Summary Statistics**

a. China

Descriptive Statistics

Variables	Mean	Std. Deviation	Observation
LY	3.8590	0.8523	31
LL	13.2951	0.2258	31
LK	3.7702	0.9801	31
LO	4.9817	0.4997	31

Correlations

Variables	LY	LL	LK	LO
LY	1.000 (0.000)			
LL	0.103 (0.589)	1.000 (0.000)		
LK	0.673 (0.000)	0.450 (0.013)	1.000 (0.000)	
LO	0.082 (0.667)	0.685 (0.000)	0.475 (0.008)	1.000 (0.000)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 28.

b. India

Descriptive Statistics

Variables	Mean	Std. Deviation	Observation
LY	4.2586	0.4639	28
LL	12.7512	0.1619	28
LK	4.2275	0.5682	28
LO	4.2205	0.4488	28

Correlations

Variables	LY	LL	LK	LO
LY	1.000 (0.000)			
LL	0.765 (0.000)	1.000 (0.000)		
LK	0.940 (0.000)	0.714 (0.000)	1.000 (0.000)	
LO	0.504 (0.007)	0.468 (0.014)	0.551 (0.003)	1.000 (0.000)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 25.



c. Indonesia

Descriptive Statistics

Variables	Mean	Std. Deviation	Observation
LY	4.2963	0.4425	29
LL	11.2405	0.1989	29
LK	4.3795	0.5004	29
LO	3.5361	0.3902	29

Correlations

Variables	LY	LL	LK	LO
LY	1.000 (0.000)			
LL	0.629 (0.000)	1.000 (0.000)		
LK	0.953 (0.000)	0.545 (0.003)	1.000 (0.000)	
LO	0.459 (0.014)	0.093 (0.639)	0.430 (0.022)	1.000 (0.000)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 26.

d. Malaysia

Descriptive Statistics

Variables	Mean	Std. Deviation	Observation
LY	4.1626	0.5122	28
LL	8.9639	0.2729	28
LK	4.1982	0.5613	28
LO	2.6903	0.3797	28

Correlations

Variables	LY	LL	LK	LO
LY	1.000 (0.000)			
LL	0.479 (0.012)	1.000 (0.000)		
LK	0.953 (0.000)	0.485 (0.010)	1.000 (0.000)	
LO	0.902 (0.000)	0.640 (0.000)	0.872 (0.000)	1.000 (0.000)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 25.

e. Philippines

Descriptive Statistics

Variables	Mean	Std. Deviation	Observation
LY	4.2644	0.3531	38
LL	9.9650	0.3135	38
LK	4.0815	0.42832	38
LO	2.4714	0.2826	38

Correlations

Variables	LY	LL	LK	LO
LY	1.000 (0.000)			
LL	0.241 (0.150)	1.000 (0.000)		
LK	0.741 (0.000)	0.422 (0.009)	1.000 (0.000)	
LO	0.086 (0.612)	0.026 (0.878)	0.476 (0.003)	1.000 (0.000)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 35.

f. Thailand

Descriptive Statistics

Variables	Mean	Std. Deviation	Observation
LY	3.9779	0.6811	37
LL	10.1735	0.2897	37
LK	4.3424	0.6845	37
LO	2.8995	0.6586	37

Correlations

Variables	LY	LL	LK	LO
LY	1.000 (0.000)			
LL	0.668 (0.000)	1.000 (0.000)		
LK	0.960 (0.000)	0.690 (0.000)	1.000 (0.000)	
LO	0.639 (0.000)	0.025 (0.886)	0.530 (0.001)	1.000 (0.000)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 34.

**Appendix Table 4.2: Augmented Dickey-Fuller (ADF) Unit Root Test Results for LY, LL, LK, and LO**

Country	Series	Level		First Difference	
		Intercept	Intercept & Trend	Intercept	Intercept & Trend
China	LY	-1.853[6] (0.347)	-3.122[3] (0.122)	-3.914[3] (0.006)	-4.154[5] (0.017)
	LL	-2.429[0] (0.143)	-0.253[0] (0.988)	-4.044[0] (0.004)	-4.852[0] (0.003)
	LK	0.178[4] (0.966)	-2.801[1] (0.311)	-4.869[3] (0.001)	-4.709[3] (0.005)
	LO	2.008[0] (0.999)	-1.881[0] (0.640)	-3.752[0] (0.008)	-3.654[2] (0.044)
India	LY	2.222[0] (0.999)	-0.269[0] (0.987)	-4.032[0] (0.005)	-4.792[0] (0.004)
	LL	0.249[6] (0.969)	-0.119[6] (0.995)	-4.939[6] (0.001)	-4.070[5] (0.022)
	LK	1.815[0] (0.999)	-1.246[0] (0.879)	-4.490[0] (0.002)	-5.018[0] (0.002)
	LO	-1.669[0] (0.435)	-0.820[0] (0.951)	-3.876[0] (0.007)	-3.988[0] (0.022)
Indonesia	LY	-1.692[0] (0.424)	-1.504[1] (0.803)	-3.811[0] (0.008)	-3.905[0] (0.026)
	LL	-1.670[1] (0.417)	-2.110[1] (0.517)	-5.579[0] (0.000)	-7.097[0] (0.000)
	LK	-1.819[0] (0.364)	-2.198[1] (0.472)	-4.199[1] (0.003)	-4.215[1] (0.014)
	LO	-1.548[0] (0.495)	-1.042[0] (0.921)	-4.754[0] (0.001)	-4.794[0] (0.004)
Malaysia	LY	-0.656[0] (0.842)	-1.267[0] (0.874)	-3.954[0] (0.006)	-3.894[0] (0.027)
	LL	-1.583[0] (0.477)	0.441[3] (0.998)	-5.229[0] (0.003)	-5.459[0] (0.001)
	LK	-1.222[0] (0.645)	-2.086[1] (0.529)	-3.632[0] (0.012)	-3.555[0] (0.054)
	LO	-1.115[0] (0.695)	0.957[0] (0.934)	-4.392[0] (0.002)	-4.444[0] (0.008)
Philippines	LY	-0.442[0] (0.891)	-2.701[1] (0.242)	-3.599[1] (0.011)	-3.528[1] (0.052)
	LL	-1.933[2] (0.314)	-3.365[0] (0.072)	-7.538[0] (0.000)	-7.669[0] (0.000)
	LK	-2.187[1] (0.214)	-2.948[1] (0.161)	-4.079[0] (0.003)	-4.126[0] (0.013))
	LO	-1.735[0] (0.406)	-1.549[1] (0.793)	-5.122[0] (0.000)	-5.070[0] (0.001)

*Continued.*

Country	Series	Level		First Difference	
		Intercept	Intercept & Trend	Intercept	Intercept & Trend
Thailand	LY	-1.528[1] (0.508)	-1.579[1] (0.781)	-3.236[0] (0.026)	-3.487[0] (0.056)
	LL	-1.546[1] (0.499)	-0.666[1] (0.968)	-2.681[2] (0.088)	-8.303[0] (0.000)
	LK	-1.616[1] (0.464)	-2.237[1] (0.455)	-3.372[0] (0.019)	-3.396[0] (0.068)
	LO	-0.644[1] (0.848)	-2.000[1] (0.581)	-4.029[0] (0.004)	-3.949[0] (0.020)

**Notes:** Figures in the parentheses indicate p values while figures in brackets are optimum lag length determined by Schwarz Information Criteria (SIC). LY, LL, LK and LO stands for log of GDP, labour, capital and oil consumption, respectively.

**Appendix Table 4.3: Phillips Perron (PP) Unit Root Test Results for LY, LL, LK, and LO**

Country	Series	Level		First Difference	
		Intercept	Intercept & Trend	Intercept	Intercept & Trend
China	LY	-0.142[4] (0.936)	-2.458[2] (0.345)	-2.646[6] (0.096)	-2.681[6] (0.91)
	LL	-2.337[1] (0.168)	-0.253[0] (0.988)	-4.049[2] (0.004)	-4.847[1] (0.003)
	LK	0.371[5] (0.978)	-2.248[4] (0.448)	-3.661[4] (0.010)	-3.635[4] (0.044)
	LO	1.905[4] (0.999)	-2.716[22] (0.238)	-3.774[1] (0.008)	-4.899[3] (0.003)
India	LY	2.222[1] (0.999)	-0.331[1] (0.985)	-4.080[2] (0.004)	-4.974[1] (0.004)
	LL	1.093[2] (0.996)	0.695[0] (0.999)	-4.429[0] (0.002)	-4.568[0] (0.003)
	LK	2.002[2] (0.999)	-1.246[0] (0.879)	-4.490[0] (0.002)	-5.018[1] (0.002)
	LO	-1.572[1] (0.483)	-0.820[0] (0.951)	-3.860[2] (0.007)	-3.925[3] (0.025)
Indonesia	LY	-1.692[0] (0.424)	-1.377[1] (0.846)	-3.816[1] (0.008)	-3.919[1] (0.025)
	LL	-2.365[14] (0.329)	-1.603[5] (0.766)	-5.571[2] (0.000)	-7.288[2] (0.000)
	LK	-1.799[4] (0.373)	-2.042[2] (0.554)	-3.629[5] (0.012)	-3.527[5] (0.057)
	LO	-1.535[2] (0.501)	-1.259[1] (0.877)	-4.749[2] (0.001)	-4.786[2] (0.004)
Malaysia	LY	-0.656[0] (0.842)	-1.461[1] (0.818)	-3.925[3] (0.006)	-3.861[3] (0.029)
	LL	-1.267[2] (0.629)	-0.365[2] (0.984)	-5.301[3] (0.002)	-6.421[7] (0.001)
	LK	-1.272[1] (0.628)	-1.667[1] (738)	-3.611[2] (0.013)	-3.532[2] (0.057)
	LO	-1.097[1] (0.702)	-1.086[1] (0.913)	-4.392[0] (0.002)	-4.444[0] (0.008)
Philippines	LY	-0.689[2] (0.837)	-2.057[2] (0.552)	-3.284[2] (0.023)	-3.223[2] (0.096)
	LL	-1.224[1] (0.571)	-3.289[3] (0.094)	-9.778[35] (0.000)	-19.905[23] (0.000)
	LK	-2.130[2] (0.235)	-2.302[2] (0.423)	-4.011[3] (0.004)	-3.969[4] (0.019)
	LO	-1.782[3] (0.383)	-1.735[3] (0.715)	-5.144[2] (0.000)	-5.102[5] (0.001)

*Continued*

Country	Series	Level		First Difference	
		Intercept	Intercept & Trend	Intercept	Intercept & Trend
Thailand	LY	-1.458[2] (0.543)	-1.077[3] (0.919)	-3.312[1] (0.022)	-3.506[2] (0.054)
	LL	-1.056[3] (0.722)	-1.239[4] (0.887)	-7.770[3] (0.000)	-8.066[3] (0.000)
	LK	-1.317[2] (0.611)	-1.569[2] (0.786)	-3.285[4] (0.023)	-3.287[4] (0.085)
	LO	-1.311[3] (0.614)	-1.782[3] (0.693)	-4.083[2] (0.003)	-4.013[2] (0.017)

**Notes:** Figures in the parentheses indicate optimum bandwidth determined by Newey-West using Bartlett kernel while figures in brackets are p values from Mackinnon (1996). Optimal lag length is determined by Schwartz Information Criteria. LY, LL, LK and LO stands for log of GDP, labour, capital and oil consumption, respectively

**Appendix Table 4.4: Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Unit Root  
Test Results for LY, LL, LK, and LO**

Country	Series	Level		First Difference	
		Intercept	Intercept & Trend	Intercept	Intercept & Trend
China	LY	0.732[4]	0.171[2]	0.065[4]	0.056[4]
	LL	0.695[3]	0.181[4]	0.433[3]	0.102[0]
	LK	0.729[4]	0.208[1]	0.079[1]	0.079[5]
	LO	0.704[4]	0.175[4]	0.334[2]	0.117[9]
India	LY	0.678[4]	0.174[3]	0.366[2]	0.079[1]
	LL	0.674[4]	0.184[4]	0.352[2]	0.094[0]
	LK	0.675[4]	0.169[3]	0.359[1]	0.054[2]
	LO	0.667[4]	0.219[3]	0.259[1]	0.083[1]
Indonesia	LY	0.678[4]	0.150[4]	0.241[2]	0.088[0]
	LL	0.672[4]	0.177[4]	0.461[2]	0.137[8]
	LK	0.638[4]	0.147[3]	0.193[4]	0.078[5]
	LO	0.673[4]	0.149[3]	0.229[1]	0.106[2]
Malaysia	LY	0.666[4]	0.147[4]	0.151[0]	0.117[0]
	LL	0.669[4]	0.146[4]	0.279[2]	0.141[2]
	LK	0.565[4]	0.159[4]	0.106[1]	0.073[1]
	LO	0.643[0]	0.151[4]	0.196[1]	0.116[1]
Philippines	LY	0.741[5]	0.150[4]	0.138[2]	0.135[2]
	LL	0.744[5]	0.203[4]	0.379[15]	0.500[36]
	LK	0.627[5]	0.187[4]	0.210[0]	0.059[2]
	LO	0.553[5]	0.181[4]	0.148[3]	0.096[3]
Thailand	LY	0.719[5]	0.153[4]	0.229[3]	0.086[2]
	LL	0.675[5]	0.169[3]	0.186[3]	0.103[3]
	LK	0.627[5]	0.147[2]	0.125[2]	0.069[2]
	LO	0.708[5]	0.183[4]	0.142[3]	0.084[3]
Critical Values					
1%		0.739	0.216	0.739	0.216
5%		0.463	0.146	0.463	0.146
10%		0.347	0.119	0.347	0.119

**Notes:** Figures in brackets are optimum bandwidth determined by Newey-West using Bartlett kernel.. LY, LL, LK and LO stands for log of GDP, labour, capital and oil consumption, respectively

# Chapter 5

## Economic Development, Pollutant Emissions, and Oil Consumption: A Demand-Side Approach

### 5.1 Introduction

This chapter builds upon the theoretical settings presented in Section 3.2.2 of Chapter 3. In this chapter a comprehensive *demand-side* analysis is made by performing an empirical analysis of two separate models. The first model deals with demand for oil consumption which is a function of output and oil prices, while in the second model carbon emission is an endogenous variable which is a function of oil consumption and output. To the author's knowledge none of the previous studies analyze both of these demand sides jointly. Most of the studies empirically investigate the first model in the context of energy consumption.

Another important feature of the study is the incorporation of oil prices in the first model. As most of the previous studies include energy consumption in their model, they end up taking consumer price index (CPI) as a proxy of price variable. Whereas, in this study the inclusion of oil consumption opens up an opportunity to perform a more comprehensive work of incorporating oil prices on which oil consumption is determined. In addition to that, studies analyzing the output of carbon emission are almost non-existent. Thus, through investigating both of these models empirically, this study intends to contribute significantly in the study of identifying the dynamic relationship among oil consumption, pollutant emissions, and economic activity.

The econometric methodology used in this chapter is similar to that of the previous chapter. However, this chapter is arranged around two different building blocks; one is the model of oil consumption demand and the other is the model of carbon emission output. The next section describes the data and data sources, followed by a discussion of the unit root tests. The fourth section performs cointegration test, the Granger causality tests in a vector error correction (VEC) framework, generalized impulse responses and variance decompositions (as out of sample causality tests) tests and a simple panel data estimation for the oil consumption demand model. A



similar econometric exercise is performed for the carbon emission demand model in the penultimate section followed by the chapter summary.

## **5.2 Data**

Annual data on output, crude oil price levels, carbon emissions and oil consumption are used in the empirical analysis. Time spans for data of China, India, Indonesia, Malaysia, Philippines and Thailand are 1965 to 2004, 1965 to 2004, 1967 to 2004, 1970 to 2004, 1965 to 2004 and 1965 to 2004, respectively. The rationale behind selecting these periods is the availability of data. For all the countries, output and prices are represented by constant-dollars GDP and real local crude oil prices. Constant-dollars gross domestic product data are collected from the World Bank World Tables of December 2007, which are available on dxtime data series 2432 written by EconData released on 20 December 2007 in the EconData compact disk.

Local oil price is constructed from the data series of international oil prices, which are adjusted with the currency conversion factor. International oil prices are in the U.S. dollars per barrel and are collected from British Petroleum (BP) Statistical Review, 2008, located at <http://www.bp.com>. This source is used to get data back to 1965, as for all the other sources any data series prior to 1970 in this regard is non-existent. From 1965 to 1983 the prices represent Arabian Light posted at Ras Tanura, while from 1983 to 2004 they represent Brent prices. The source of currency conversion factors is World Bank World Tables of December 2007, which is available on dxtime data series 2432 written by EconData released on 20 December 2007 in the EconData compact disk. Afterwards, the local oil prices are deflated by the GDP deflator of individual countries to get the real local oil prices. GDP deflator is also collected from World Bank World Tables of December 2007, which is available on dxtime data series 2432 written by EconData released on 20 December 2007 in the EconData compact disk. The base year for all the real data series is 2000.

As in the previous chapter, oil consumption data are collected from Statistical Review of World Energy, 2008 published by British Petroleum (BP). Consumption figures are in million tonnes and include inland demand plus international aviation and marine bunkers and refinery fuel and loss.

Carbon (CO<sub>2</sub>) emission per capita data are collected from World Development Indicators, 2008 available on [www.worldbank.org](http://www.worldbank.org). In order to get total carbon emission, the per capita figure is multiplied by total population of individual countries. Total population data are also taken from the World Development Indicators. All the variables are transformed into their logarithmic forms before estimation. Graphical representations of data are given below in Figure 5.1 (overleaf).

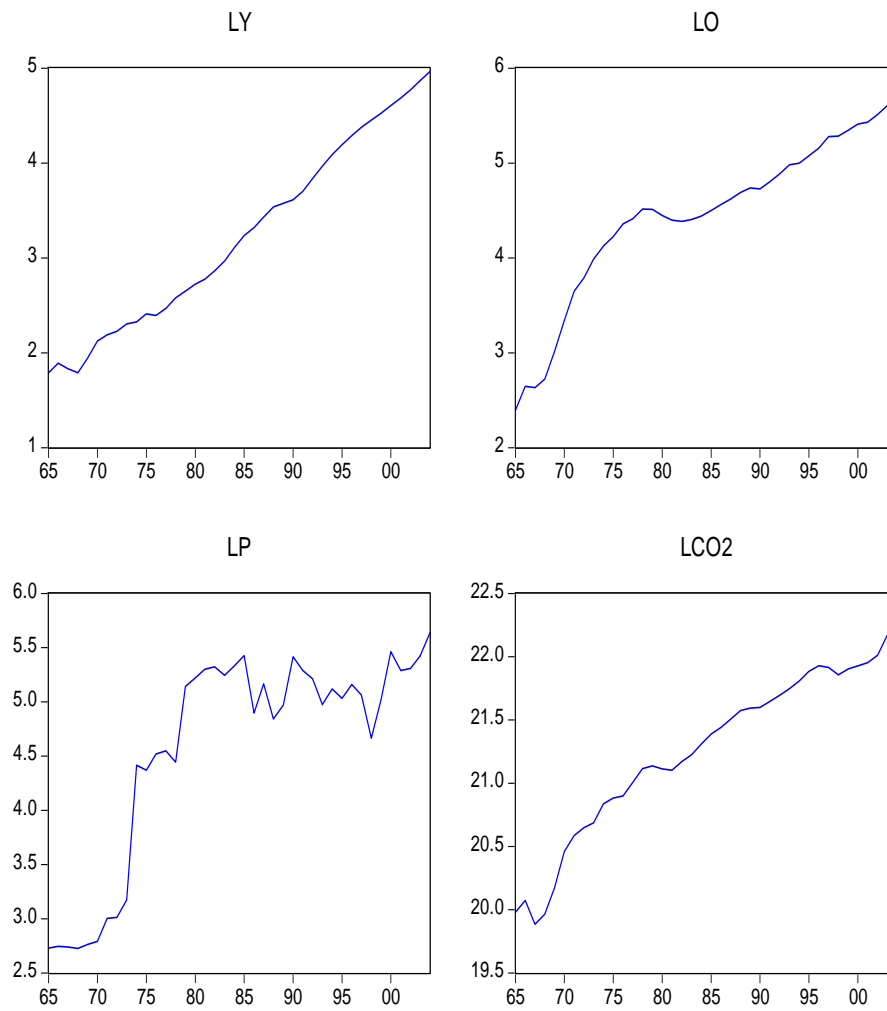
From the graphs of four variables for individual countries, it can be inferred that for Indonesia, Malaysia, and Thailand there are spikes around the period of Asian financial crisis, *i.e.* from 1997- mid 1998. In addition to that, all the variables seem to be non-stationary at levels and real local oil prices seem to be most volatile among all the variables in the system. Further, summary statistics of all the variables are offered in Appendix Table 5.1. The simple correlation analysis indicates that output, oil consumption, and carbon emission are significantly correlated for all the countries except China and Philippines. Prior to identifying causality among the variables, an investigation of time-series properties of the data is warranted and the following section discusses these properties.

### **5.3 Time-Series Properties of Data**

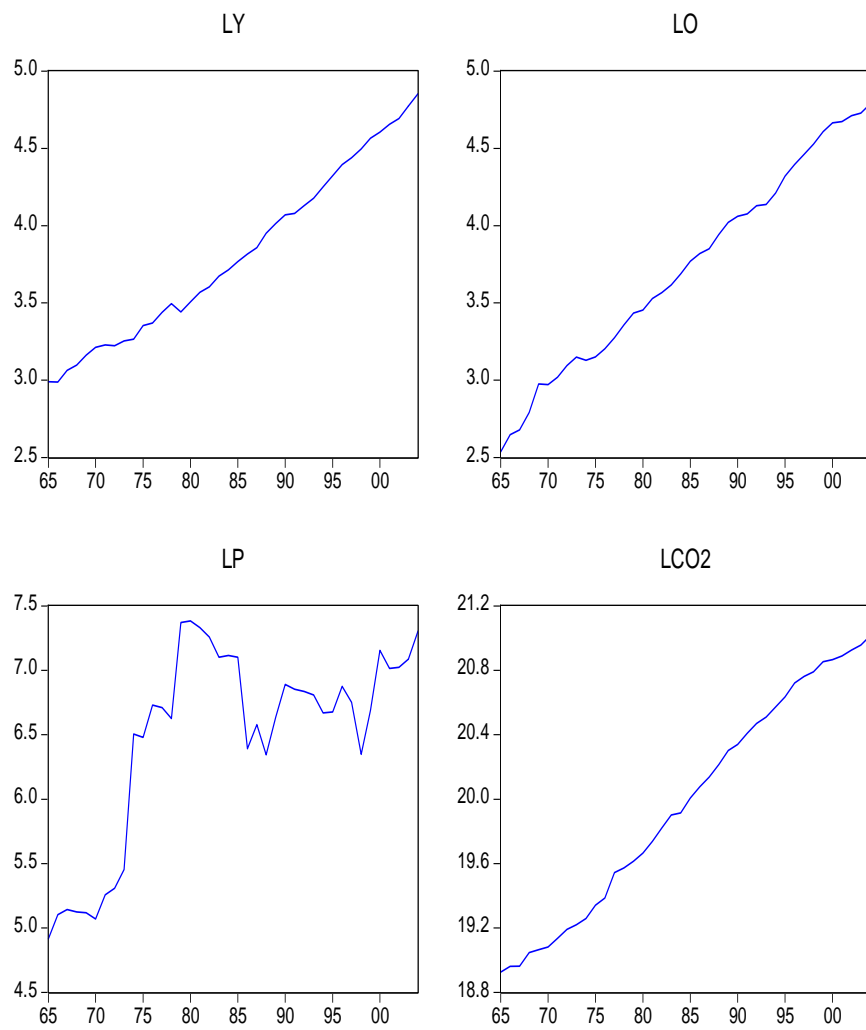
Prior to carrying out unit root tests for the variables, this section first tests for the appropriateness of the logarithmic transformation for each of the variables used in this chapter. For the ADF auxiliary equation in each variable, the study tests for the hypothesis that  $H_0: \phi_p = 0$  (in equation 3.25), which implies appropriate logarithmic transformation, versus the alternative of  $H_a: \phi_p \neq 0$ , which indicates inappropriate logarithmic transformation. The results of the logarithmic transformation test are presented in Table 5.1.

**Figure 5.1: Variables Used in This Chapter**

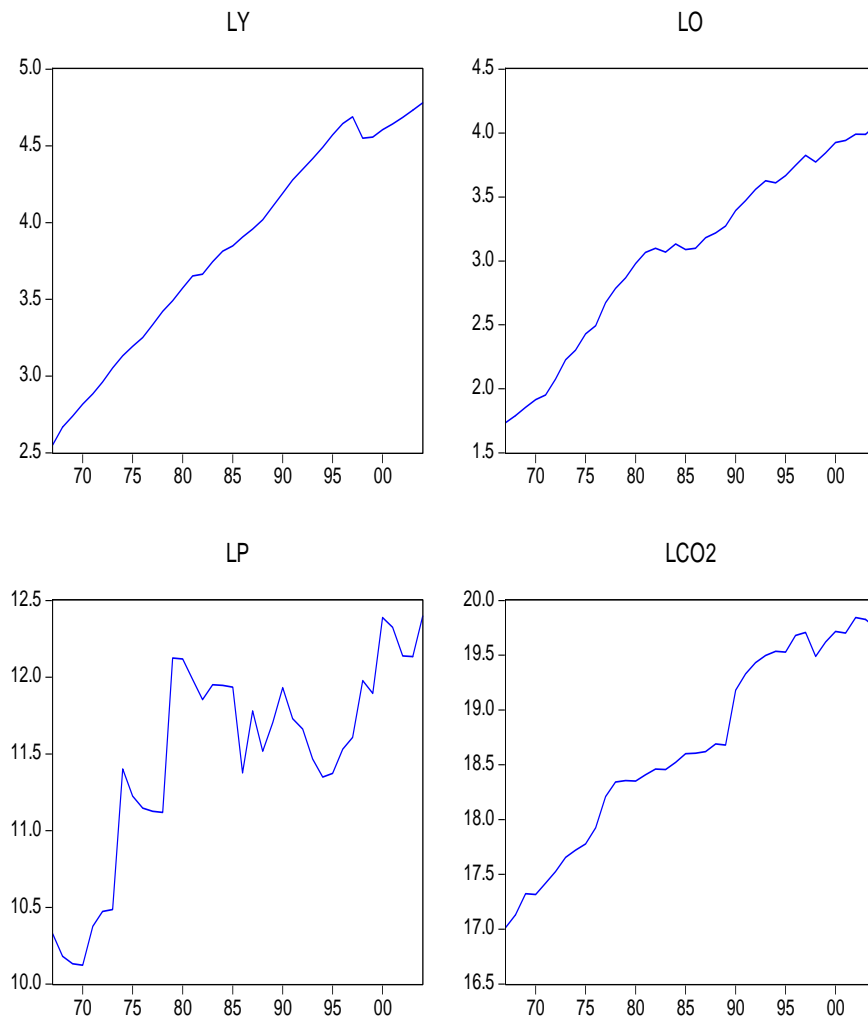
**a. China**



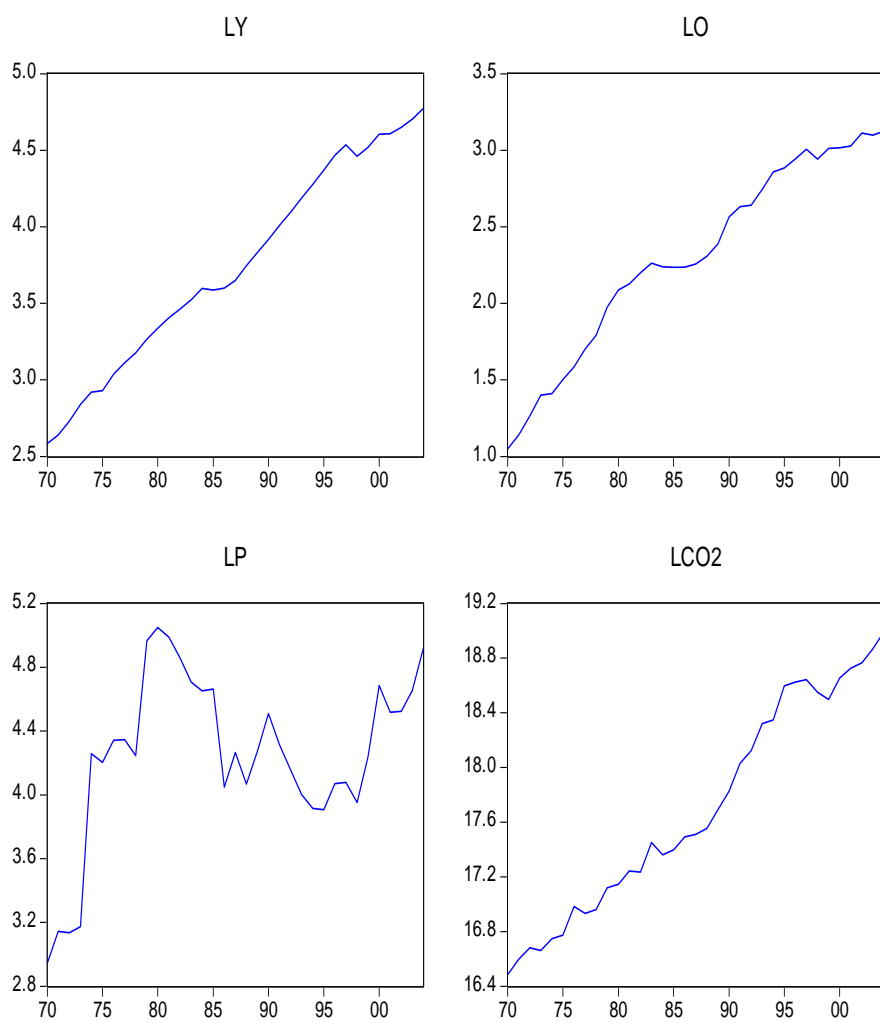
## b. India



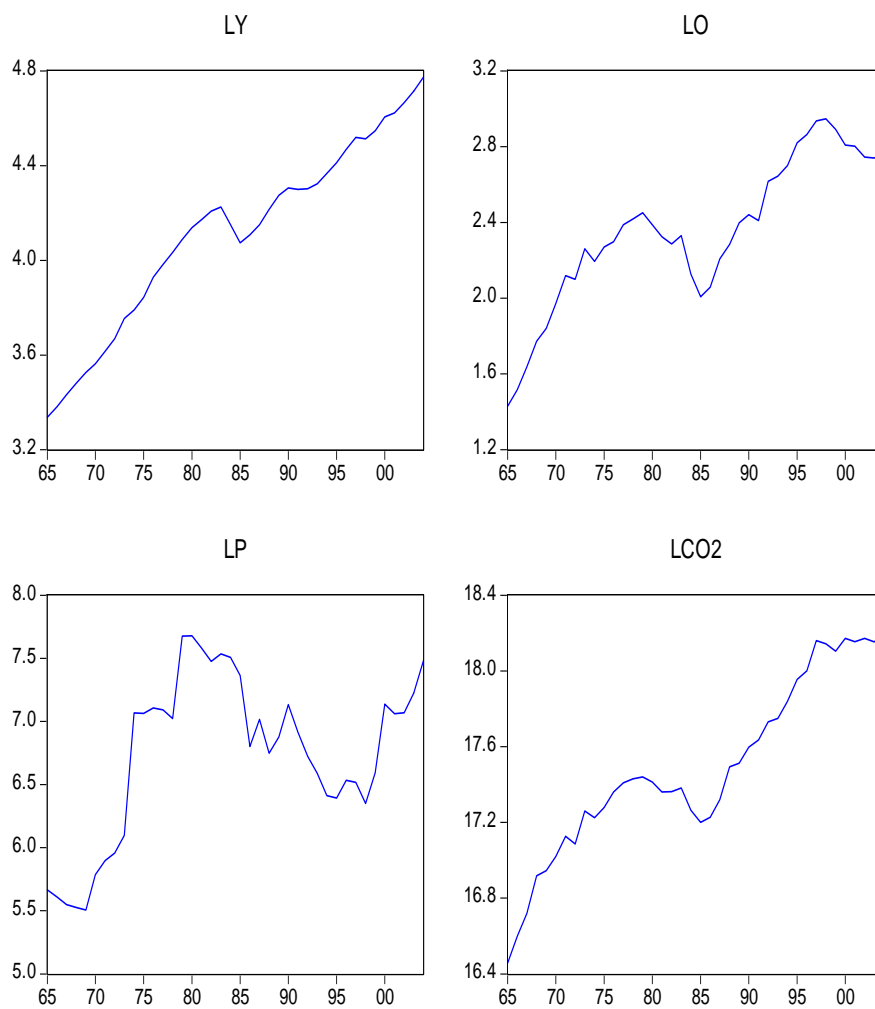
**c. Indonesia**



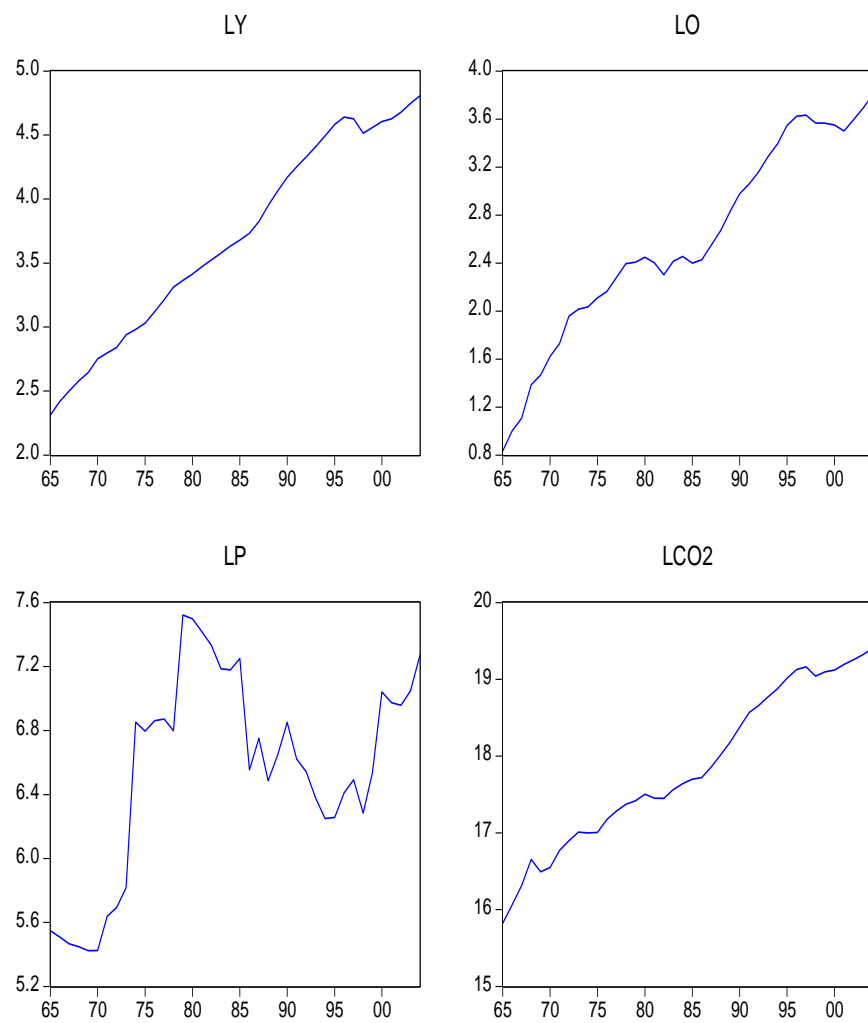
#### d. Malaysia



**e. Philippines**



## f. Thailand



Note: LY, LO, LP and LCO<sub>2</sub> represents log of output, oil consumption, real local oil prices and carbon emission, respectively.



**Table 5.1: Test of Non-Linear Logarithmic Transformation of Output, Oil Consumption, Oil Prices, and Carbon Emission**

Country	Series	$\hat{\phi}_4$	S. E.	$T(\hat{\phi}_4)$	Prob. ( $\hat{\phi}_4$ )	$\bar{R}^2$	Country	Series	$\hat{\phi}_4$	S. E.	$T(\hat{\phi}_4)$	Prob. ( $\hat{\phi}_4$ )	$\bar{R}^2$
China	LY	2.094	4.162	0.503	0.618	0.053	India	LY	-0.845	1.528	-0.553	0.585	0.229
	LO	0.271	1.069	0.253	0.802	0.433		LO	-2.766	2.583	-1.071	0.292	-0.018
	LP	0.153	0.290	0.527	0.602	-0.122		LP	0.104	0.292	0.355	0.725	-0.126
	LCO <sub>2</sub>	0.173	1.224	0.141	0.889	0.397		LCO <sub>2</sub>	-4.467	3.401	-1.313	0.199	-0.034
Indonesia	LY	3.358	2.297	1.462	0.155	0.001	Malaysia	LY	2.701	3.367	0.802	0.429	0.107
	LO	1.682	2.525	0.666	0.511	0.054		LO	0.268	2.434	0.110	0.913	0.062
	LP	0.130	0.383	0.340	0.737	0.089		LP	0.058	0.348	0.166	0.869	0.159
	LCO <sub>2</sub>	0.188	0.511	0.368	0.715	0.112		LCO <sub>2</sub>	-0.027	0.178	-0.153	0.879	0.076
Philippines	LY	-0.342	2.753	-0.1242	0.902	0.218	Thailand	LY	2.969	1.758	1.689	0.101	0.186
	LO	-1.196	1.363	-0.877	0.387	0.006		LO	-0.643	1.353	-0.475	0.638	0.053
	LP	-0.120	0.367	-0.331	0.743	0.001		LP	0.037	0.299	0.123	0.903	0.119
	LCO <sub>2</sub>	0.137	0.156	0.874	0.389	0.051		LCO <sub>2</sub>	-1.399	1.020	-1.372	0.179	0.005

Note: Ordinary least square estimation. Dependent variables are DLY, DLO, DLP and DLCO<sub>2</sub>. Lags order 3 is chosen for each of the equation.

It is apparent from Table 5.1 (opposite) that all of the variables for all the individual countries do not reject the null hypothesis  $\phi_4 = 0$  in equation 3.25. Hence, the test results indicate that the natural logarithmic transformations of all the variables are appropriate for testing for a single unit root. The following sub-section discusses the results of unit root and structural break tests.

### *5.3.1 Unit root and Perron's structural break tests*

This study performs three different unit root tests, namely Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests. The results of these tests are presented in Appendix Tables 5.2, 5.3 and 5.4, respectively. According to the results of the unit root tests it can be inferred that all the series for all the countries have unit root at their levels, while all these variables are stationary at their first differences. The graphical representation of the variables reveals some spikes in the concerned variables for some countries during the time of Asian financial crisis and the traditional unit root test cannot be relied upon if the underlying series contains structural break(s). Therefore, this study uses Perron's (1997) unit root test, which allows for a structural break and the test results are summarized in Table 5.2 (overleaf).

The Perron test results provide further evidence of the existence of unit roots in all series of different countries (except for output in Indonesia) when breaks are allowed. Interestingly enough, even after having different time spans for the data, findings from this test are similar to these of the previous chapter in that only the output series for Indonesia has a single structural break in both intercept and trend, which occurs in 1996. Thus, for Indonesian model this chapter takes a similar approach as the previous chapter and uses a dummy variable in the estimation process for Indonesia to deal with this change in overall structure. Prior to the break date the dummy takes the value of 0, while after the break date the dummy takes 1. For all the other countries, when the underlying series is found non-stationary, the selected value of  $T_b$  no longer yields a consistent estimate of the break point (Perron 1997). Therefore, it may be concluded that the underlying data are non-stationary at levels but stationary at their first differences.

**Table 5.2: Perron Innovational Outlier Model with Change in Both Intercept and Slope for LY, LO, LP, and LCO<sub>2</sub>**

Country	Series	$T$	$T_b$	$k^1$	$t_{\hat{\beta}}$	$t_{\hat{\theta}}$	$t_{\hat{\gamma}}$	$t_{\hat{\delta}}$	$\hat{\alpha}$	$t_{\alpha}$	Inference
China	LY	18	1982	0	3.54	-1.86	2.49	-0.79	0.498	-3.469	NS
	LO	14	1978	0	1.76	0.26	-1.28	1.05	0.755	-2.189	NS
	LP	13	1977	0	4.02	3.93	-3.98	-1.78	0.405	-4.197	NS
	LCO <sub>2</sub>	32	1996	2	3.28	-2.89	2.74	1.16	0.747	-4.308	NS
India	LY	13	1977	0	2.26	0.60	-0.81	2.74	0.207	-4.362	NS
	LO	30	1994	0	3.30	1.61	-1.41	-0.23	0.571	-3.470	NS
	LP	13	1977	0	2.65	2.38	-2.59	-0.76	0.583	-2.914	NS
	LCO <sub>2</sub>	31	1995	0	3.48	1.56	-1.84	1.07	0.686	-3.326	NS
Indonesia	LY	30	1996	0	5.78	-0.40	-0.56	6.32	0.489	-5.858**	S
	LO	15	1981	0	3.86	2.78	-3.73	1.18	0.559	-3.629	NS
	LP	18	1984	0	3.48	0.85	-2.37	1.33	0.365	-3.989	NS
	LCO <sub>2</sub>	22	1988	0	3.52	4.78	-4.06	-3.88	0.564	-4.283	NS
Malaysia	LY	30	1999	0	4.15	-1.96	1.52	6.53	0.584	-4.222	NS
	LO	15	1984	0	4.04	2.67	-3.76	1.49	0.525	-3.819	NS
	LP	18	1987	0	3.21	0.75	-2.00	1.22	0.369	-3.641	NS
	LCO <sub>2</sub>	22	1991	0	3.28	4.32	-3.74	-3.90	0.584	-3.996	NS
Philippines	LY	18	1982	5	3.79	-0.43	-2.05	4.84	0.579	-3.925	NS
	LO	14	1978	0	0.97	-1.15	-0.17	1.09	0.797	-2.244	NS
	LP	13	1977	0	2.11	1.56	-2.01	-0.42	0.735	-2.058	NS
	LCO <sub>2</sub>	15	1979	0	1.46	-2.89	0.79	0.74	0.706	-3.033	NS
Thailand	LY	33	1997	0	2.59	-0.33	0.41	-1.05	0.617	-3.122	NS
	LO	14	1978	0	0.97	-1.15	-0.17	1.09	0.797	-2.244	NS
	LP	13	1977	0	2.11	1.56	-2.01	-0.42	0.735	-2.058	NS
	LCO <sub>2</sub>	15	1979	0	1.46	-2.89	0.79	0.74	0.706	-3.033	NS

**Note:** 1%, 5% and 10% critical values are -6.32, -5.59 and -5.29, respectively (Perron, 1997). The optimal lag length is determined by Akaike Information Criterion ( $AIC$ ) with  $k_{\max} = 10$ . NS stands for Non-stationary at levels. LY, LO, LP and LCO<sub>2</sub> stand for log of output, oil consumption, oil price and CO<sub>2</sub> emissions, respectively. \*, \*\*, and \*\*\* indicate significant at 1%, 5%, and 10% level respectively.

Having made a thorough investigation of the time-series properties of data, now both the demand for output and output for carbon emission models are to be estimated. In case of each of the models, the number of cointegrating relationships is identified first, followed by an analysis of short-run and long-run causality. The robustness of the causality tests are checked using impulse response functions and variance decompositions. Finally, a simple panel-data analysis is performed to check the overall relationship between oil consumption, output and oil prices; and between

carbon emission, output, and oil consumption. The next section covers the econometric analysis of the first model.

#### **5.4 The Linkage among Oil Consumption, Output, and Oil Prices**

The basic framework of this section is to analyse relationship between oil consumption and output in a *demand-side* model where oil consumption is a function of aggregate output and oil prices. The first step toward that task is to look for any long-run cointegrating relationship among the variables by employing cointegration tests.

##### *5.4.1 Cointegration test for variables*

In order to carry out the cointegration test, the order of the VAR model is to be selected first. In selecting the optimum lag length, maximum lag lengths for all the countries are selected as six. This study accepts the optimum lag lengths provided by AIC criterion. The optimum lag lengths suggested by the AIC criterion for China, India, Indonesia, Malaysia, Philippines and Thailand are 3, 4, 3, 2, 2 and 3, respectively<sup>25</sup>. Once the lag lengths are selected, it is appropriate to perform the cointegration tests for the variables. This study adopts Johansen cointegration test for this purpose and the results for different countries are presented in Table 5.3 (overleaf).

It is apparent from Table 5.3 that for China, India, and Indonesia there are at most two long-run cointegrating relationships, while for Malaysia, Philippines and Thailand there are at most one cointegrating relationship among the variables at the 5% level. Evidence of cointegration implies the existence of both short-run and long-run causality. However, it does not indicate the direction of the causal relationship. Hence, to shed light on the direction of causality, this study estimates the error correction models (ECM) to perform causality tests and the results are reported in Table 5.4.

##### *5.4.2 The Granger causality tests*

According to Table 4.4 the significance of the Wald  $\chi^2$ -statistics in the short-run effects indicates short-run causality, while the long-run causality is indicated by the significance of the Joint Wald  $\chi^2$ -statistics where all the error correction terms are

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<sup>25</sup> Results not reported due to space limitation. However, results will be provided upon request.

allowed for. For example, in the first equation for china (the equation for output), none of the short-run  $\chi^2$ -statistics is significant. Hence in this equation none of the three variables causes output in the short-run, while the significance of Joint Wald  $\chi^2$ -statistics for oil consumption and prices mean in the long-run oil consumption and prices Granger causes output. Furthermore, the significance of one of the three error correction terms implies that output in China adjusts actively to restore the long-run equilibrium relationship within the system.

The results from China imply that in the short-run causality runs from output to oil consumption, while in the long-run causality runs in both of the directions *i.e.* from output to oil consumption and from oil consumption to output. Oil prices cause oil consumption in both the short and long run. Output and oil consumption interact to restore the long-run equilibrium relationship.

For India oil consumption Granger causes output both in the short run and long run and oil prices cause oil consumption in the short run. This result is consistent with the finding of Asafu-Adjaye (2000), where the author finds a uni-directional causality running from energy consumption to output in India. The results further indicate that both oil consumption and output adjust to restore the long-run equilibrium relationship whenever there is a deviation from the equilibrium cointegrating relationship. For Indonesia, in both the short run and long run, the direction of causality is just the opposite, from income to oil consumption. All the variables in the model interact together to restore the long-run equilibrium.

The results of the causality tests for Malaysia are similar to that of India. Here, causality runs from oil consumption to output both in the short run and long run. In the long run oil prices Granger cause oil consumption. Just as India, output and oil consumption adjust to reach to the long-run equilibrium condition. In Philippines there exists a uni-directional causality running from output to oil consumption both in the short run and long run. Only oil consumption appears to bear the burden of adjustment towards the long-run equilibrium in response to a short-run deviation.

**Table 5.3: Johansen's Test for Multiple Cointegrating Relationships and Tests of Restrictions on Cointegrating Vector(s) [Intercept, no Trend<sup>26</sup>]**

Country	Null Hypothesis	Optimal lag in VAR	Test Statistic	
			Max-eigen value	Trace Stat.
China	$r = 0$		42.582**	97.522**
	$r \leq 1$	3	27.936**	44.941**
	$r \leq 2$		7.005	7.005
India	$r = 0$		29.597**	55.302**
	$r \leq 1$	4	21.037**	25.705**
	$r \leq 2$		4.669	4.669
Indonesia	$r = 0$		23.250**	40.159**
	$r \leq 1$	3	15.595**	21.909**
	$r \leq 2$		7.315	7.315
Malaysia	$r = 0$		19.440***	31.816***
	$r \leq 1$	2	9.475	13.675
	$r \leq 2$		4.200	4.200
Philippines	$r = 0$		24.217**	34.521***
	$r \leq 1$	2	9.269	14.303
	$r \leq 2$		5.034	5.034
Thailand	$r = 0$		30.213**	54.084**
	$r \leq 1$	3	13.425	17.871
	$r \leq 2$		8.446	8.446

**Note:** Variables included are output, oil prices and oil consumption.  $r$  indicates number of cointegrations. The optimal lag length of VAR is selected by Schwarz Bayesian Criterion. Critical values are based on Johansen and Juselius (1990). \*, \*\*, and \*\*\*\* indicate significant at 1%, 5%, and 10% level respectively.

<sup>26</sup> Same as 22.

**Table 5.4: Temporal Causality Results Based on Parsimonious Vector Error Correction Models (VECM)**

Countries	Dependent variables	Short-run effects			Source of causation				
		$\Delta LY$	$\Delta LO$	$\Delta LP$	ECT(s) only		$\Delta LY, ECT$	$\Delta LO, ECT$	$\Delta LP, ECT$
		Wald $\chi^2$ -statistics			t-ratio		Wald $\chi^2$ -statistics		
China	$\Delta LY$	-	0.146	1.826	-7.387*	1.352	-	2.846***	25.530*
	$\Delta LO$	27.092*	-	3.779***	-5.267*	3.318*	18.219*	-	5.291*
	$\Delta LP$	1.165	1.169	-	1.308	-1.417	0.053	1.413	-
India	$\Delta LY$	-	3.197***	0.317	-3.385*	0.421	-	4.030**	3.964**
	$\Delta LO$	0.234	-	12.257*	1.751***	-4.209*	0.098	-	1.965
	$\Delta LP$	2.157	0.166	-	-1.451	-0.590	2.389	0.023	-
Indonesia	$\Delta LY$	-	0.008	0.029	2.638**	-1.180	-	0.068	0.207
	$\Delta LO$	2.615***	-	0.101	2.854*	-2.666**	2.881**	-	0.011
	$\Delta LP$	0.049	0.088	-	-2.323**	2.189**	0.106	0.135	-
Malaysia	$\Delta LY$	-	3.530***	1.932	-4.110*		-	9.363*	6.505**
	$\Delta LO$	0.129	-	0.564	-3.011*		0.054	-	7.535*
	$\Delta LP$	0.083	0.297	-	-0.644		0.035	0.543	-
Philippines	$\Delta LY$	-	0.083	0.178	-0.339		-	0.030	0.002
	$\Delta LO$	9.286*	-	1.782	-2.897*		11.068*	-	2.462
	$\Delta LP$	0.626	0.329	-	-1.075		0.511	0.029	-
Thailand	$\Delta LY$	-	2.488	1.726	-2.142**		-	3.075***	0.605
	$\Delta LO$	15.812*	-	0.297	-2.500**		16.490*	-	7.931*
	$\Delta LP$	1.438	0.054	-	-0.361		1.759	0.299	-

**Note:** The vector error correction model (VECM) is based on an optimally determined (Schwarz Bayesian Information Criterion) lag structure (Appendix Table 5.6) and a constant.  
 \*, \*\*, and \*\*\* indicate significant at 1%, 5%, and 10% level, respectively.

For Thailand, in the short run there is a uni-directional causality running from income to oil consumption, while in the long run the causality is bi-directional. Moreover, oil prices cause consumption in the long run. Output and oil consumption interact together to restore the long-run equilibrium.

One important finding from the causality tests is that for all the countries except Indonesia oil prices seem to be exogenous in the model. However, since Indonesia is a net oil exporter the presence of oil prices in the short-run adjustment process is not unusual. To investigate the robustness of the causality results this study performs generalized impulse response functions and generalized variance decompositions analysis. The results of these analyses are presented in the following section.

#### *5.4.3 Generalized impulse response functions and generalized forecast error variance decomposition*

This section discusses the results of impulse response functions and variance decomposition analyses of the oil consumption demand model. The results of the impulse response functions are presented in Figure 5.2. Some of the significant findings are discussed below.

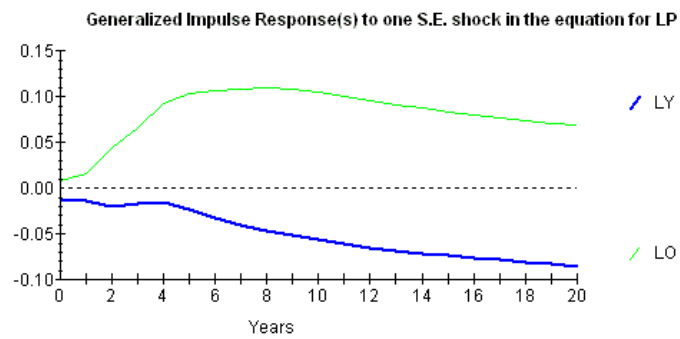
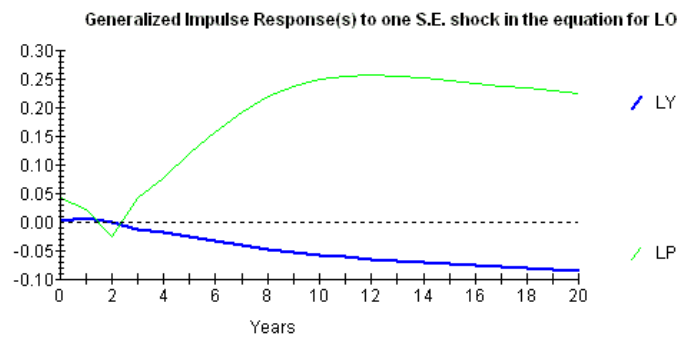
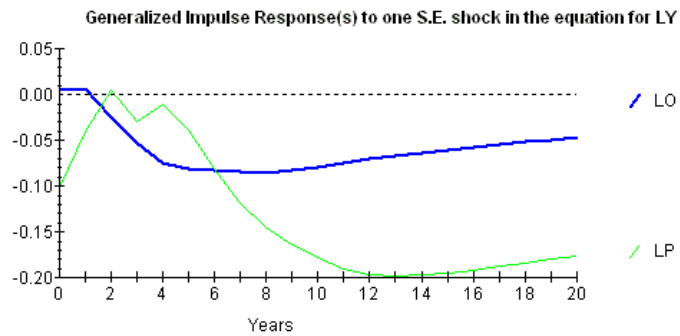
For China, in response to a unit standard error (SE) shock in output, future oil consumption decreases up to -5% at the end of 20 years and it persists into the future. Output also decreases up to -10% at the end of 20 years in response to a unit S.E. shock in oil consumption and persists into the future indicating the existence of bi-directional causality between oil consumption and output. In response to a one unit S.E. shock to oil price oil consumption increases up to 10% at the end of 8 years and starts to fall down to 5% at the end of 20 years, while output falls down to -10% at the end of 20 years in response to the shock in oil prices.

In India, in response to a one S.E. shock in oil consumption output falls up to -7.5% at the end of 20 years suggesting a uni-directional causality running from output to oil consumption. Oil consumption and output also falls down to -8.0% and -5.0%, respectively at the end of 20 years in response to a one S.E. shock in oil prices and persist into the future.

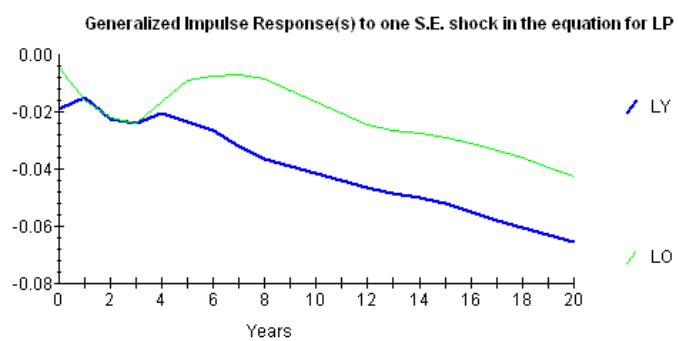
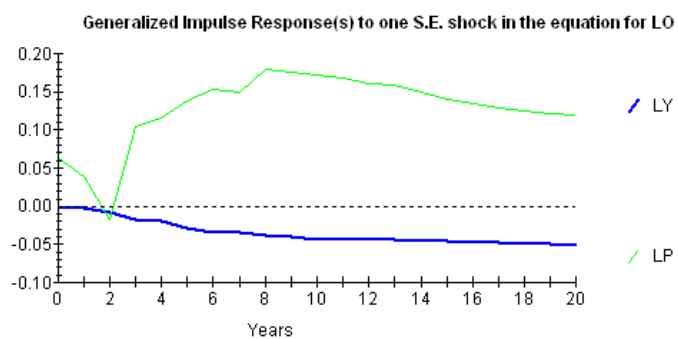
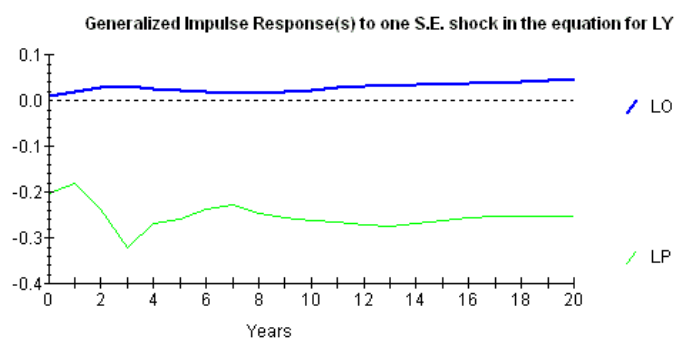


**Figure 5.2: Findings from Generalized Impulse Response Function**

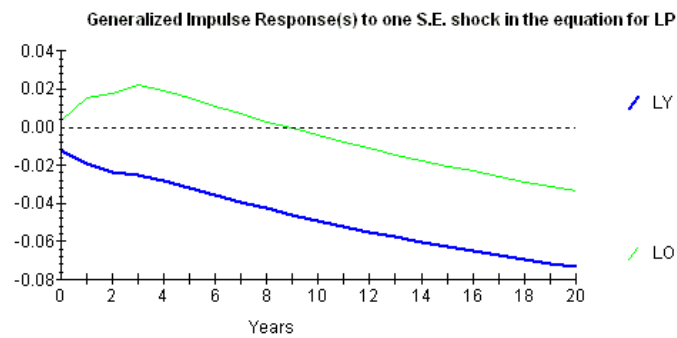
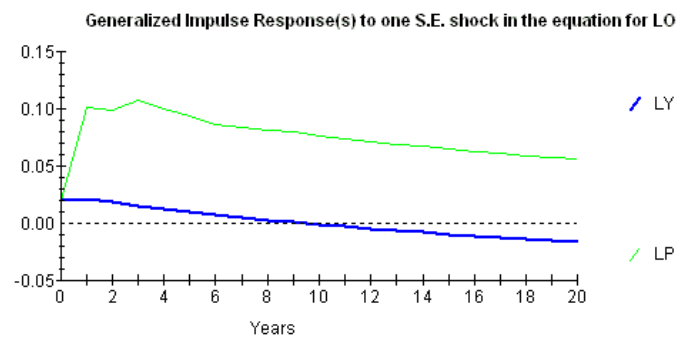
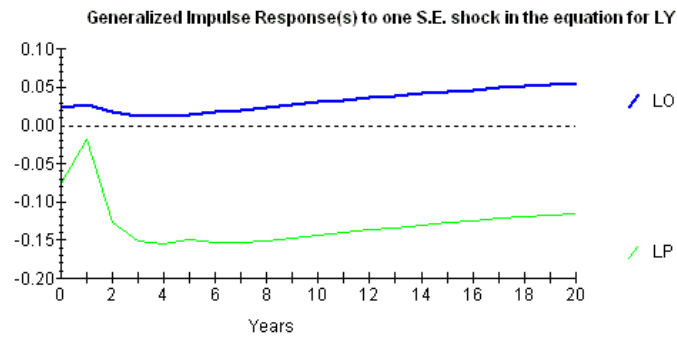
**a. China**



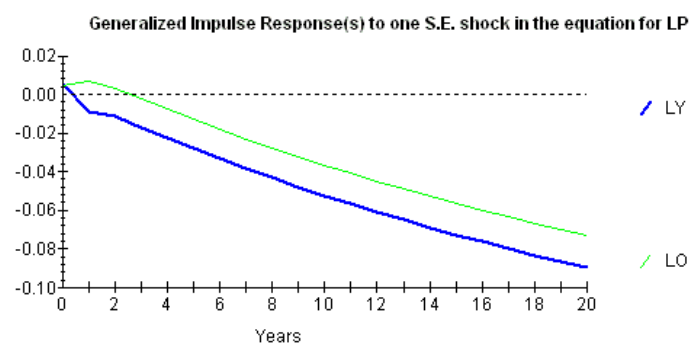
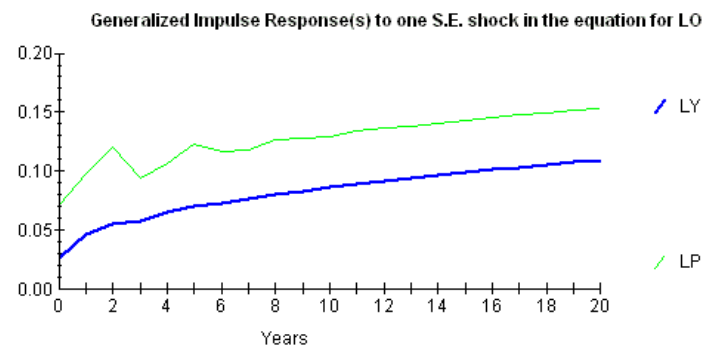
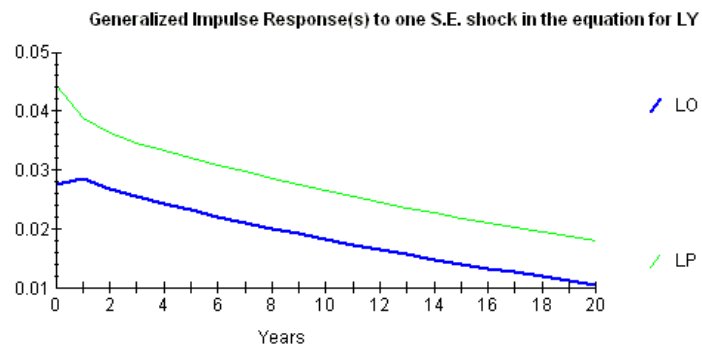
## b. India



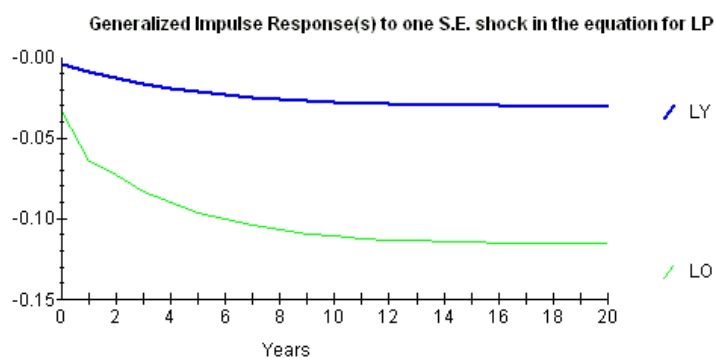
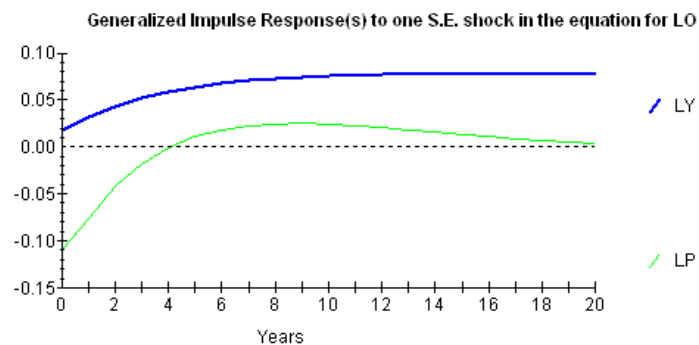
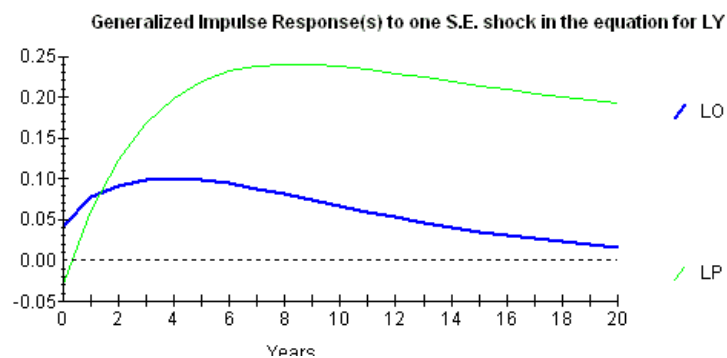
### c. Indonesia



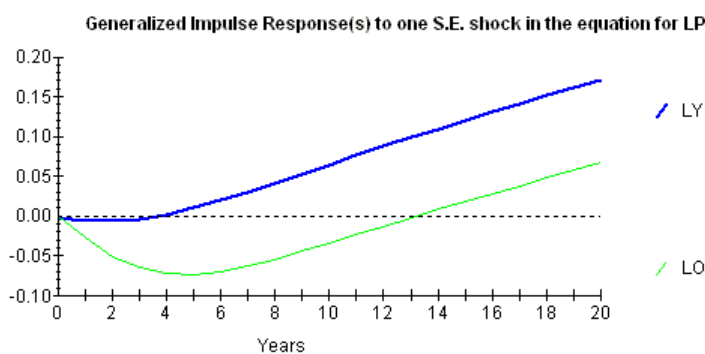
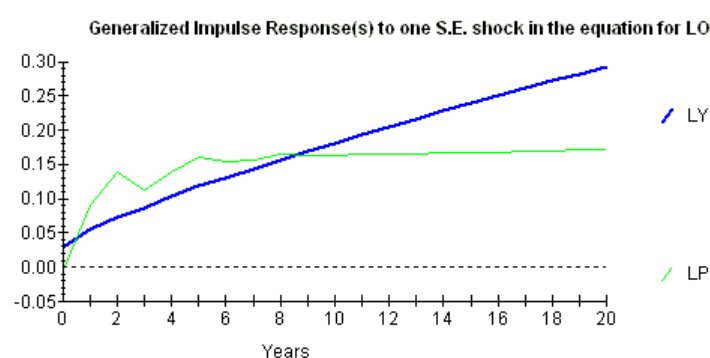
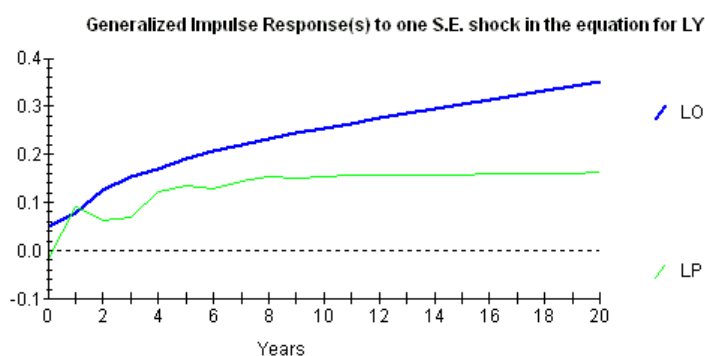
#### d. Malaysia



# e. Philippines



## f. Thailand



For Indonesia, in response to a one unit S.E. shock in output, oil consumption rises up to 5.0% after 20% years as it keeps rising into the future. Both oil consumption and output falls down to -8.0% and -5.0%, respectively at the end of 20 years in response of a one unit S.E. shock in oil prices and the trends continues into the future indicating the importance of oil prices in reducing oil consumption in the future.

For Malaysia, in response to a one S.E. shock in oil consumption output rises up to 10% after 20 years and persists into the future, while in response to a one unit S.E. shock in oil prices both output and oil consumption falls gradually and at the end of

20 years the magnitudes of decrease in output and oil consumption are -10.0% and -8.0%.

For Philippines, in response to a one S.E. shock in oil consumption output goes up to 7.5% in the 20<sup>th</sup> year and persists into the future. However in Thailand, oil consumption rises up to 30% after 20 years as it keeps on increasing into the future and output also increases up to 30% and persists into the future in response to a unit shock in output and oil consumption, respectively. Furthermore in response to a one unit S.E. shock in oil prices both oil consumption and output falls down to -12.0% and -5.0% at the end of 20 years and the decreasing trend continues into the future.

Summarising the findings of the impulse responses, they confirm the direction of causality among the variables in different countries included in this study. Furthermore, the results reveal that in the long run oil price is a significant determinant of oil consumption in all of the countries.

The results of forecast error variance decompositions are presented in Table 5.5 (overleaf). The results of variance decompositions for China suggest that the explanatory power of oil consumption to the variations in output increase as the time goes by, after 20 years almost 43.9% of the variations in output can be explained by oil consumption. Furthermore, output also holds a fair portion of explanation (22.6%) of the variation in oil consumption at the end of 20 years. Oil prices play significant role in explaining the variations in both output and oil consumption. In the 1<sup>st</sup> year oil prices explain 0.27% and 0.43% variations in output and oil consumption, respectively, while the magnitudes of explanations of oil prices in the variations of output and oil consumption increase up to 24.9% and 40.5%, respectively after 20 years.

**Table 5.5: Findings from Forecast Error Variance Decomposition**

**a. China**

Years	Variance Decomposition of LY			Variance Decomposition of LO			Variance Decomposition of LP		
	LY	LO	LP	LY	LO	LP	LY	LO	LP
1	0.988	0.124	0.027	0.009	0.998	0.043	0.191	0.038	0.995
5	0.847	0.209	0.081	0.177	0.711	0.298	0.159	0.281	0.756
10	0.644	0.369	0.182	0.222	0.632	0.375	0.244	0.544	0.424
15	0.579	0.416	0.229	0.228	0.615	0.397	0.283	0.537	0.419
20	0.548	0.439	0.249	0.226	0.613	0.405	0.295	0.530	0.423

**b. India**

Years	Variance Decomposition of LY			Variance Decomposition of LO			Variance Decomposition of LP		
	LY	LO	LP	LY	LO	LP	LY	LO	LP
1	0.875	0.331	0.164	0.094	0.987	0.347	0.379	0.012	0.993
5	0.346	0.728	0.339	0.039	0.906	0.497	0.568	0.011	0.909
10	0.269	0.787	0.331	0.034	0.873	0.640	0.572	0.011	0.920
15	0.165	0.854	0.445	0.028	0.845	0.704	0.583	0.010	0.923
20	0.106	0.865	0.550	0.025	0.822	0.744	0.586	0.009	0.926

**c. Indonesia**

Years	Variance Decomposition of LY			Variance Decomposition of LO			Variance Decomposition of LP		
	LY	LO	LP	LY	LO	LP	LY	LO	LP
1	0.993	0.173	0.099	0.167	0.945	0.051	0.066	0.115	0.894
5	0.937	0.083	0.163	0.179	0.886	0.144	0.168	0.149	0.590
10	0.843	0.033	0.224	0.309	0.822	0.116	0.224	0.134	0.550
15	0.771	0.019	0.263	0.524	0.583	0.124	0.245	0.128	0.536
20	0.719	0.016	0.288	0.638	0.349	0.175	0.257	0.123	0.529

**d. Malaysia**

Years	Variance Decomposition of LY			Variance Decomposition of LO			Variance Decomposition of LP		
	LY	LO	LP	LY	LO	LP	LY	LO	LP
1	0.895	0.363	0.029	0.207	0.998	0.009	0.019	0.016	0.995
5	0.717	0.359	0.137	0.169	0.973	0.013	0.016	0.019	0.993
10	0.492	0.242	0.359	0.133	0.868	0.094	0.015	0.019	0.992
15	0.329	0.255	0.436	0.099	0.725	0.222	0.014	0.019	0.992
20	0.228	0.202	0.555	0.073	0.589	0.349	0.013	0.018	0.992

**e. Philippines**

Years	Variance Decomposition of LY			Variance Decomposition of LO			Variance Decomposition of LP		
	LY	LO	LP	LY	LO	LP	LY	LO	LP
1	0.998	0.179	0.019	0.439	0.897	0.298	0.035	0.137	0.934
5	0.995	0.177	0.028	0.531	0.765	0.409	0.299	0.044	0.604
10	0.993	0.177	0.033	0.453	0.701	0.531	0.457	0.025	0.431
15	0.991	0.177	0.036	0.359	0.648	0.627	0.508	0.018	0.373
20	0.990	0.178	0.038	0.287	0.596	0.693	0.524	0.015	0.352

**f. Thailand**

Years	Variance Decomposition of LY			Variance Decomposition of LO			Variance Decomposition of LP		
	LY	LO	LP	LY	LO	LP	LY	LO	LP
1	0.983	0.613	0.006	0.649	0.911	0.052	0.054	0.052	0.924
5	0.959	0.682	0.003	0.818	0.692	0.129	0.100	0.171	0.801
10	0.885	0.693	0.043	0.878	0.713	0.075	0.194	0.263	0.693
15	0.803	0.677	0.101	0.895	0.747	0.038	0.250	0.314	0.631
20	0.740	0.656	0.149	0.884	0.762	0.030	0.284	0.343	0.594

Note: All the figures are estimates rounded to three decimal places.



For India, after 20 years oil consumption explains almost 86.5% variations in output, while 55.0% and 74.4% variations in output and oil consumption is explained by oil prices.

For Indonesia 63.8% variations in oil consumption is explained by output at the end of 20 years. Moreover, after 20 years oil prices explain 28.8% and 17.5% forecast error variations in output and oil consumption, respectively.

For Malaysia, oil consumption explains more than 20% forecast error variations in output after 20 years indicating a uni-directional causality running from oil consumption to output. Oil prices explain 55.5% error variations in output and 34.9% variations in oil consumption.

In Philippines, the scenario is just the opposite *i.e.* after 20 years output explains 28.7% of the variations in oil consumption.

For Thailand, both output and oil consumption can explain a fair portion of each other's variations. After 20 years oil consumption explains 65.6% and output explains 88.4% variations in output and oil consumption, respectively. The explanatory power of oil prices in the variation of oil consumption increases as the years go by and reach up to 69.3% at the end of 20 years.

Hence, both impulse response functions and variance decompositions confirm the direction of causality between oil consumption and output with respect to individual countries indicating the robustness of the results of causality tests and the results further indicates that oil prices hold substantial amount of explanatory power in justifying the forecast error variations in both output and oil consumption for most of the countries. Finally, the results of panel estimation of the oil consumption demand model is provided in Table 5.6.

#### 5.4.4 Panel data analysis

The results of the panel data analysis under three different effect specifications indicate that both output and oil price levels are important determinants of demand for oil consumption in this region when all the countries are analysed together<sup>27</sup>.

**Table 5.6: Panel Data Analysis for Oil Consumption**

Variable(s)	Effect Specifications		
	1	2	3
Intercept	1.531*	0.236***	2.031*
LY	0.499*	0.834*	0.558*
LP	-0.035	-0.035	-0.141*
Effects:			
Time fixed effect	None	none	yes
Country effect	None	yes	yes
$R^2$	0.104	0.972	0.982
Adjusted $R^2$	0.095	0.971	0.977
F-statistics	11.963*	1011.527*	218.647*

Note: Dependent variable is LO. Ordinary least square estimates. \*, \*\*, and \*\*\* indicate significant at 1%, 5%, and 10% level respectively LY, LO and LP denotes log of output, oil consumption, and oil prices.

In the last model with both time and country fixed effects the long-run elasticity of output and oil prices in oil consumption are 0.558 and -0.141, respectively. Both elasticities seem to be highly significant and variations in the estimated elasticities in all three models confirm the heterogeneity of conditions across the countries. Furthermore, all the variables have expected signs in the estimated regression. Thus, the results of the panel data analysis conform to the findings of causality direction and signs of relationships identified for individual countries in the previous sections of Granger causality tests, impulse responses functions and variance decomposition analysis. In the following section carbon emission demand model is analysed by a similar econometric exercise.

<sup>27</sup> If the data is from the same country the approach would have been appropriate. However, to get a first approximation about the importance of oil consumption in economic activities from the demand-side for this whole region the author has made such an extreme assumption of data from similar countries.

## 5.5 The Linkage among Oil Consumption, Output and Pollutant Emissions

This section builds upon the basic premise that, two major determinants of carbon emissions are output and oil consumption. Hence, this section analyses the dynamic relationship among these three variables in the concerned economies. The results of the cointegration tests are presented in Table 5.7.

### 5.5.1 Cointegration test for variables

In order to carry out the cointegration test, the order of the VAR model is to be selected first. In selecting the optimum lag length, maximum lag lengths for all the countries are set as six. This study accepts the optimum lag lengths provided by AIC criterion. The optimum lag lengths suggested by the AIC criterion for China, India, Indonesia, Malaysia, Philippines and Thailand are 2, 4, 2, 3, 4 and 3, respectively<sup>28</sup>. Once the lag lengths are selected, it is appropriate to perform the cointegration tests for the variables. This study adopts Johansen cointegration test for this purpose and the results for different countries are presented in Table 5.7 (overleaf).

It is apparent from Table 5.7 that for India and Philippines there are at most two long-run cointegrating relationships, while for all other countries *i.e.* China, Indonesia, Malaysia, and Thailand there are at least one cointegrating relationship among the variables at the 10% level<sup>29</sup>. Evidence of cointegration implies the existence of both short-run and long-run causality. However, it does not indicate the direction of the causal relationship. Hence, to shed light on the direction of causality, this study estimates the error correction models (ECM) to perform causality tests and the results are reported in Table 5.8.

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<sup>28</sup> Results not reported due to space limitation. However, results will be provided upon request.

<sup>29</sup> A detailed discussion about multiple cointegrating relationships is offered in Section 3.3.3 of this dissertation.

**Table 5.7: Johansen's Test for Multiple Cointegrating Relationships and Tests of Restrictions on Cointegrating Vector(s) [Intercept, no Trend]**

Country	Null Hypothesis	Optimal lag in VAR	Test Statistic	
			Max-eigen value	Trace Stat.
China	$r = 0$		28.529**	47.437**
	$r \leq 1$	2	12.161	17.408
	$r \leq 2$		6.746	6.746
India	$r = 0$		34.338**	66.347**
	$r \leq 1$	4	19.553**	32.009**
	$r \leq 2$		7.457	7.457
Indonesia	$r = 0$		22.068**	34.546**
	$r \leq 1$	2	10.116	14.478
	$r \leq 2$		4.362	4.362
Malaysia	$r = 0$		24.581**	44.388**
	$r \leq 1$	3	10.473	17.806
	$r \leq 2$		8.333	8.333
Philippines	$r = 0$		19.685**	35.410**
	$r \leq 1$	4	11.519	18.725***
	$r \leq 2$		7.205	7.205
Thailand	$r = 0$		24.724**	42.285**
	$r \leq 1$	3	11.609	17.561
	$r \leq 2$		5.951	5.951

**Note:** Variables included are output, oil consumption and carbon emission.  $r$  indicates number of cointegrations. The optimal lag length of VAR is selected by Schwarz Bayesian Criterion. Critical values are based on Johansen and Juselius (1990). \*, \*\*, and \*\*\*\* indicate significant at 1%, 5%, and 10% level respectively.

**Table-5.8: Temporal Causality Results Based on Parsimonious Vector Error Correction Models (VECM)**

Countries	Dependent variables	Short-run effects			Source of causation				
		$\Delta Y$	$\Delta LO$	$\Delta LCO_2$	ECT(s) only		$\Delta Y$ , ECT	$\Delta LO$ , ECT	$\Delta \Delta LCO_2$ , ECT
		Wald $\chi^2$ -statistics			t-ratio		Wald $\chi^2$ -statistics		
China	$\Delta Y$	-	11.110*	13.181*	5.528*		-	20.693*	5.134**
	$\Delta LO$	7.475*	-	1.488	-3.593*		8.942*	-	1.286
	$\Delta LCO_2$	3.150***	0.445	-	-2.954*		4.246**	2.998**	-
India	$\Delta Y$	-	4.888**	8.899*	4.027*	-2.203**	-	4.634**	8.686*
	$\Delta LO$	1.081	-	0.099	-0.597	-3.686*	1.589	-	0.003
	$\Delta LCO_2$	3.065***	10.347*	-	4.484*	-0.344	3.704***	8.763*	-
Indonesia	$\Delta Y$	-	1.269	0.223	-3.745*		-	3.159***	1.721
	$\Delta LO$	3.284**	-	0.184	-2.994*		3.006***	-	3.103***
	$\Delta LCO_2$	4.743*	7.356*	-	-0.531		4.450*	6.182*	-
Malaysia	$\Delta Y$	-	3.721**	4.161**	-3.111*		-	3.962**	5.487*
	$\Delta LO$	1.594	-	0.003	0.709		3.932**	-	0.014
	$\Delta LCO_2$	2.696	0.082	-	-0.561		2.583	0.040	-
Philippines	$\Delta Y$	-	1.177	1.391	1.571	2.736**	-	2.159	0.739
	$\Delta LO$	3.468**	-	0.316	-.0239	1.096	5.416*	-	0.492
	$\Delta LCO_2$	3.741***	0.018	-	-1.929***	0.673	3.201***	3.171***	-
Thailand	$\Delta Y$	-	4.148*	1.241	1.527		-	5.016*	0.425
	$\Delta LO$	10.169*	-	0.654	-2.231**		10.307*	-	1.407
	$\Delta LCO_2$	3.926**	3.187**	-	0.369		4.996**	2.242***	-

**Note:** The vector error correction model (VECM) is based on an optimally determined (Schwarz Bayesian Information Criterion) lag structure (Appendix Table 5.7) and a constant. \*, \*\*, and \*\*\* indicate significant at 1%, 5%, and 10% level, respectively.

### 5.5.2 *The Granger causality tests*

According to the results of causality tests, in China, there is a bi-directional short-run and long-run causality between oil consumption and output. However, in the previous causality test within the oil consumption demand model in Table 5.4, in the short run causality only runs from output to oil consumption. The long-run causality dynamics remain the same between these variables for both of the models. As far as output and carbon emission are concerned, there also exists a bi-directional causality between these two variables both in the short and long run. All the variables interact to restore the long-run cointegrating relationship within the model.

For India, oil consumption Granger causes output in both short and long run, while there is a bi-directional causality between carbon emission and output in both of the time frames. The uni-directional causality from oil consumption to output is also found in the previous model of oil consumption demand (see Table 5.4). Here, all the variables actively participate to ensure a long-run equilibrium relationship among the variables.

In Indonesia, output Granger causes oil consumption in the short run, while bi-directional causality between the variables exists in the long run. However, in the previous oil consumption demand model causality in Table 5.4 only runs from output to oil consumption in the long run. In this model nevertheless the significance of long-run causality from oil consumption to output is very low. Furthermore, output Granger causes pollutant emission both in the short run and long run. Output and oil consumption interact in a dynamic fashion to restore long-run equilibrium.

For Malaysia, while uni-directional causality runs from oil consumption to output in the short run, the long-run causality runs from both of the directions. Nevertheless, long-run causality from output to oil consumption is absent in the causality test of the previous model in Table 5.4. Carbon emission causes output both in the short and long run<sup>30</sup>. Only output moves actively when there is disequilibrium within the model.

---

<sup>30</sup> This is an unexpected result. However, empirical results some of the times are subject to errors.

In Philippines, output Granger causes oil consumption both in the short run and long run. The direction of causality between oil consumption and output is similar to the of the causality found in the previous model of oil demand presented in Table 5.4. In both of the periods output causes carbon emission. All the variables interact together to restore long-run equilibrium.

For Thailand, there is a bi-directional causality between output and oil consumption both in the short and long run and in both of these time frames output Granger causes pollutant emission. According to the causality test results of the oil consumption demand model presented in Table 5.4, the short-run causality from oil consumption to output is absent. Thus, from most of the countries new causality directions are unveiled as pollutant emission is included in the output oil consumption relationship justifying the inclusion of the second model in the overall demand analysis.

An important feature of the causality tests is that for all the countries except Malaysia, oil consumption causes pollutant emission in the long run. This finding conforms to the usual understanding that pollutant emission is positively correlated with the degree of oil consumption. The following sub-section investigates the robustness of the causality tests results with the help of two out-of-sample causality tests, namely generalized impulse response functions and generalized variance decompositions.

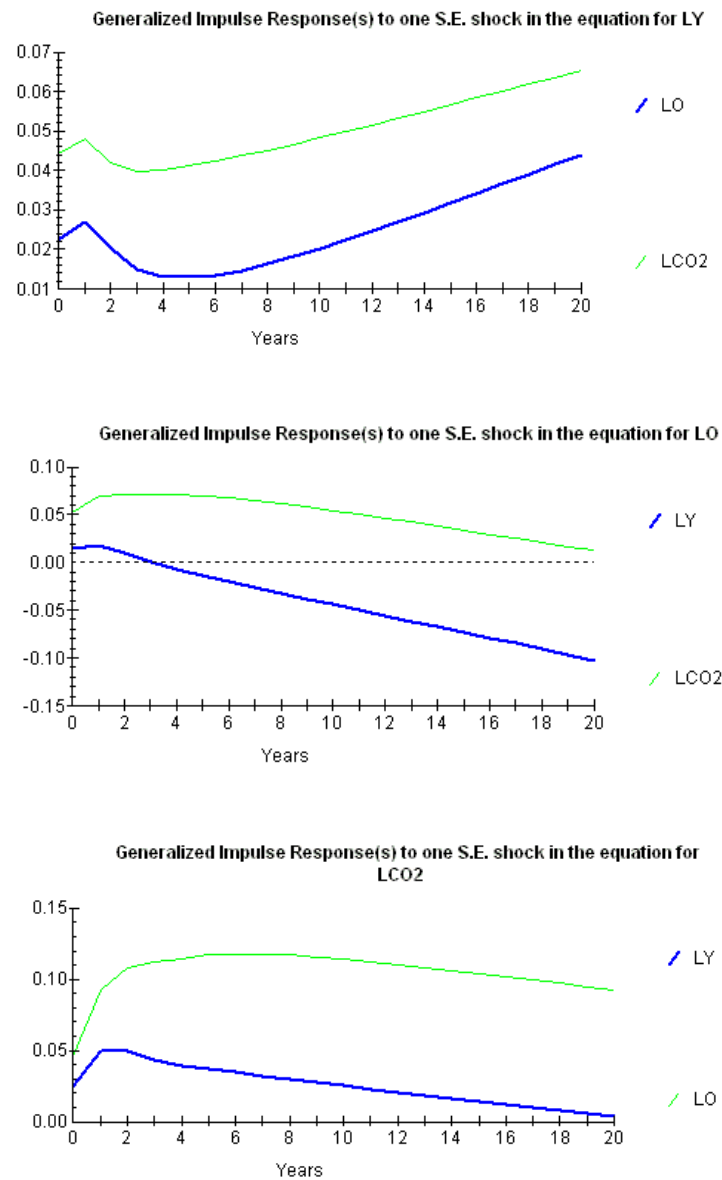
### *5.5.3 Generalized impulse response functions and generalized forecast error variance decomposition*

The results of the impulse response functions are presented in Figure 5.3. (overleaf) For China, in response to a unit standard error (SE) shock in output, future oil consumption and carbon emission increase up to 4% and 7%, respectively, at the end of 20 years and the increasing trend continues into the future. Output also decreases with a one S.E. shock in oil consumption up to -10% at the end of 20 years and persists into the future indicating the existence of bi-directional causality between oil consumption and output. In response to a one unit S.E. shock to oil consumption carbon emission starts to fall down from the second year and this decreasing trend continues in the future. Both output and oil consumption also increases in the long

run in response to a one S. E. shock in carbon emission, but by declining amount as time goes on.

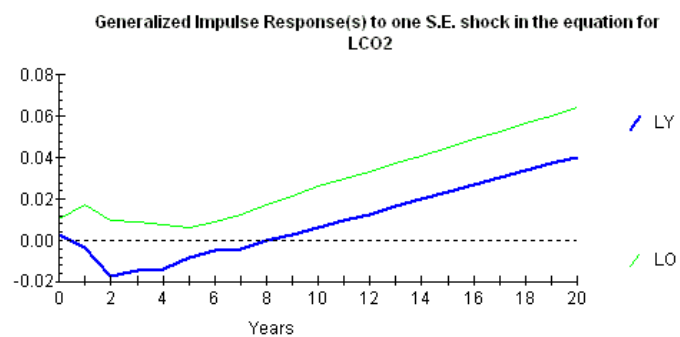
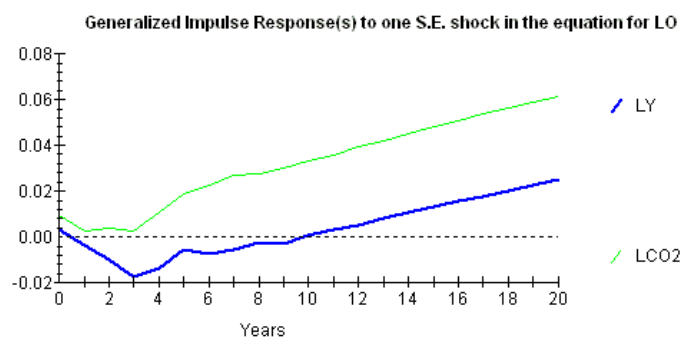
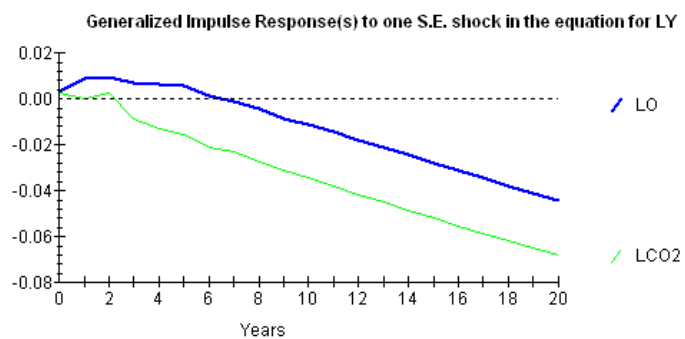
**Figure 5.3: Findings from Impulse Response Function**

**a. China**

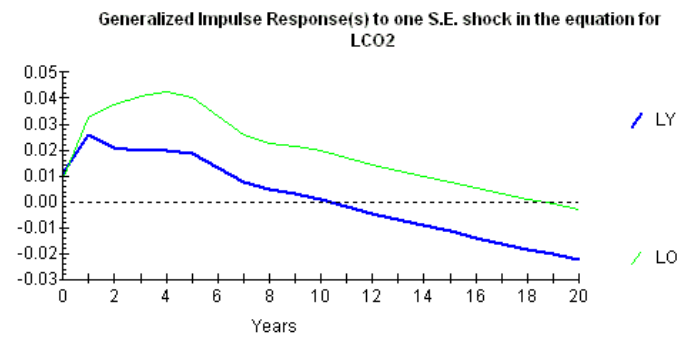
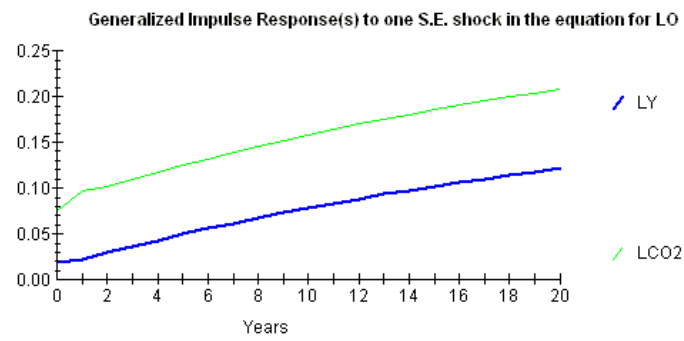
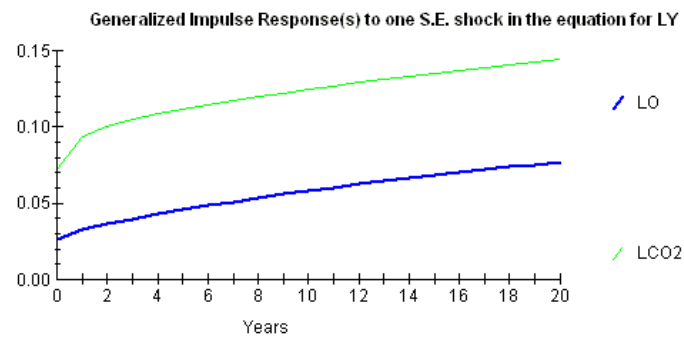




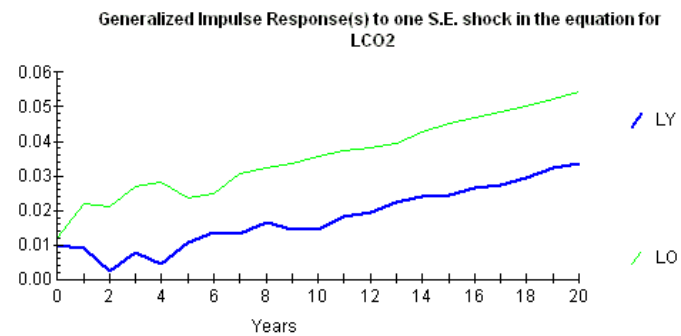
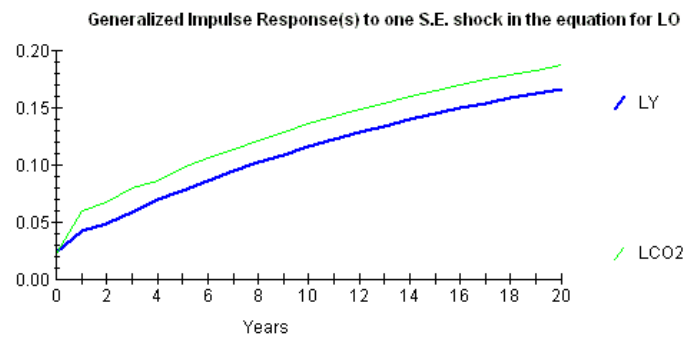
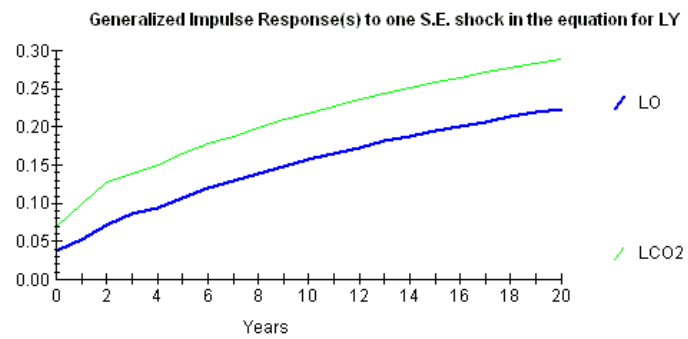
## b. India



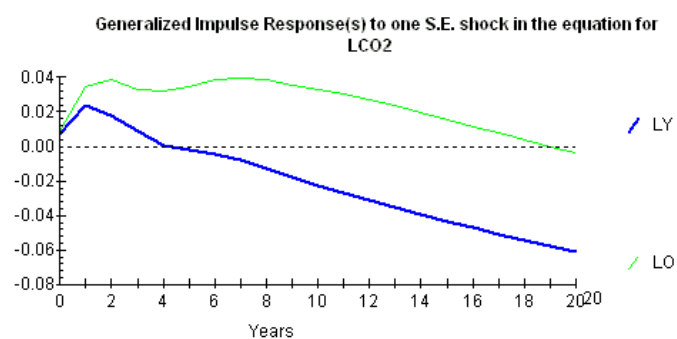
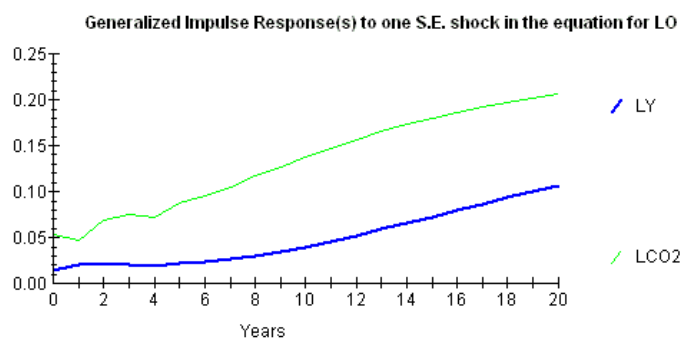
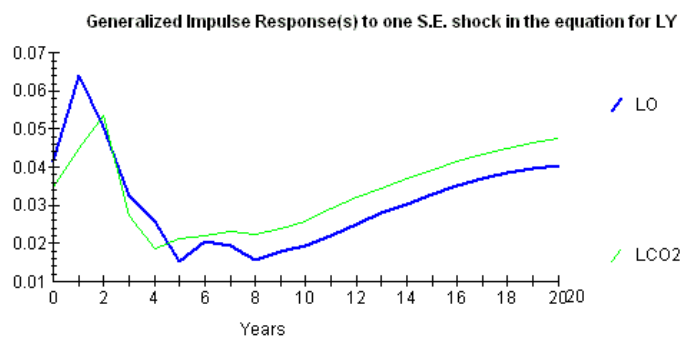
### c. Indonesia



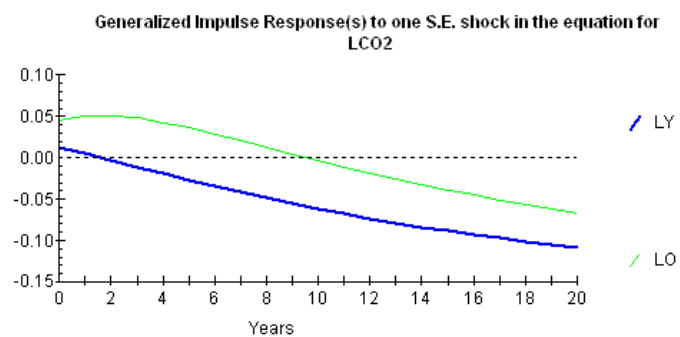
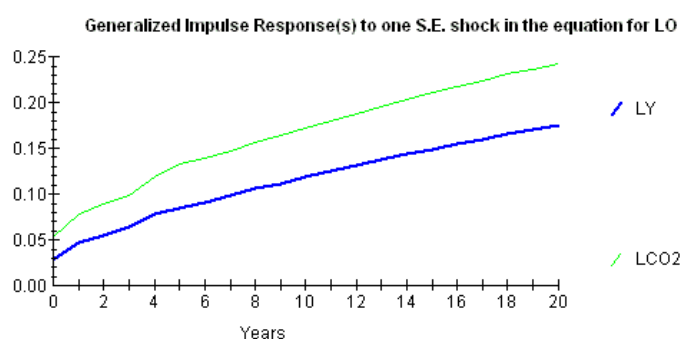
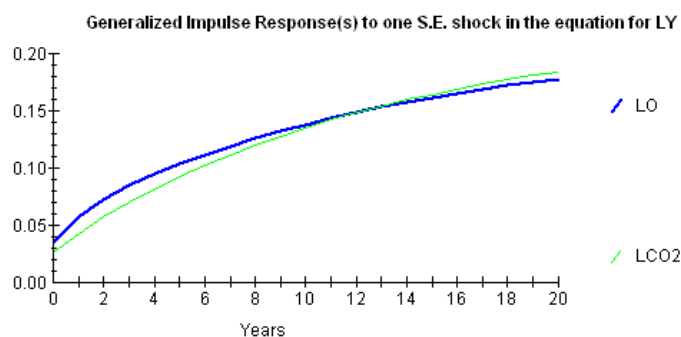
#### d. Malaysia



# e. Philippines



## f. Thailand



In India, in response to a one S.E. shock in oil consumption, output and carbon emission increase up to 2% and 6%, respectively at the end of 20 years suggesting a uni-directional causality running from oil consumption to output. In response to a

one S.E. shock in carbon emission both oil consumption and output goes up to 6% and 4%, respectively, as the trends persist into the future.

For Indonesia, the situation is just opposite. Here, in response to the shock in output oil consumption and carbon emission rise up to 7% and 15%, respectively after 20 years as it keeps rising into the future. In response to a one unit S.E. shock in oil consumption both carbon emission and output increases up to 20% and 10%, respectively, and the increasing trend persists into the future. Furthermore, in response to a one S.E. shock in carbon emission both output and oil consumption goes up in the short run until 4<sup>th</sup> year. However, after the 4<sup>th</sup> year both oil consumption and output fall sharply reaching -1% and -3% at the end of 20 years and the decreasing trend continues into the future.

For Malaysia, oil consumption and carbon emission rises up to 20% and 30%, respectively after 20 years following a one S.E. shock to output and continues to be increasing into the future, while in response to a one S.E. shock in oil consumption output and carbon emission rise up to 15% and 17% , respectively, after 20 years and persists into the future. Moreover, output and oil consumption rise up to 3% and 5%, respectively in response to a one S.E. shock in carbon emission.

For Philippines, in response to a one S.E. shock in output oil consumption and pollutant emission go up to 3% and 5%, respectively in the 20<sup>th</sup> year and this persists into the future. Both carbon emission and output also rise up to 20% and 7.5% after 20 years in response to a one S.E. shock in oil consumption and this persists into the future, while in response to a one S.E. shock in carbon emission both oil consumption and output continues to decrease into the future.

In Thailand, in response to one S. E. shock in output, oil consumption rises up to 20% after 20 years as it keeps on increasing into the future and output also increase up to 15% and persists into the future in response to a unit S.E. shock in output and oil consumption, respectively. Carbon emission goes up to 25% at the end of 20 years in response to a one S.E shock in oil consumption, while in response to a one S.E. shock in carbon emission both output and oil consumption decrease up to -12% and -10%, respectively at the end of 20 years as the decreasing trend persists into the

future. Thus, the findings of the impulse responses confirm the direction of causality in different countries included in this study.

**Table 5.9: Findings from Forecast Error Variance Decomposition**

**a. China**

Years	Variance Decomposition of LY			Variance Decomposition of LO			Variance Decomposition of LCO <sub>2</sub>		
	LY	LO	LCO <sub>2</sub>	LY	LO	LCO <sub>2</sub>	LY	LO	LCO <sub>2</sub>
1	0.885	0.087	0.513	0.600	0.934	0.069	0.241	0.432	0.979
5	0.744	0.029	0.364	0.566	0.866	0.019	0.166	0.424	0.951
10	0.616	0.081	0.189	0.577	0.852	0.016	0.173	0.382	0.948
15	0.512	0.154	0.099	0.614	0.840	0.023	0.202	0.318	0.928
20	0.436	0.220	0.056	0.656	0.819	0.042	0.234	0.252	0.876

**b. India**

Years	Variance Decomposition of LY			Variance Decomposition of LO			Variance Decomposition of LP		
	LY	LO	LCO <sub>2</sub>	LY	LO	LCO <sub>2</sub>	LY	LO	L LCO <sub>2</sub>
1	0.956	0.053	0.014	0.019	0.920	0.259	0.006	0.089	0.986
5	0.657	0.144	0.181	0.151	0.717	0.326	0.128	0.147	0.785
10	0.661	0.124	0.173	0.149	0.471	0.558	0.209	0.217	0.649
15	0.513	0.189	0.338	0.163	0.292	0.617	0.245	0.226	0.597
20	0.349	0.233	0.502	0.199	0.253	0.593	0.265	0.230	0.570

**c. Indonesia**

Years	Variance Decomposition of LY			Variance Decomposition of LO			Variance Decomposition of LCO <sub>2</sub>		
	LY	LO	LCO <sub>2</sub>	LY	LO	LCO <sub>2</sub>	LY	LO	LCO <sub>2</sub>
1	0.957	0.256	0.450	0.204	0.114	0.992	0.391	0.417	0.987
5	0.745	0.224	0.770	0.283	0.120	0.877	0.381	0.428	0.991
10	0.537	0.180	0.918	0.354	0.152	0.752	0.327	0.431	0.990
15	0.418	0.155	0.961	0.384	0.158	0.794	0.288	0.432	0.986
20	0.349	0.139	0.974	0.397	0.161	0.814	0.260	0.431	0.980

**d. Malaysia**

Years	Variance Decomposition of LY			Variance Decomposition of LO			Variance Decomposition of LCO <sub>2</sub>		
	LY	LO	LCO <sub>2</sub>	LY	LO	LCO <sub>2</sub>	LY	LO	LCO <sub>2</sub>
1	0.906	0.392	0.598	0.428	0.986	0.095	0.622	0.276	0.819
5	0.781	0.688	0.755	0.401	0.850	0.214	0.696	0.323	0.803
10	0.734	0.636	0.794	0.381	0.725	0.371	0.691	0.346	0.796
15	0.712	0.652	0.809	0.371	0.654	0.451	0.684	0.359	0.792
20	0.699	0.658	0.816	0.366	0.611	0.496	0.679	0.367	0.788

**e. Philippines**

Years	Variance Decomposition of LY			Variance Decomposition of LO			Variance Decomposition of LCO <sub>2</sub>		
	LY	LO	LCO <sub>2</sub>	LY	LO	LCO <sub>2</sub>	LY	LO	LCO <sub>2</sub>
1	0.992	0.226	0.264	0.582	0.757	0.794	0.458	0.713	0.958
5	0.922	0.333	0.451	0.649	0.552	0.804	0.188	0.698	0.899
10	0.555	0.445	0.720	0.662	0.476	0.759	0.076	0.709	0.832
15	0.267	0.498	0.833	0.671	0.491	0.734	0.053	0.765	0.797
20	0.153	0.511	0.842	0.738	0.416	0.720	0.049	0.804	0.776

#### f. Thailand

Years	Variance Decomposition of LY			Variance Decomposition of LO			Variance Decomposition of LCO <sub>2</sub>		
	LY	LO	LCO <sub>2</sub>	LY	LO	LCO <sub>2</sub>	LY	LO	LCO <sub>2</sub>
1	0.983	0.517	0.259	0.589	0.964	0.622	0.473	0.605	0.960
5	0.971	0.527	0.234	0.855	0.789	0.597	0.853	0.692	0.637
10	0.919	0.493	0.152	0.911	0.747	0.501	0.927	0.671	0.445
15	0.876	0.467	0.107	0.926	0.718	0.417	0.932	0.637	0.328
20	0.845	0.448	0.082	0.928	0.692	0.353	0.919	0.607	0.257

Note: All the figures are estimates rounded to three decimal places.

The results of forecast error variance decompositions are presented in Table 5.9. According to the decompositions results for China, oil consumption explains 22.0% of the variations in output after 20 years, while 65.6% of the variations in oil consumption is explained by output after the same period of time. Both oil consumption and output explain a significant portion of carbon emission. After 20 years 23.4% variations in carbon emission can be explained by output, while oil consumption explains 25.2% variations in pollutant emission.

For India, after 20 years 23.3% of the variation in output is explained by oil consumption confirming the causality direction from oil consumption to output. Carbon emission explains a fair portion of output and oil consumption, too. After 20 years 50.2% variation in output is explained by carbon emission, while 59.3% variation in oil consumption is explained by carbon emission. Oil consumption and output explain 23% and 26.5% variations in carbon emission, respectively.

For Indonesia, after 20 years, 97.4% variations in output is explained by carbon emission, while 39.7% variation in oil consumption is explained by output. After 20 years, oil consumption and output explain 43.1% and 26% variations in carbon emission, respectively.

For Malaysia, oil consumption explains 65.8% variations in output and carbon emission explain 81.6% variations in output after 20 years. After 20 years, output and oil consumption explain 36.6% and 49.6% variations in oil consumption, respectively. 67.9% variation in carbon emission is explained by output after 20 years, while 36.7% variations in carbon emission can be explained by oil consumption.

For Philippines, after 20 years, 51.1% variation in output is explained by oil consumption and carbon emission explains 84.2% of variations in output. 73.8%



variation in oil consumption is explained by output and carbon emission explains 72.0% variations in oil consumption after 20 years. 80.4% of variations in carbon emission can be explained by oil consumption.

The Thai results confirm bi-directional causality between the variables. After 20 years 44.8% of the variation in output is explained by oil consumption, while 92.8% variation in oil consumption is explained by output. A significant portion of the variability in oil consumption is also explained by CO<sub>2</sub> with a magnitude of 62.2% to 35.3% from 1<sup>st</sup> to 20<sup>th</sup> year. Both oil consumption and output explain carbon emission a great deal, too. In the 20<sup>th</sup> year output explains 91.9%, while oil consumption explains 60.7% variations in carbon emission.

Thus, the results of variance decompositions also indicate the robustness of the causality tests for individual countries.

#### 5.5.4 Panel-data analysis

The study also estimates the carbon emission demand in a panel analysis. The results are reported in Table 5.10<sup>31</sup>.

**Table 5.10: Panel Data Analysis for CO<sub>2</sub>**

Variable(s)	Effect Specifications		
	1	2	3
Intercept	15.224*	15.159*	16.317*
LY	0.351*	0.082***	0.160**
LO	1.579*	1.079*	1.011*
Effects:			
Time fixed effect	None	none	yes
Country effect	None	yes	yes
$R^2$	0.981	0.990	0.993
Adjusted $R^2$	0.981	0.989	0.991
F-statistics	5360.571*	2936.191*	571.475*

Note: Dependent variable is LCO<sub>2</sub>. Ordinary least square estimates. \*, \*\*, and \*\*\*\* indicate significant at 1%, 5%, and 10% level respectively LY, LO and LCO<sub>2</sub> denotes log of output, labour, capital and oil consumption.

<sup>31</sup> Same as 26.

The results from the panel data analysis presented the above table reveal that both output and oil consumption are major determinants in carbon emission in all the three models of effect specifications. In the first model of demand for oil consumption, according to the Table 5.6, under both fixed country and fixed time effects, the long-run elasticities for output and oil price on oil consumption are 0.558% and -0.141%, respectively, while in model of output of carbon emission under the same effect scenario, elasticities of output and oil consumption are 0.160% and 1.011%, respectively.

## 5.6 Summary

This chapter examines the dynamic relationships between output, CO<sub>2</sub> emissions, oil price, and oil consumption in the context of two *demand-side* models. The first model investigates oil consumption-output relationship in the light of oil consumption demand framework, while the second model investigates the relationships between the three variables in a carbon emission output framework.

In the first model, the variables considered are oil consumption, output, and oil price levels. In China, the study finds a uni-directional short-run causality running from output to oil consumption, while in the long-run there is a bi-directional causality between the variables. For India, oil consumption Granger causes output both in short run and long run. Output Granger causes oil consumption in Indonesia both in the short run and long run. For Malaysia, causality runs from oil consumption to output in short and long run, whereas in both of the time periods output Granger causes oil consumption in Philippines. The Thai results vary in two different time periods, in the short run there is a uni-directional causality running from output to oil consumption, while in the long run a bi-directional causality between the variables is found. As far as the relationship between oil prices and consumption is concerned, for most of the countries oil prices are found to be one of the determinants of oil consumption demand. The results for India and Thailand's whole period are consistent with the findings of the previous study of Asafu-Adjaye (2000), where the author finds a similar causality direction in the energy consumption, output and CPI framework.

In the model for carbon emission the causality directions between oil consumption and output are similar for most of the concerned countries. Some of the deviations from the aforesaid causality are as follows. For China and Thailand, bi-directional causality between oil consumption and output is found in both short and long run. For Indonesia and Malaysia, bi-directional causality between the variables is observed in the long run. However, for most of the countries oil consumption causes carbon emission in the long-run.

One very important finding of the empirical analysis of this chapter is that for all the countries except Malaysia output Granger causes pollutant emission ( $\text{CO}_2$ ) both in the short run and long run, suggesting that economic growth proceeds degradation of environment. Thus, for most of these countries, economic growth induces increase in pollution levels. This finding is not surprising given that in most of these emerging economies much energy inputs have been consumed in the production process to promote heavy industrialization. Nevertheless, despite the findings from this chapter, the policymakers of these countries should be mindful that a persistent decline in environmental quality may exert a negative externality to the economy through affecting human health, and thereby reduce productivity in the long-run.

As discussed in Chapter 2 that oil consumption is primarily dependent on oil prices and oil price volatility. Impact of oil prices on output is analysed in this chapter. However, oil price volatility also affects the economy through the channels of investment uncertainty and sectoral reallocation. The next chapter deals with analysing the impact of oil price volatility on the economic activities. Standard time series econometrics techniques are employed in this regard.

## Appendix to Chapter 5

**Appendix Table 5.1: Summary Statistics**

### a. China

#### Descriptive Statistics

Variables	Mean	Std. Deviation	Observation
LY	3.2343	0.99767	40
LO	4.4435	0.86014	40
LP	4.5730	0.98715	40
LCO <sub>2</sub>	21.2534	0.66056	40

#### Correlations

Variables	LY	LO	LP	LCO <sub>2</sub>
LY	1.000 (0.000)			
LO	0.0604 (0.000)	1.000 (0.000)		
LP	-0.825 (0.000)	-0.583 (0.000)	1.000 (0.000)	
LCO <sub>2</sub>	0.513 (0.001)	0.834 (0.000)	0.655 (0.000)	1.000 (0.000)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 37.

### b. India

#### Descriptive Statistics

Variables	Mean	Std. Deviation	Observation
LY	3.8139	0.56145	40
LO	3.7289	0.66123	40
LP	6.4784	0.76889	40
LCO <sub>2</sub>	19.9700	0.68870	40

#### Correlations

Variables	LY	LO	LP	LCO <sub>2</sub>
LY	1.000 (0.000)			
LO	0.153 (0.353)	1.000 (0.000)		
LP	-0.782 (0.000)	-0.295 (0.069)	1.000 (0.000)	
LCO <sub>2</sub>	0.024 (0.885)	0.096 (0.056)	-0.267 (0.100)	1.000 (0.000)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 37.

**c. Indonesia****Descriptive Statistics**

Variables	Mean	Std. Deviation	Observation
LY	3.8407	0.68917	38
LO	3.0721	0.71001	38
LP	11.4817	0.66492	38
LCO <sub>2</sub>	18.6569	0.88179	38

**Correlations**

Variables	LY	LO	LP	LCO <sub>2</sub>
LY	1.000 (0.000)			
LO	0.695 (0.000)	1.000 (0.000)		
LP	0.149 (0.377)	0.690 (0.000)	1.000 (0.000)	
LCO <sub>2</sub>	0.761 (0.000)	0.670 (0.000)	0.108 (0.524)	1.000 (0.000)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 35.

**d. Malaysia****Descriptive Statistics**

Variables	Mean	Std. Deviation	Observation
LY	3.7476	0.67193	35
LO	2.3077	0.63165	35
LP	4.2508	0.52891	35
LCO <sub>2</sub>	17.7028	0.78253	35

**Correlations**

Variables	LY	LO	LP	LCO <sub>2</sub>
LY	1.000 (0.000)			
LO	0.714 (0.000)	1.000 (0.000)		
LP	0.107 (0.548)	-0.501 (0.003)	1.000 (0.000)	
LCO <sub>2</sub>	0.628 (0.000)	0.101 (0.517)	-0.382 (0.026)	1.000 (0.000)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 32.

**e. Philippines**

**Descriptive Statistics**

Variables	Mean	Std. Deviation	Observation
LY	4.1144	0.39475	40
LO	2.3553	0.38924	40
LP	6.7337	0.65261	40
LCO <sub>2</sub>	17.4898	0.46420	40

**Correlations**

Variables	LY	LO	LP	LCO <sub>2</sub>
LY	1.000 (0.000)			
LO	0.482 (0.002)	1.000 (0.000)		
LP	0.849 (0.000)	0.120 (0.465)	1.000 (0.000)	
LCO <sub>2</sub>	0.372 (0.020)	0.917 (0.000)	0.005 (0.977)	1.000 (0.000)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 37.

**f. Thailand**

**Descriptive Statistics**

Variables	Mean	Std. Deviation	Observation
LY	3.6925	0.77701	40
LO	2.5838	0.82251	40
LP	6.5472	0.63706	40
LCO <sub>2</sub>	17.8477	1.03527	40

**Correlations**

Variables	LY	LO	LP	LCO <sub>2</sub>
LY	1.000 (0.000)			
LO	0.595 (0.000)	1.000 (0.000)		
LP	-0.123 (0.456)	0.115 (0.487)	1.000 (0.000)	
LCO <sub>2</sub>	0.684 (0.000)	0.807 (0.000)	-0.304 (0.060)	1.000 (0.000)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 37.

**Annexure Table 5.2: Augmented Dickey-Fuller (ADF) Unit Root Test Results  
for LY, LO, LP, and LCO<sub>2</sub>**

Country	Series	Level		First Difference	
		Intercept	Intercept & Trend	Intercept	Intercept & Trend
China	LY	1.196[1] (0.998)	-3.163[1] (0.107)	-4.493[0] (0.000)	-4.811[0] (0.002)
	LO	-1.284[1] (0.627)	-2.165[1] (0.495)	-3.300[0] (0.022)	-3.263[0] (0.077)
	LP	-1.606[0] (0.469)	-1.667[0] (0.747)	-6.827[0] (0.000)	-6.881[0] (0.000)
	LCO <sub>2</sub>	-2.334[2] (0.129)	-2.443[1] (0.353)	-5.186[1] (0.000)	-5.931[1] (0.000)
India	LY	2.022[0] (0.999)	-1.386[0] (0.849)	-6.776[0] (0.000)	-7.397[0] (0.000)
	LO	-1.204[0] (0.663)	-3.053[1] (0.107)	-5.827[0] (0.000)	-5.785[0] (0.000)
	LP	-1.876[0] (0.339)	-1.859[0] (0.656)	-6.411[0] (0.000)	-6.395[0] (0.000)
	LCO <sub>2</sub>	-0.103[0] (0.942)	-1.801[0] (0.685)	-6.562[0] (0.000)	-6.473[0] (0.000)
Indonesia	LY	-2.443[0] (0.106)	-0.759[0] (0.961)	-4.280[0] (0.002)	-4.696[0] (0.003)
	LO	-2.288[0] (0.181)	-1.092[0] (0.917)	-4.686[0] (0.001)	-5.186[5] (0.001)
	LP	-1.612[0] (0.467)	-2.235[0] (0.456)	-7.095[0] (0.000)	-7.040[0] (0.000)
	LCO <sub>2</sub>	-1.743[0] (0.402)	-1.658[0] (0.749)	-5.421[0] (0.000)	-5.636[0] (0.000)
Malaysia	LY	-1.239[0] (0.646)	-1.661[0] (0.746)	-4.736[0] (0.001)	-4.849[0] (0.002)
	LO	-1.871[0] (0.159)	-1.839[3] (0.661)	-4.285[0] (0.002)	-4.929[0] (0.002)
	LP	-2.519[0] (0.120)	-2.378[0] (0.384)	-5.965[0] (0.000)	-5.922[0] (0.000)
	LCO <sub>2</sub>	-0.087[0] (0.943)	-2.219[0] (0.465)	-6.652[0] (0.000)	-6.567[0] (0.000)
Philippines	LY	-0.935[1] (0.766)	-2.525[1] (0.315)	-3.709[1] (0.008)	-3.687[1] (0.035)
	LO	-2.573[0] (0.107)	-2.304[1] (0.422)	-4.633[0] (0.001)	-4.822[0] (0.002)
	LP	-1.556[1] (0.495)	-1.542[0] (0.797)	-5.749[0] (0.000)	-5.699[0] (0.000)
	LCO <sub>2</sub>	-1.972[1] (0.298)	-2.285[0] (0.432)	-5.298[0] (0.000)	-5.302[0] (0.001)

*Continued*

Country	Series	Level		First Difference	
		Intercept	Intercept & Trend	Intercept	Intercept & Trend
Thailand	LY	-1.081[1] (0.714)	-1.755[1] (0.706)	-3.617[0] (0.010)	-3.696[0] (0.035)
	LO	-1.488[1] (0.529)	-2.611[1] (0.278)	-3.979[3] (0.004)	-4.046[0] (0.015)
	LP	-1.591[0] (0.478)	-1.642[0] (0.758)	-6.452[0] (0.000)	-6.389[0] (0.000)
	LCO <sub>2</sub>	-1.084[1] (0.712)	-2.579[1] (0.291)	-5.000[0] (0.000)	-5.001[0] (0.001)

**Notes:** Figures in the parentheses indicate p values while figures in brackets are optimum lag length determined by Schwarz Information Criteria (SIC). LY, LO, LP and LCO<sub>2</sub> stand for log of output, oil consumption, oil price and CO<sub>2</sub> emissions, respectively.



**Annexure Table 5.3: Phillips Perron (PP) Unit Root Test Results for LY, LO, LP, and LCO2**

Country	Series	Level		First Difference	
		Intercept	Intercept & Trend	Intercept	Intercept & Trend
China	LY	2.266[12] (0.999)	-2.379[7] (0.389)	-4.328[12] (0.002)	-4.784[16] (0.002)
	LO	-2.637[3] (0.094)	-2.585[2] (0.289)	-3.357[3] (0.019)	-3.310[2] (0.079)
	LP	-1.595[1] (0.475)	-1.608[1] (0.771)	-6.827[0] (0.000)	-6.936[2] (0.000)
	LCO <sub>2</sub>	-1.289[9] (0.621)	-1.736[7] (0.716)	-3.724[14] (0.008)	-3.534[16] (0.049)
India	LY	4.000[8] (1.000)	-1.045[4] (0.925)	-6.763[1] (0.000)	-8.729[6] (0.000)
	LO	-1.204[0] (0.663)	-3.144[0] (0.101)	-5.919[5] (0.000)	-5.846[5] (0.000)
	LP	-1.868[1] (0.343)	-1.844[2] (0.664)	-6.412[1] (0.000)	-6.395[0] (0.000)
	LCO <sub>2</sub>	-0.106[3] (0.942)	-1.978[1] (0.595)	-6.546[3] (0.000)	-6.463[3] (0.000)
Indonesia	LY	-1.844[0] (0.162)	-0.759[0] (0.961)	-4.288[1] (0.002)	-4.677[2] (0.003)
	LO	-2.058[3] (0.262)	-1.265[3] (0.881)	-4.782[3] (0.000)	-5.216[3] (0.001)
	LP	-1.419[4] (0.562)	-2.169[1] (0.492)	-7.307[5] (0.000)	-7.327[6] (0.000)
	LCO <sub>2</sub>	-1.737[1] (0.405)	-1.757[1] (0.705)	-5.421[5] (0.000)	-5.622[2] (0.000)
Malaysia	LY	-1.189[1] (0.668)	-1.848[1] (0.659)	-4.749[1] (0.001)	-4.861[1] (0.002)
	LO	-2.715[3] (0.102)	-1.561[3] (0.787)	-4.337[3] (0.002)	-4.961[3] (0.002)
	LP	-2.509[1] (0.122)	-2.364[1] (0.391)	-5.965[0] (0.000)	-5.922[0] (0.000)
	LCO <sub>2</sub>	-0.031[1] (0.949)	-2.282[2] (0.432)	-6.644[1] (0.000)	-6.560[1] (0.000)
Philippines	LY	-1.239[1] (0.648)	-1.889[1] (0.641)	-3.367[2] (0.019)	-3.291[3] (0.083)
	LO	-2.340[3] (0.165)	-2.234[3] (0.459)	-4.704[3] (0.001)	-4.917[3] (0.002)
	LP	-1.580[1] (0.483)	-1.581[1] (0.783)	-5.749[0] (0.000)	-5.699[5] (0.000)
	LCO <sub>2</sub>	-1.772[4] (0.388)	-2.508[4] (0.323)	-5.349[3] (0.000)	-5.379[3] (0.001)

*Continued*

Country	Series	Level		First Difference	
		Intercept	Intercept & Trend	Intercept	Intercept & Trend
Thailand	LY	-1.625[3] (0.461)	-1.313[3] (0.869)	-3.661[1] (0.009)	-3.696[0] (0.035)
	LO	-2.049[3] (0.266)	-2.508[3] (0.323)	-3.942[2] (0.004)	-4.038[2] (0.016)
	LP	-1.570[4] (0.488)	-1.638[2] (0.759)	-6.452[2] (0.000)	-6.390[2] (0.000)
	LCO <sub>2</sub>	-1.670[1] (0.438)	-2.653[2] (0.261)	-4.935[4] (0.000)	-4.921[4] (0.002)

**Notes:** Figures in the parentheses indicate optimum bandwidth determined by Newey-West using Bartlett kernel while figures in brackets are p values from Mackinnon (1996). Optimal lag length is determined by Schwartz Information Criteria. LY, LO, LP and LCO<sub>2</sub> stand for log of output, oil consumption, oil price and CO<sub>2</sub> emissions, respectively.

**Annexure Table 5.4: Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Unit Root  
Test Results for LY, LO, LP, and LCO<sub>2</sub>**

Country	Series	Level		First Difference	
		Intercept	Intercept & Trend	Intercept	Intercept & Trend
China	LY	0.773[5]	0.207[4]	0.380[6]	0.161[12]
	LO	0.735[5]	0.233[5]	0.309[4]	0.153[4]
	LP	0.778[5]	0.172[5]	0.148[0]	0.075[1]
	LCO <sub>2</sub>	0.763[5]	0.179[4]	0.148[5]	0.111[7]
India	LY	0.776[5]	0.199[5]	0.488[0]	0.094[8]
	LO	0.782[5]	0.217[2]	0.125[0]	0.060[0]
	LP	0.770[5]	0.250[5]	0.162[1]	0.077[0]
	LCO <sub>2</sub>	0.770[5]	0.218[2]	0.191[3]	0.191[3]
Indonesia	LY	0.741[5]	0.175[4]	0.434[4]	0.058[1]
	LO	0.725[5]	0.159[5]	0.292[4]	0.063[3]
	LP	0.740[5]	0.246[4]	0.112[6]	0.107[7]
	LCO <sub>2</sub>	0.731[5]	0.217[4]	0.237[0]	0.059[2]
Malaysia	LY	0.795[5]	0.227[4]	0.154[2]	0.066[1]
	LO	0.783[5]	0.253[4]	0.355[4]	0.056[3]
	LP	0.797[4]	0.225[4]	0.197[1]	0.135[0]
	LCO <sub>2</sub>	0.789[5]	0.192[4]	0.075[1]	0.065[1]
Philippines	LY	0.757[5]	0.235[5]	0.178[2]	0.124[1]
	LO	0.755[5]	0.279[4]	0.201[4]	0.103[3]
	LP	0.773[5]	0.256[5]	0.154[1]	0.132[0]
	LCO <sub>2</sub>	0.739[5]	0.287[5]	0.169[3]	0.121[4]
Thailand	LY	0.772[5]	0.217[2]	0.238[3]	0.075[3]
	LO	0.763[5]	0.282[4]	0.216[4]	0.098[3]
	LP	0.295[5]	0.139[5]	0.138[2]	0.118[2]
	LCO <sub>2</sub>	0.774[5]	0.268[4]	0.195[1]	0.091[2]
Critical Values					
1%		0.739	0.216	0.739	0.216
5%		0.463	0.146	0.463	0.146
10%		0.347	0.119	0.347	0.119

**Notes:** Figures in brackets are optimum bandwidth determined by Newey-West using Bartlett kernel. LY, LO, LP and LCO<sub>2</sub> stand for log of output, oil consumption, oil price and CO<sub>2</sub> emissions, respectively.

## Chapter 6

### Impact of Oil Price Volatility on Economic Development: A Short-Run Impact Channel

#### 6.1 Introduction

The previous two chapters explore the relationships between oil consumption and economic activities on the basis of both the *supply-side* and *demand-side* analyses. Furthermore, in the previous chapter for the complete *demand-side* analysis, the impact of oil prices on economic activities is investigated. With the help of vector error correction regression both short-run and long-run dynamics of these relationships are identified. From the oil price and economic activity relationship it is found that, oil price shocks exert adverse impacts on output.

Alternatively, as pointed out in Section 3.2.3 of Chapter 3, large oil price changes, either increases or decreases, *i.e.* oil price volatility, may adversely affect the economy in the short run because they delay business investment by raising uncertainty or by inducing costly sectoral resource reallocation. In relation to these hypotheses, this chapter explores the short-run impact of oil price volatility on economic activities.

The next section describes the data and data sources, followed by a discussion on the unit root tests in section 6.3. Causality test results based on vector autoregressive model along with impulse response functions and variance decompositions are presented in section 6.4. A summary concludes the chapter.

#### 6.2 Data

This chapter uses quarterly data on three different variables, namely oil price volatility, GDP growth and inflation. The data periods covered for China, India, Indonesia, Malaysia, Philippines and Thailand are 1999:2 to 2008:1, 1996:4 to 2008:1, 1993:2 to 2008:1, 1991:2 to 2008:1, 1986:1 to 2008:1, and 1993:2 to 2008:1, respectively. GDP growth rate and inflation data are quarter to quarter change based on real GDP and CPI data. For China, real GDP is constructed from nominal GDP and GDP deflator data collected from International Financial Statistics (IFS)

Compact Disk (CD) of September 2008, a publication of International Monetary Fund (IMF). Nominal GDP is not seasonally adjusted and is in Million Chinese Yuan. Codes for nominal GDP and GDP deflator are 92499BZF and 92499BIPZF, respectively. The base year for real GDP is 2000. CPI data are also collected from IFS CD September 2008 and the code is 92464XZF.

For India, the nominal GDP data are collected from Main Economic Indicators (MEI), a publication of Organization for Economic Co-operation and Development (OECD) and the data code is INOSN014A. Data on GDP deflator are collected from IFS CD September 2008 with the data code of 53499BIPZF. Both nominal GDP and GDP deflator are in Million Indian Rupee. Real GDP with a base year of 2000 is calculated from adjusting nominal GDP with the deflator. CPI data are also extracted from IFS CD of September 2008 based on Million Indian Rupee and the data code is 53464ZF. Quarter to quarter growth is calculated from real GDP and CPI to reach quarterly GDP growth and inflation of India.

For Indonesia, real GDP with the base year of 2000 is collected from Main Economic Indicators (MEI) by OECD. The unit for real GDP is Billion Indonesian Rupiah and the code is IDOSN029D. CPI for Indonesia is collected from IFS CD of September 2008 and the data code is 53664ZF. Afterwards GDP growth and inflation are calculated from quarter to quarter growth of real GDP and CPI.

With respect to Malaysia, all the relevant data of nominal GDP, GDP deflator and CPI are collected from IFS CD of September 2008. The base year for GDP deflator and CPI is 2000. The data code for nominal GDP, GDP deflator and CPI are 54899BZF, 54899BIPZF and 54864ZF, respectively. The scale for all the series is Million Malaysian Ringgit. Real GDP is then calculated through dividing nominal GDP by GDP deflator and then quarter to quarter growth rates of real GDP and CPI determine GDP growth rate and inflation for Malaysia.

Nominal GDP, GDP deflator and CPI data for Philippines are also found from IFS CD, September 20008. Base year for GDP deflator and CPI is 2000. Scale for all the series is Million Philippine Peso. The data codes are 56699BZF, 56699BIPZF and 56664ZF for nominal GDP, GDP deflator and CPI, respectively. Both nominal GDP

and GDP deflator are used to get real GDP. The quarter to quarter growth rates of real GDP and CPI represent quarterly GDP growth and inflation data for Philippines.

Similar to Malaysia and Philippines, all the three series for Thailand are collected from IFS CD of September 2008. The codes for nominal GDP, GDP deflator and CPI are 57899BZF, 57899BIPZF and 57864ZF, respectively, and the base year for GDP Deflator and CPI is 2000. After constructing real GDP from current GDP and the deflator, quarterly growth rates are calculated from real GDP and CPI.

Based on the nature of data under consideration, various volatility measures, both parametric and non-parametric (such as historical volatility (HS), stochastic volatility (SV), implied volatility (IV), realized volatility (RV) and conditional volatility (CV)) have been suggested in the literature. The parametric models can reveal well documented time varying and clustering features of conditional and implied volatility. However, the validity of the estimate relies a great deal on the model specifications along with the particular distributional assumptions and, in the instances of implied volatility, another assumption regarding the market price of volatility risk has to be met (Andersen *et al.* 2001 a, ABDE hereafter). This stylized fact is also unveiled in a seminal article by Andersen *et al.* (2001 b, ABDL hereafter), where they argue that the existence of multiple competing parametric models points out the problem of misspecification. Moreover, the conditional volatility (CV) and stochastic volatility (SV) models are hard to adopt in a multivariate framework for most of the practical applications.

An alternative measure of volatility, termed as *realized volatility*, is introduced by ABDE (2001 a) and ABDL (2001 b, 2003). Furthermore, the theory of quadratic variation suggests that, under appropriate conditions, realized volatility is an unbiased and highly efficient estimator of volatility of returns, as shown in ABDL (2001 and 2003), and Barndorff-Nielsen & Shephard (2002, 2001a). In addition to that, by treating volatility as observed rather than latent, the approach facilitates modelling and forecasting using simple methods based on observable data (ABDL, 2003).

According to Andersen *et al.* (2004), *realized volatility* or *realized variance* is the summation of intra-period squared returns

$$RV_t(h) \equiv \sum_{i=1}^{t/h} r_{t-1+ih}^{(h)2}$$

where the  $h$ -period return (in this study this is daily oil price return) is given by  $r_t^{(h)} = \log(S_t) - \log(S_{t-h})$ ,  $t$  is the total number of working days in a quarter and  $h$  is 1 as this study uses daily price data. Hence,  $1/h$  is a positive integer. In accordance with the theory of quadratic variation, the realized volatility  $RV_t(h)$  converges uniformly in probability to  $IV_t$  as  $h \rightarrow 0$ , as such allowing for ever more accurate nonparametric measurements of integrated volatility. Furthermore, papers of Zhang *et al.* (2005) and Aït-Sahalia *et al.* (2005) state that the realized variance is a consistent and asymptotically normal estimator once suitable scaling is performed.

In calculating the quarterly volatility measure, the daily crude oil prices of “Arab Gulf Dubai FOB \$US/BBL” are considered and transformed into local prices by adjusting the world oil prices with the respective foreign exchange rates. Dubai oil prices are collected from Datastream and the source is ICIS Pricing, and exchange rates for different currencies are also found from Datastream and the source is GTIS-FTID.

The estimated realized volatility all the concerned countries are presented in the form of data tables in Appendix Table 6.1, while graphical representations of data are given below in Figure 6.1. It is to be noted here that, the GDP growth and inflation data are in percentage changes in real GDP and inflation, while RV are summation of quarterly price returns expressed as fractions. These figures reveal two important facts; (i) crude oil price has been highly volatile in recent years, particularly in the second half of 1990s and (ii) since none of the GDP data are seasonally adjusted, there are signs of seasonality in the GDP growth data series for all the countries. Hence, this study performs seasonal adjustment for GDP growth data of all the countries.

The seasonal adjustment is performed through implementing the U.S. Census Bureau's X12 seasonal adjustment program. The X11 additive method along with

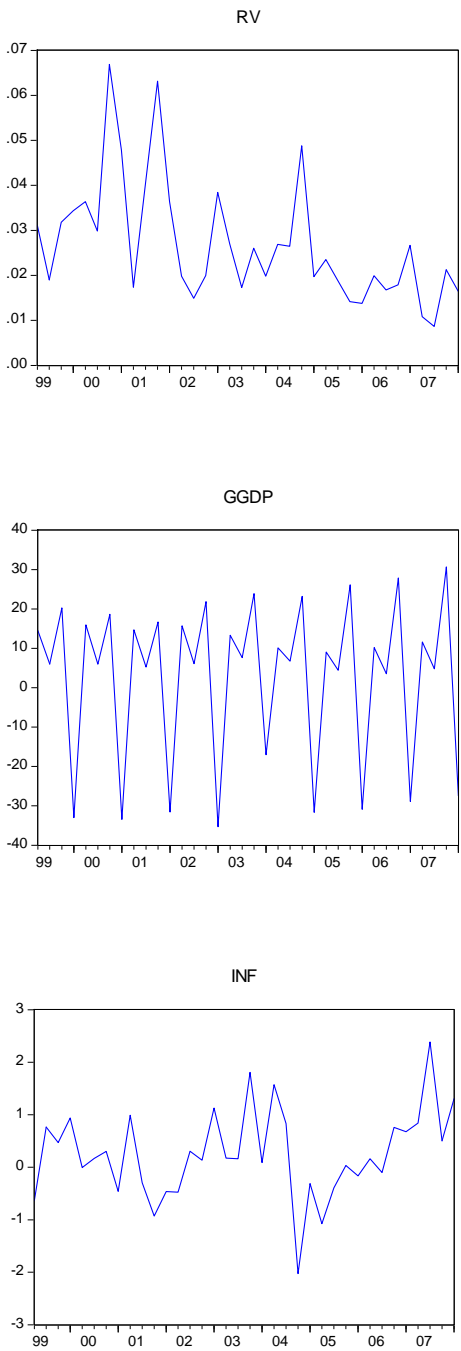
default X12 seasonal filter has been adopted in this regard. All the seasonally adjusted GDP growth series are presented in Appendix Figure 6.1. From visual scrutiny of the seasonally adjusted series along with realized volatility and inflation data, it can be inferred that with respect to most of the series for Indonesia, Malaysia and Thailand there are spikes around the period of Asian financial crisis, *i.e.* from early 1997- mid 1998. This is not unusual given the fact that these three economies were among the most severely affected ones during the crisis period. In addition to that, all the variables seem to be stationary at levels.

Summary statistics of all the variables are offered in Appendix Table 6.2. The simple correlation analysis indicates that GDP growth rate, oil price volatility and inflation are significantly correlated for most of the countries. Another significant finding is that, for most of the countries, GDP growth is negatively and inflation is positively correlated with the oil price volatility. Prior to identifying causality among the variables, an investigation of time-series properties of the data is warranted and the following section discusses these properties.

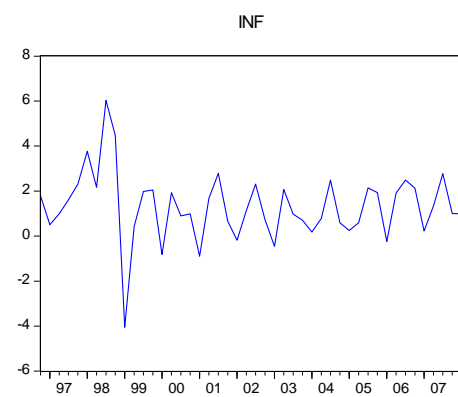
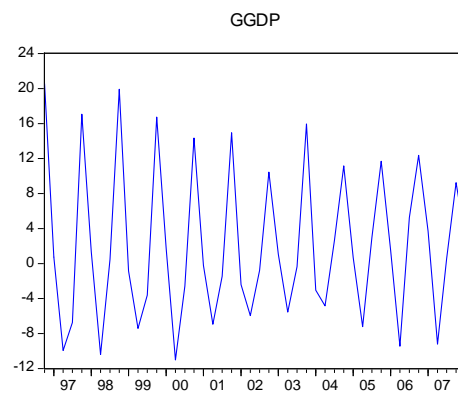
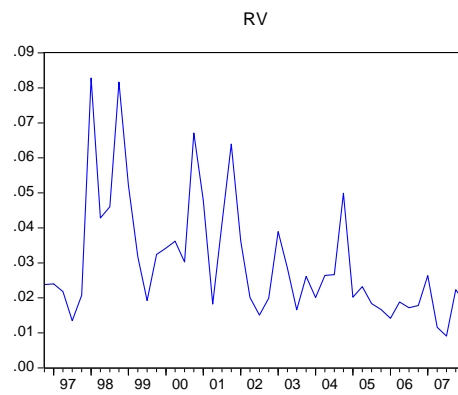


**Figure-6.1: Variables Used in This chapter**

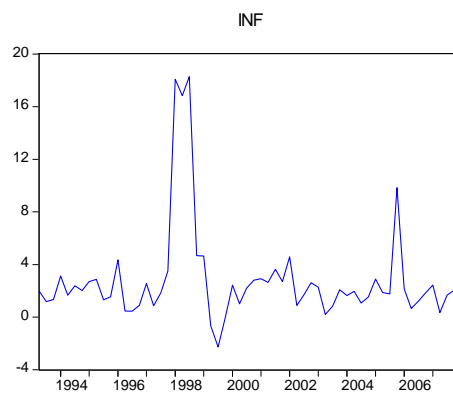
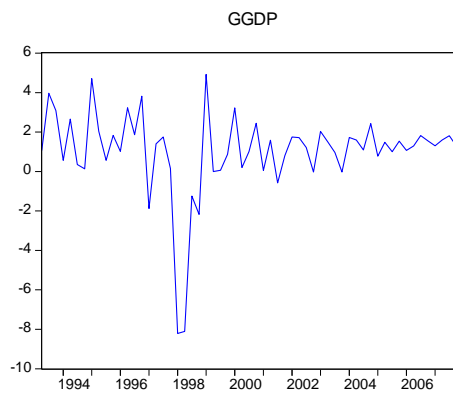
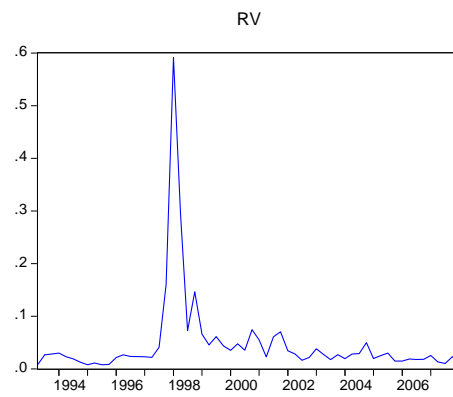
**a. China**



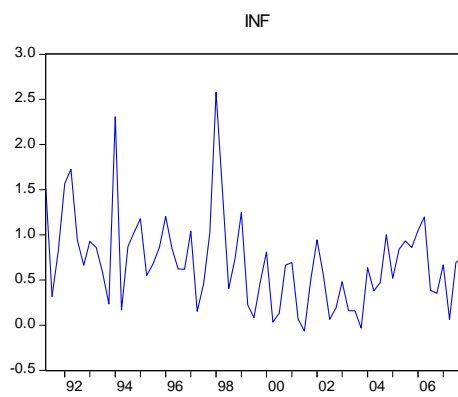
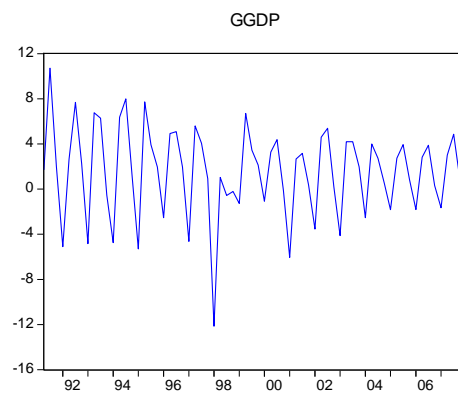
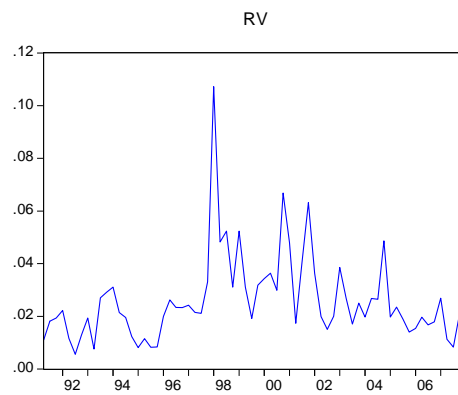
## b. India



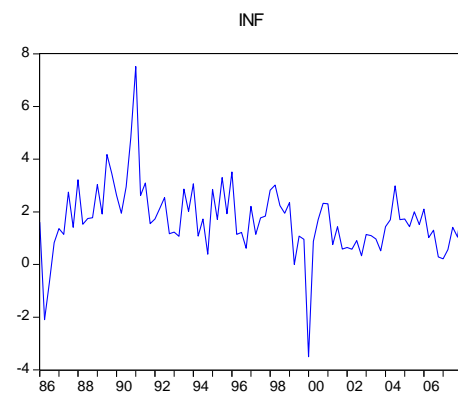
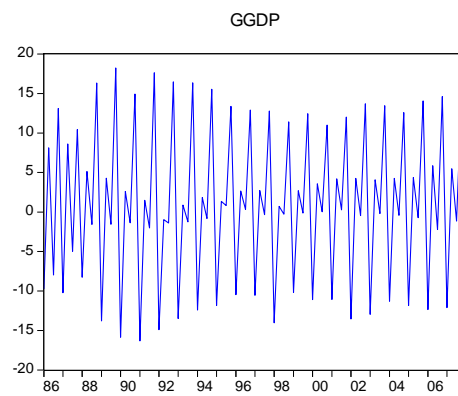
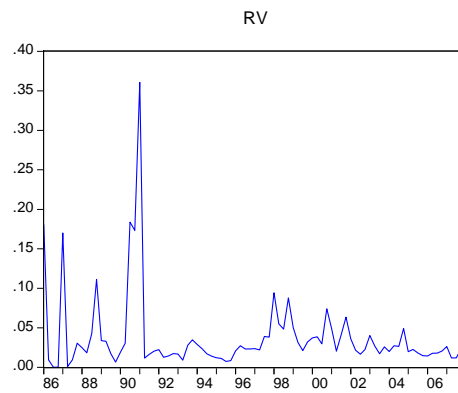
### c. Indonesia



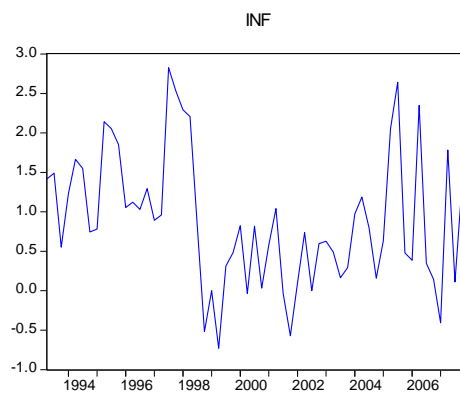
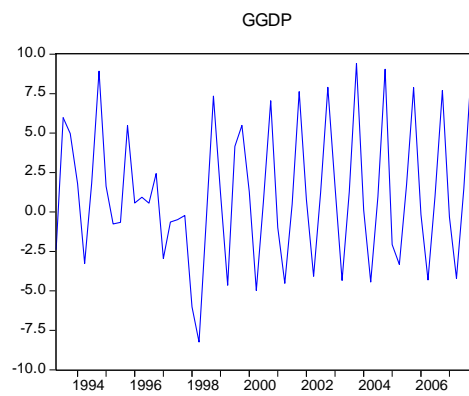
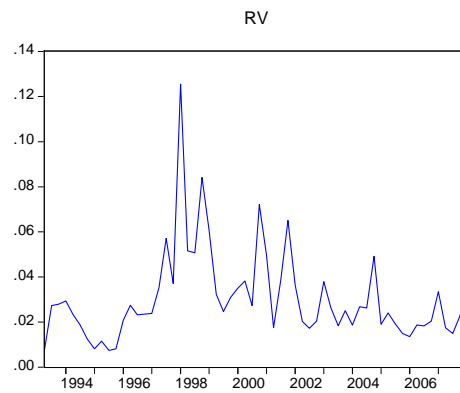
#### d. Malaysia



**e. Philippines**



## f. Thailand



Note: RV, GGDP and INF stand for realized volatility for oil prices, GDP growth and inflation, respectively.

### 6.3 Time-Series Properties of Data

This study performs three different unit root tests, namely Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) unit root tests. The results of these tests are presented in Appendix Tables 6.3, 6.4 and 6.5, respectively. According to the results of the unit root tests, it can be inferred that all three series for all the countries are stationary at their levels<sup>32</sup>. The graphical representations of the variables reveal some spikes in the concerned variables for Indonesia, Malaysia and Thailand during the Asian financial crisis. Thus, this study performs two different VAR analyses for these three countries; where one VAR analysis is performed for the whole time period, while another VAR analysis is performed for the period after the crisis, *i.e.* from the fourth quarter of 1998 after which the impact of the crisis seems to diminish. The next section presents the findings from the VAR analyses for each of the countries separately.

### 6.4 The Impact of Oil Price Volatility on Economic Activities

This section discusses the impacts of oil price volatility in each economy separately. For Indonesia, Malaysia and Thailand, seemingly the most affected countries by the financial crisis, two different VAR systems are employed to investigate and compare the impact of oil price volatility on economic activities for the whole time period and for the period after the crisis. And for China, India and Philippines, seemingly the least affected economies, one VAR analysis is performed for the whole time period.

A battery of tests is performed to identify the appropriate model for investigating the relationship among the variables under consideration. In selecting the correct form of the model, the first step is to select the appropriate lag length for individual models followed by a test for model stability. Afterwards, this study performs the VAR Granger causality/ block exogeneity Wald test to investigate the exogeneity of realized volatility for all the models with respect to different countries.

In selecting the appropriate lag length, the VAR lag order selection criteria have been consulted along with the test for lag exclusion. Since we are using quarterly data for this study, the maximum lag length provided in lag selection test is 6. The results of the lag exclusion tests are presented in Appendix Table 6.6. According to

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<sup>32</sup> This result is expected since both GDP growth and inflation have already been differenced and RV is the sum of the squares of price returns.

the majority of the criteria, the appropriate lag length suggested for China, India, Indonesia for the whole sample period, Indonesia after 1998:4, Malaysia for the whole period, Malaysia after 1998:4, Philippines, Thailand for the whole period and Thailand after 1998:4 are 3, 2, 4, 4, 2, 2, 1, 1 and 2, respectively<sup>33</sup>. Lag exclusion tests are also carried out for the suggested lags for each of these countries in respective time periods. The  $\chi^2$  (Wald) statistics for the significance of all the endogenous variables at the suggested lags for each equation separately and jointly reveal that the  $\chi^2$  test statistics for lag exclusion are significant, *i.e.* according to the test the lag lengths suggested for individual countries for different time periods are shown to be appropriate for the VAR systems under consideration<sup>34</sup>.

The test for stability of the VAR systems is checked and the results are reported in Appendix Table 6.7. The *inverse* characteristic roots of the auto-regressive (AR) polynomial indicate that the estimated VAR is stable (stationary) if all roots have a modulus less than one and lie inside the unit circle. Since no root lies outside the unit circle and all the modulus are less than one, the VAR models for different countries in this regard are stable. Thus, results from all the tests demonstrate that all the VARs with suggested lags are appropriate for investigating the relationship between volatility of oil prices and other concerned macroeconomic indicators.

#### *6.4.1 Impact analysis for China*

According to the VAR result of China in Appendix Table 6.8a, the coefficients and t-statistics for most of the lags in GDP growth equation reveal that oil price volatility seems to have negative impact in GDP growth. Granger causality tests are consulted to find out the direction of causality among the variables. The results of the Granger causality tests for China are reported in Table 6.1 (overleaf). The causality tests reveal that, in China, there exists a bi-directional causality between oil price volatility and GDP growth. In addition to that, there is also a bi-directional causality between GDP growth and inflation.

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<sup>33</sup> Results not reported due to space limitation. However, results will be provided upon request.

<sup>34</sup> The test for exogeneity for RV is also performed and the test statistics for most of the VAR systems indicate that RV can be considered as an endogenous variable in the systems. However, the results of the VAR systems are not expected to be biased even if RV is exogenous for some of the models.



**Table-6.1: Granger Causality Test for China**

Null Hypotheses	$\chi^2$	D.F.	Probability
RV does not Granger causes GGDP	8.342	3	0.065
INF does not Granger causes GGDP	6.638	3	0.084
GGDP does not Granger causes RV	8.838	3	0.052
INF does not Granger causes RV	3.894	3	0.273
GGDP does not Granger causes INF	31.697	3	0.000
RV does not Granger causes INF	0.618	3	0.892

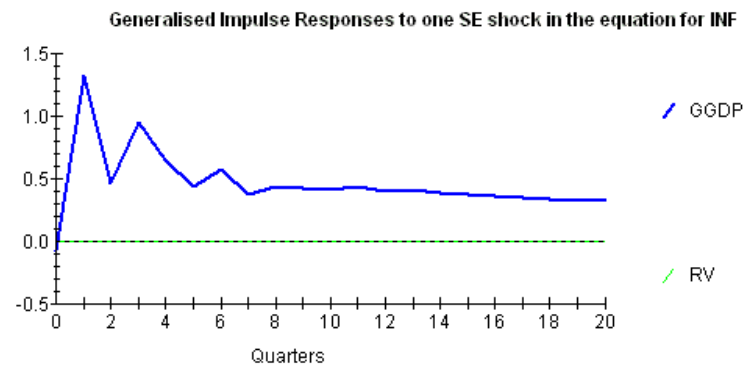
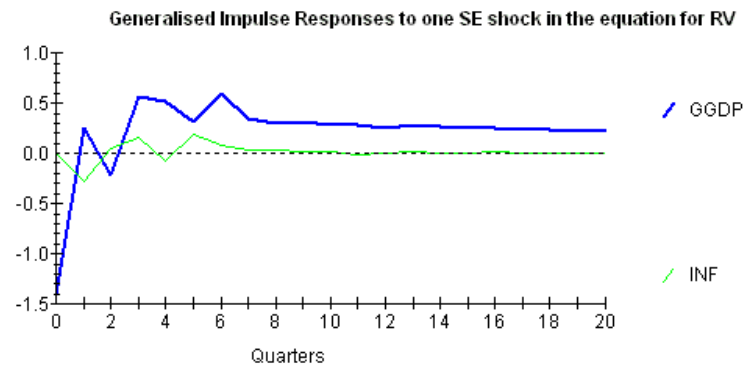
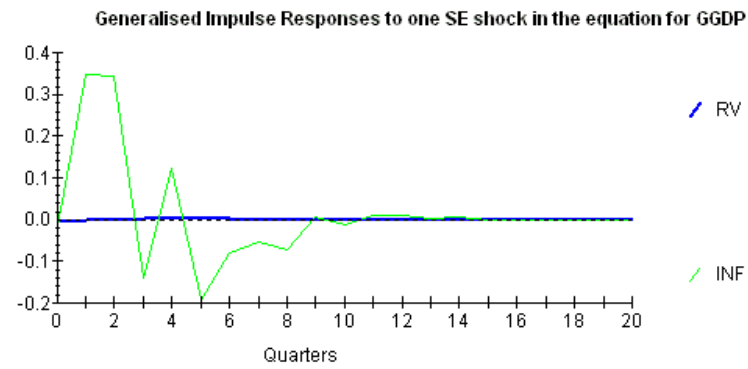
**Note:** Here RV is dependent variable.

The Granger causality test suggests which of the variables in the models have statistically significant impacts on the future values of each of the variables in the system (Brooks, 2002). However, the result will not, by construction, be able to explain the sign of the relationship or how long these impacts will remain effective in the future. As discussed in Chapter 3, impulse response functions and variance decompositions give this information.

The results of impulse response functions are presented in Figure 6.2 (overleaf). According to the figures, in response to a one S.E. shock to realized volatility of oil prices GDP growth instantly becomes negative and after one quarter time horizon the response seems to diminish. Furthermore, in response to a one S.E. shock in GDP growth inflation responds positively before it diminishes after three quarters.

In response to a one S.E. shock in inflation GDP growth rises during the first quarter and from the second quarter time horizon the response seems to die down and persist horizontally into the future. Thus, the impulse response functions of China confirm most of the findings from the causality test except for the causality from GDP growth to oil price volatility. Thus, according to the impulse response functions oil price volatility has a short-term negative impact on GDP growth in China.

**Figure-6.2: Findings from Generalized Impulse Response Function for China**



The results of variance decompositions are presented in Table 6.2. According to the results, 17.10% of the variations in GDP growth can be explained by realized volatility at the end of five quarters, while this figure goes up to 20.90% after twenty quarters. Inflation also explains a fair portion of the variations in output growth. On the other hand, 25.50% variation in realized volatility can be explained by GDP growth after five quarters as it goes down to 16.80% at the end of twenty quarters. GDP growth explains inflation with an amount of 28.90% after five quarters which increases up to 29.70% at the end of twenty quarters. Hence, the results of variance decomposition analysis also conform to the causality directions identified.

**Table-6.2: Findings from Generalized Forecast Error Variance Decomposition for China**

Quarters	Variance Decomposition of GGDP			Variance Decomposition of RV			Variance Decomposition of INF		
	GGD P	RV	INF	GGD P	RV	INF	GGD P	RV	INF
1	0.829	0.178	0.154	0.270	0.875	0.012	0.224	0.154	0.733
5	0.693	0.171	0.225	0.255	0.852	0.077	0.289	0.141	0.613
10	0.624	0.201	0.259	0.202	0.677	0.149	0.298	0.148	0.603
15	0.579	0.205	0.284	0.179	0.633	0.106	0.297	0.148	0.603
20	0.551	0.209	0.299	0.168	0.609	0.135	0.297	0.148	0.603

Note: All the figures are estimates rounded to three decimal places.

Therefore, according to the VAR analysis along with the causality test, impulse responses functions and variance decompositions, it can be inferred that in China oil price volatility impacts GDP growth in the short run and both GDP growth and inflation are strongly tied together.

#### 6.4.2 Impact analysis for India

According to the VAR output for India reported in Appendix Table 6.8b, it can be inferred that oil price volatility has significant negative impact on GDP growth and positive impact in inflation as indicated by the coefficients and t-statistics of RV in GDP growth and inflation equations within the VAR system, respectively. The results from Granger causality test are presented in Table 6.3 (overleaf). The causality test reveals that there is a bi-directional causality between realized volatility and GGDP growth. A bi-directional causality is also found between realized volatility and inflation. The causality between GDP growth and inflation is also bi-directional.

**Table-6.3: Granger Causality Test for India**

Null Hypotheses	$\chi^2$	D.F.	Probability
RV does not Granger causes GGDP	4.3341	2	0.098
INF does not Granger causes GGDP	5.107	2	0.093
GGDP does not Granger causes RV	4.095	2	0.088
INF does not Granger causes RV	2.851	2	0.091
GGDP does not Granger causes INF	6.976	2	0.031
RV does not Granger causes INF	11.091	2	0.004

**Note:** Here RV is dependent variable.

The impulse response functions are presented in Figure 6.3 (overleaf). In response to a one S.E. shock in GGDP, initially inflation responds positively and afterwards it becomes negative and the response minimal after two quarters time horizon. GDP growth's response to a one S.E. shock in RV is negative and the impact appears is minimal after three quarters time horizon. Inflation's response to one S.E shock in RV is positive and the impact dies down after two quarters. In response to a one S.E. shock in inflation GDP growth responds positively at the first place and afterward the response starts to fall and this decreasing trend persists into the future.

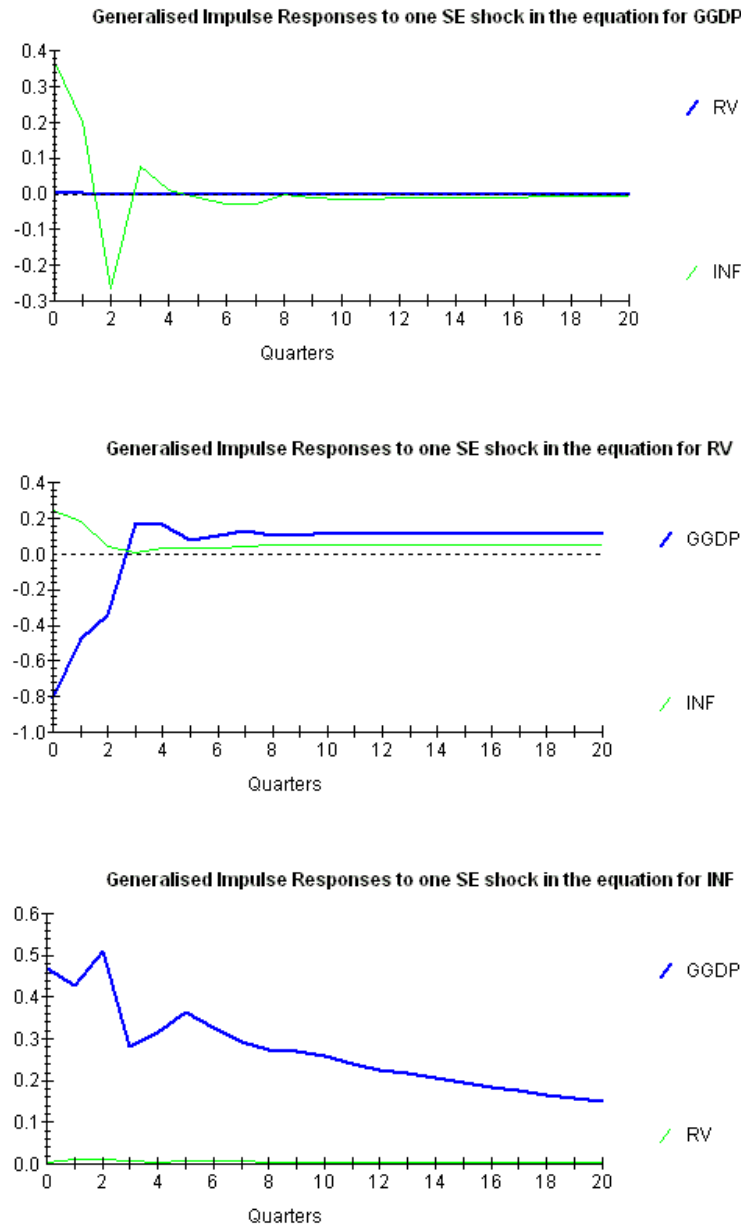
The results of variance decomposition are reported in Table 6.4. After five quarters, 18.20% and 20.50% variations in GDP growth can be explained by realized volatility in oil prices and inflation, respectively. After twenty quarters time horizon, these figures go up to 27.40% and 28.30% for oil price volatility and inflation, respectively.

**Table-6.4: Findings from Generalized Forecast Error Variance Decomposition for India**

Quarters	Variance Decomposition of GGDP			Variance Decomposition of RV			Variance Decomposition of INF		
	GGDP	RV	INF	GGDP	RV	INF	GGDP	RV	INF
1	0.913	0.054	0.109	0.046	0.971	0.139	0.169	0.079	0.825
5	0.716	0.182	0.205	0.123	0.832	0.169	0.169	0.226	0.652
10	0.617	0.235	0.251	0.117	0.810	0.191	0.161	0.274	0.618
15	0.571	0.261	0.272	0.114	0.806	0.196	0.157	0.295	0.604
20	0.546	0.274	0.283	0.113	0.804	0.199	0.155	0.306	0.597

Note: All the figures are estimates rounded to three decimal places.

**Figure-6.3: Findings from Generalized Impulse Response Function for India**



As far as variation in realized volatility is concerned, variance decompositions reveal that very little variations in oil price volatility can be explained by either GDP growth or inflation, whereas GDP growth and realized volatility explain a fair

portion of variations in inflation. After five quarters GDP growth and realized volatility explain 16.90% and 22.60% of variations in inflation, respectively. After twenty quarters 15.50% and 30.60% of variations in inflation is explained by GDP growth and realized volatility, respectively.

Hence, according to the VAR analysis for India, it can be inferred that oil price volatility impacts both GDP growth and inflation in the Indian economy. Furthermore, both GDP growth and inflation are closely related.

#### 6.4.3 Impact analysis for Indonesia

This study analyses the Indonesian economy on the basis of two different VAR systems for two different time periods. The first one is for the whole data set *i.e.* from 1993:2 to 2008:1; the second VAR is for the period after the crisis *i.e.* from 1998:4 to 2008:1. These two VARs are implemented to capture any significant change in the impact analysis due to the Asian financial crisis.

Findings from the VAR estimation for the whole time period are presented in Appendix Table 6.8c. The coefficients and t-statistics for RV in GGDP growth and inflation equations indicate a negative link between oil price volatility and GGDP growth and a positive relationship between inflation and oil price volatility. The results of Granger causality test are reported in Table 6.5.

**Table-6.5: Granger Causality Test for Indonesia from 1993:2 to 2008:1**

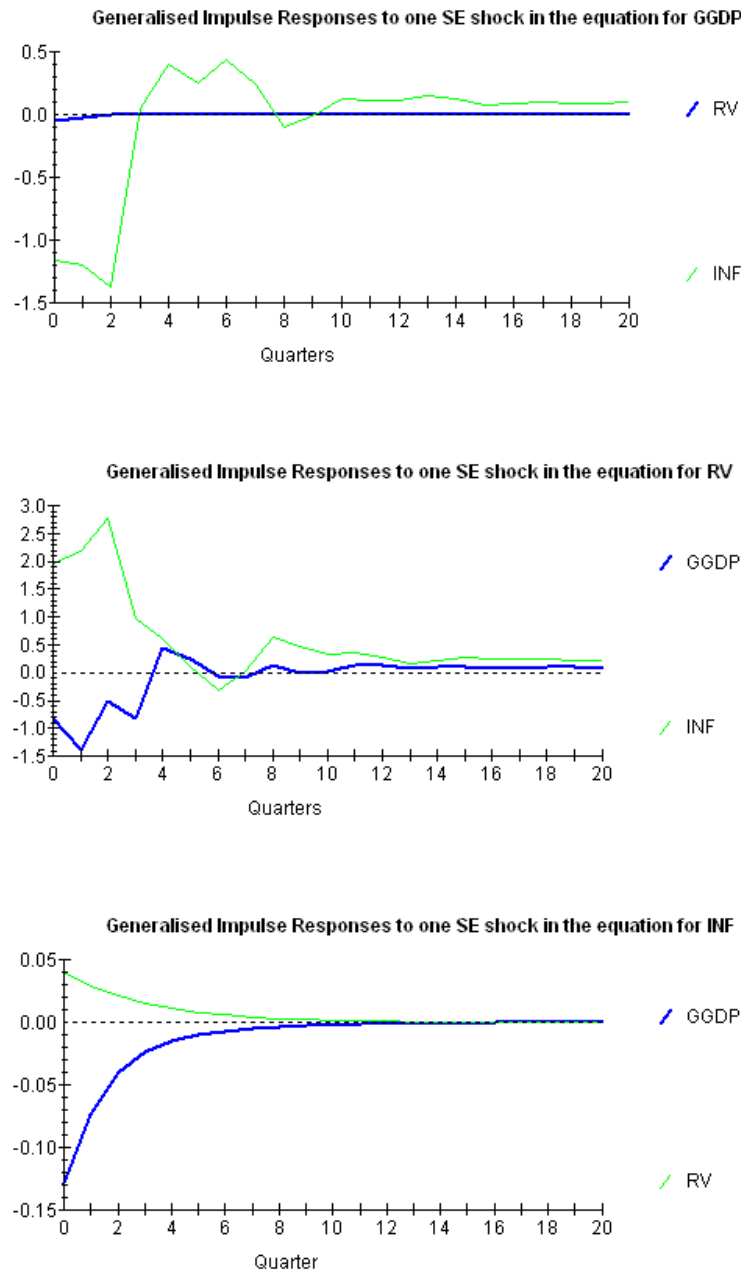
Null Hypotheses	$\chi^2$	D.F.	Probability
RV does not Granger causes GGDP	33.306	4	0.000
INF does not Granger causes GGDP	6.736	4	0.097
GGDP does not Granger causes RV	5.076	4	0.279
INF does not Granger causes RV	7.383	4	0.066
GGDP does not Granger causes INF	9.141	4	0.015
RV does not Granger causes INF	13.105	4	0.011

**Note:** Here RV is dependent variable.

According to the results, oil price volatility Granger causes both GDP growth and inflation, while only inflation causes volatility in oil prices. Moreover, there is a bi-directional causality between GDP growth and inflation.

The impulse response functions are presented in Figure 6.4.

**Figure-6.4: Findings from Generalized Impulse Response Function for Indonesia from 1993:2 to 2008:1**



In response to one S.E. shock in GDP growth, inflation seems to response negatively in the initial periods. However, the negative impact on inflation seems to work its way out of the system after three quarters time horizon. Inflation responds positively

to a one S.E. shock in oil price volatility for the first five quarters, but beyond that, the shock appears to die down. In response to a one S.E. shock in RV, GDP growth seems to respond negatively for initial four quarters and after that the impact seems to minimize. Oil price volatility responds positively to a one S.E. shock in inflation. However, the response appears to cease after seven quarters. In response to a one S.E. shock in inflation, GDP growth responds positively until seven quarters after which the impact seems to die down.

The results from variance decomposition analysis are reported in Table 6.6. The results from the variance decompositions conform to the findings of the causality test. After five quarters horizon realized volatility explains 67.90% of the variations in GDP growth, while inflation explains 35.00%. In twenty quarters time, realized volatility explains 65.30% and inflation explains 34.50% of variations in GDP growth, respectively. Inflation explains 22.70% of variations in realized volatility after five quarters and after twenty quarters inflation explains 21.10% variations in realized volatility. Furthermore, realized volatility explains a substantial portion of variations in inflation. After five quarters time horizon 80.40% of variations in inflation is explained by realized volatility. After twenty quarters this figure goes down to 76.60%. After five quarters GDP growth explains 22.30% of variations in inflations, while after twenty quarters 21.10% of variations in inflations is explained by GDP growth.

**Table-6.6: Findings from Generalized Forecast Error Variance Decomposition  
for Indonesia from 1993:2 to 2008:1**

Qua rters	Variance Decomposition of GGDP			Variance Decomposition of RV			Variance Decomposition of INF		
	GGDP	RV	INF	GGDP	RV	INF	GGDP	RV	INF
1	0.641	0.618	0.319	0.149	0.987	0.254	0.244	0.761	0.847
5	0.529	0.679	0.350	0.124	0.956	0.227	0.223	0.804	0.686
10	0.532	0.664	0.344	0.123	0.943	0.216	0.221	0.791	0.671
15	0.519	0.658	0.345	0.119	0.934	0.213	0.215	0.776	0.658
20	0.511	0.653	0.345	0.117	0.926	0.211	0.211	0.766	0.649

Note: All the figures are estimates rounded to three decimal places.

In summary, for the whole data period from 1993:2 to 2008:1, different tests within the VAR(4) framework for Indonesia reveal that oil price volatility impacts both GDP growth and inflation, and like China and India GDP growth and inflation are closely related. Furthermore, the fact that inflation causes realized volatility, keeps oil price volatility endogeneous to the VAR model. Now, this study presents the



VAR outcome for the period after the Asian financial crisis for Indonesia to see whether there is any dissimilarity in the dynamics of the impact channels.

From the coefficients and t-statistics of realized volatility in GDP growth and inflation equations of the VAR (4) estimation for the period after the crisis in Appendix Table 6.8d, it can be inferred that oil price volatility exerts negative impact on GDP growth and positive impact on inflation even after the financial crisis is over. The results of the Granger causality test are reported in Table 6.7. The Granger causality test further indicates that after the crisis oil price volatility causes both GDP growth rate and inflation of Indonesia. In addition to that, the bi-directional causality between GDP growth and inflation also holds true for the time period after the crisis. However, a significant dissimilarity between two models is that after the crisis oil price volatility seems to become exogenous in the model since none of the variable seems to cause realized volatility after the Asian financial crisis.

**Table-6.7: Granger Causality Test for Indonesia from 1998:4 to 2008:1**

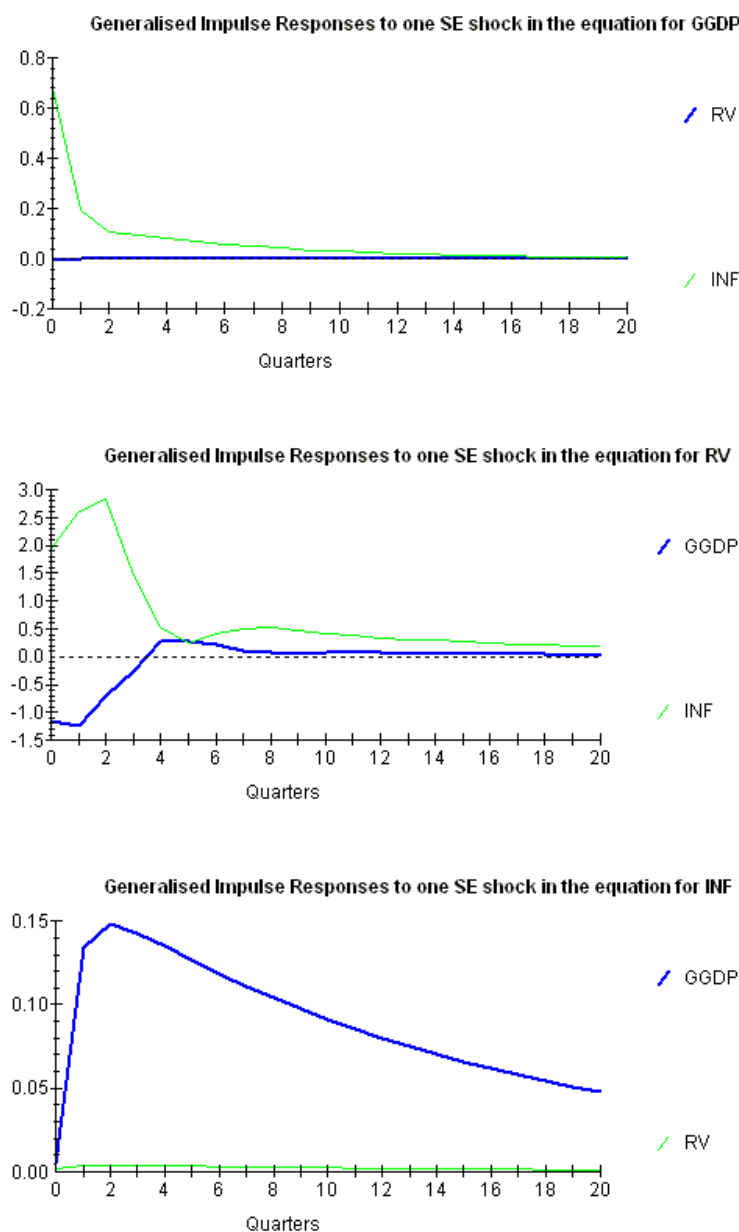
Null Hypotheses	$\chi^2$	D.F.	Probability
RV does not Granger causes GGDP	54.799	4	0.000
INF does not Granger causes GGDP	4.265	4	0.087
GGDP does not Granger causes RV	1.237	4	0.872
INF does not Granger causes RV	1.031	4	0.905
GGDP does not Granger causes INF	7.237	4	0.047
RV does not Granger causes INF	3.031	4	0.091

**Note:** Here RV is dependent variable.

This study further performs impulse response functions and variance decompositions analysis to check the robustness of the causality test. Results from impulse response functions are presented in Figure 6.5 (overleaf). In response to a one S.E. shock in GDP growth rate, inflation responds positively and this impact is minimal after eleven quarters time horizon. GDP growth responds negatively to one S.E. shock in oil price volatility in the initial period. After four quarters time horizon this negative impact in GDP growth seems to cease from the system. According to the innovations in inflation in response to a one S.E. shock in RV, inflation appears to respond positively and after five period time horizons the impact appears to make its way out

of the system. In response to a one S.E shock in inflation GDP growth seems to respond positively until twenty quarters time horizon and persists into the future.

**Figure 6.5: Findings from Generalized Impulse Response Function for Indonesia from 1998:4 to 2008:1**



The results from variance decomposition analysis are presented in Table 6.8 are consistent with the causality test and impulse response functions. Oil price volatility and inflation explains 12.40% and 17.70% variations in GDP growth after five

quarters, while after twenty quarters time horizon 18.20% and 18.10% of variations in GDP growth is explained by realized volatility and inflation, respectively. Realized volatility seems to be able to explain most of its own shocks, whereas both GDP growth and realized volatility explain a fair portion of variation in inflation. After five quarters GDP growth and RV explain 22.70% and 19.20% variation in inflation, respectively, and these figures increase up to 29.60% and 25.50% after twenty quarters.

**Table-6.8: Findings from Generalized Forecast Error Variance Decomposition for Indonesia from 1998:4 to 2008:1**

Quarters	Variance Decomposition of GGDP			Variance Decomposition of RV			Variance Decomposition of INF		
	GGDP	RV	INF	GGDP	RV	INF	GGDP	RV	INF
1	0.879	0.114	0.055	0.053	0.939	0.020	0.154	0.149	0.846
5	0.784	0.124	0.177	0.095	0.893	0.029	0.227	0.192	0.735
10	0.754	0.154	0.180	0.172	0.802	0.064	0.264	0.225	0.671
15	0.737	0.172	0.181	0.106	0.862	0.082	0.285	0.244	0.634
20	0.728	0.182	0.181	0.122	0.841	0.091	0.296	0.255	0.613

Note: All the figures are estimates rounded to three decimal places.

Based on two different VAR analyses for Indonesia, it can be inferred that for the Indonesian economy that oil price volatility impacts on both GDP growth and inflation for both of the time periods, for the whole sample period and for the period after the Asian financial crisis. Furthermore, the link between GDP growth and inflation is bi-directional for both of the VAR systems.

#### 6.4.4 Impact analysis for Malaysia

The data plots for Malaysia portrays a spike during early 1997 to mid 1998 and the Malaysian economy was one of the most adversely affected economies during the Asian financial crisis. Thus, Malaysian data are also investigated on the basis of two different VAR systems, one for the whole period from 1991:2 to 2008:1 and the other is for the period after the crisis *i.e.* from 1998:4 to 2008:1.

The VAR (2) results for the whole periods are reported on Appendix Table 6.8e. The coefficients of RV in GDP growth equation indicate that realized volatility impacts output growth negatively in Malaysia. The Granger causality test results are presented in Table 6.9. According to the causality results there are a bi-directional causality between oil price volatility and GDP growth, a uni-directional causality

running from inflation to realized volatility and a bi-directional causality between GDP growth and inflation in Malaysia for the whole period from 1991:2 to 2008:1.

**Table-6.9: Granger Causality Test for Malaysia from 1991:2 to 2008:1**

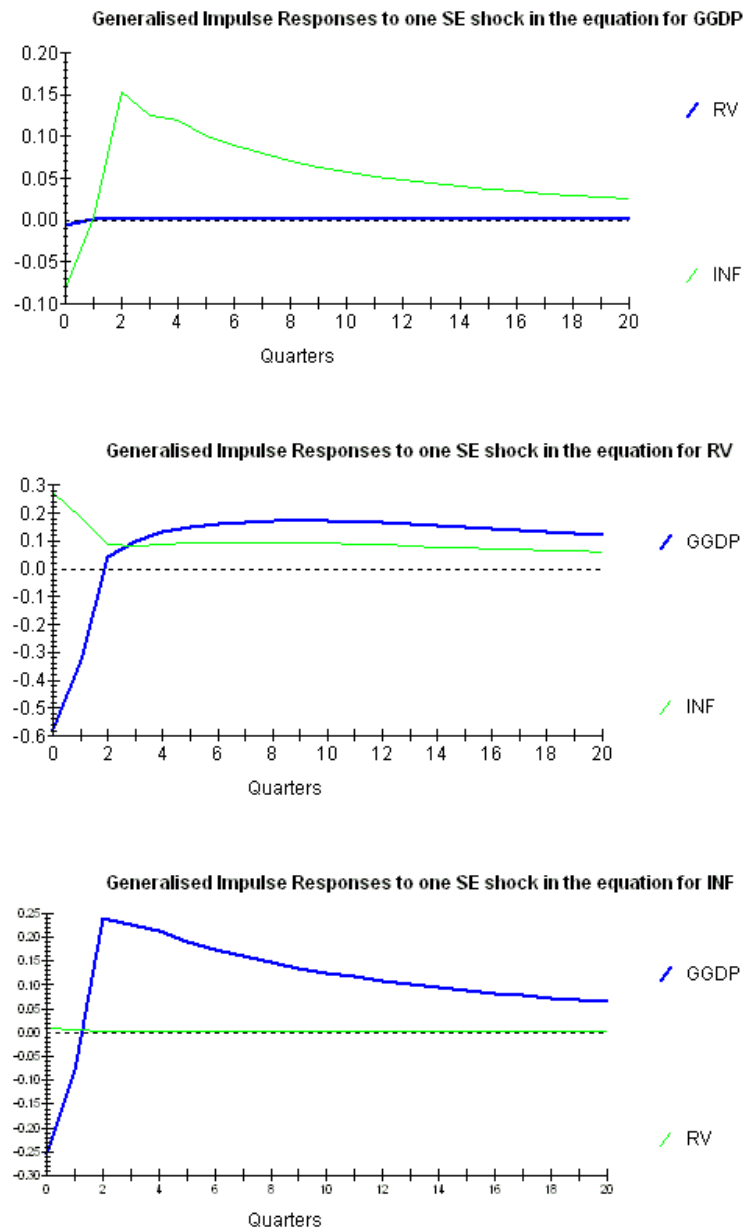
Null Hypotheses	$\chi^2$	D.F.	Probability
RV does not Granger causes GGDP	4.957	2	0.084
INF does not Granger causes GGDP	4.077	2	0.096
GGDP does not Granger causes RV	4.625	2	0.099
INF does not Granger causes RV	7.765	2	0.021
GGDP does not Granger causes INF	7.721	2	0.006
RV does not Granger causes INF	3.013	2	0.222

**Note:** Here RV is dependent variable.

Impulse response function findings are presented in Figure 6.6 (overleaf). In response to a one S.E. shock in GDP growth rate, inflation initially responds negatively. However, after one quarter the response from inflation becomes positive and it dies down afterwards. In response to a one S.E. shock in oil price volatility the response from GDP is negative and the negative impact appears to make its way out of the system after a two quarters horizon. Response from GDP growth to inflation is also negative, but the negative impact seems to cease after two quarters and become positive.

The results of variance decompositions are reported in Table 6.9. After five quarters realized volatility explains 22.20% and inflation explains 16.50% variations in GDP growth, while after twenty quarters realized volatility and inflation explain 27.30% and 19.30% of variations in GDP growth, respectively. GDP growth and inflation explain 16.90% and 18.90% of variations in RV after five quarters, respectively, while at the end of twenty quarters these figures reach up to 17.20% and 17.10% for GDP growth and inflation, respectively. GDP growth explains 27.50% of variations in inflation after five quarters and the explanatory power of GDP growth rises up to 33.20% after twenty quarters time horizon.

**Figure 6.6: Findings from Generalized Impulse Response Function for Malaysia  
from 1991:2 to 2008:1**



**Table-6.10: Findings from Generalized Forecast Error Variance Decomposition for Malaysia from 1991:2 to 2008:1**

Quarters	Variance Decomposition of GGDP			Variance Decomposition of RV			Variance Decomposition of INF		
	GGDP	RV	INF	GGDP	RV	INF	GGDP	RV	INF
1	0.896	0.135	0.122	0.094	0.945	0.247	0.320	0.019	0.966
5	0.810	0.222	0.165	0.169	0.845	0.189	0.275	0.142	0.747
10	0.749	0.242	0.184	0.169	0.802	0.176	0.297	0.161	0.652
15	0.712	0.261	0.190	0.171	0.783	0.172	0.319	0.160	0.608
20	0.690	0.273	0.193	0.172	0.773	0.171	0.332	0.158	0.584

Note: All the figures are estimates rounded to three decimal places.

Thus, according to the VAR results for the whole period it can be inferred that, oil price volatility impacts GDP growth in Malaysia, GDP growth and inflation impact each other, and both GDP growth and inflation have small impact realized volatility.

The analysis for the Malaysian economy after the financial crisis starts with the VAR (2) estimation in Appendix Table 6.8f. The coefficients of realized volatility in GDP growth equation indicate that oil price volatility has negative impact on the Malaysian output growth. Findings of causality tests are reported in Table 6.10. The causality test results for the period after the crisis are almost similar to that of the causality test results for the whole period. There exist a bi-directional causality between GDP growth and realized volatility, a bi-directional causality between inflation and GDP growth, and a uni-directional causality running from inflation to oil price volatility.

**Table-6.11: Granger Causality Test for Malaysia from 1998:4 to 2008:1**

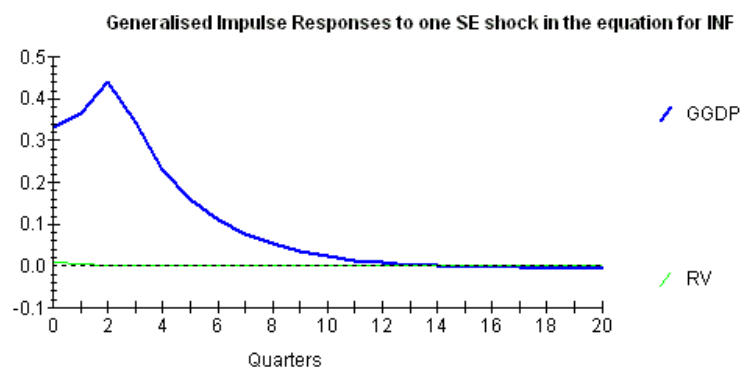
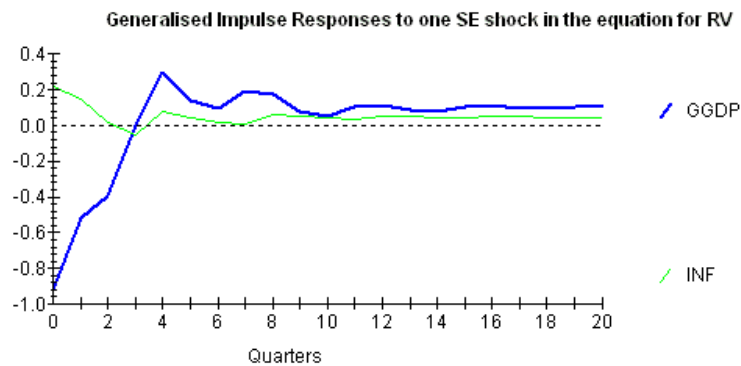
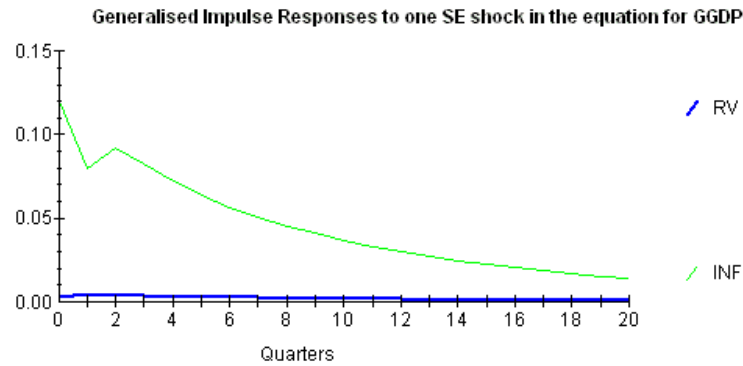
Null Hypotheses	$\chi^2$	D.F.	Probability
RV does not Granger causes GGDP	4.490	2	0.088
INF does not Granger causes GGDP	7.806	2	0.066
GGDP does not Granger causes RV	5.957	2	0.071
INF does not Granger causes RV	4.343	2	0.091
GGDP does not Granger causes INF	13.586	2	0.016
RV does not Granger causes INF	3.099	2	0.212

Note: Here RV is dependent variable.

The results from impulse response functions are presented in Figure 6.7 (overleaf). In response to a one S.E. shock in GDP growth, inflation responds positively and this positive impact persists until twenty quarters time horizon. GDP growth responds negatively in response to a one S.E. shock in oil price volatility and the negative impact appears to die away after four quarters time horizon. In response to

a one S.E. shock in inflation GDP growth responds positively and the impact appears to make its way out after twelve quarters time horizon.

**Figure-6.7: Findings from Generalized Impulse Response Function for Malaysia from 1998:4 to 2008:1**



The results of variance decomposition are reported in Table 6.11. After five quarters oil price volatility and inflation explain 20.50% and 15.30% of variations in GDP growth, respectively. Oil price volatility and inflation explain 31.50% and 19.40% of variations in GDP growth after twenty quarters, respectively. However, the explanatory powers of GDP growth and inflation in RV seem to be small and are diminishing over time. 23.70% of variations in inflation is explained by GDP growth at the end of five quarters, while after twenty quarters GDP growth explains 24.20% of variations in inflation.

**Table 6.12: Findings from Generalized Forecast Error Variance Decomposition for Malaysia from 1998:4 to 2008:1**

Quarters	Variance Decomposition of GGDP			Variance Decomposition of RV			Variance Decomposition of INF		
	GGDP	RV	INF	GGDP	RV	INF	GGDP	RV	INF
1	0.870	0.140	0.045	0.096	0.954	0.235	0.189	0.137	0.883
5	0.818	0.205	0.153	0.134	0.859	0.137	0.237	0.271	0.847
10	0.724	0.287	0.217	0.134	0.814	0.105	0.243	0.319	0.826
15	0.687	0.308	0.201	0.133	0.797	0.095	0.243	0.330	0.776
20	0.672	0.315	0.194	0.132	0.790	0.092	0.242	0.333	0.757

Note: All the figures are estimates rounded to three decimal places.

Thus, there is not much change in the two VAR analyses performed for the Malaysian economy. In both of the VAR systems, oil price volatility impacts GDP growth, while there is a very little feedback from the opposite side. Furthermore, like all the other economies analysed so far, GDP growth and inflation seem to be strongly tied together in the Malaysian economy.

#### 6.4.5 Impact analysis for Philippines

Results from VAR (1) estimation for Philippines are reported in Appendix Table 6.8g. According to the coefficient and t-statistic for realized volatility in inflation equation, it can be inferred that in Philippines oil price volatility positively affects inflation. Results from the Granger causality test are given in Table 6.12 (overleaf). The Granger causality test indicates a bi-directional causality between oil price volatility and inflation, and also a bi-directional causality between GDP growth and inflation. For the purpose of checking the robustness of the Granger causality test impulse responses and variance decompositions are implemented.



**Table-6.13: Granger Causality Test for Philippines**

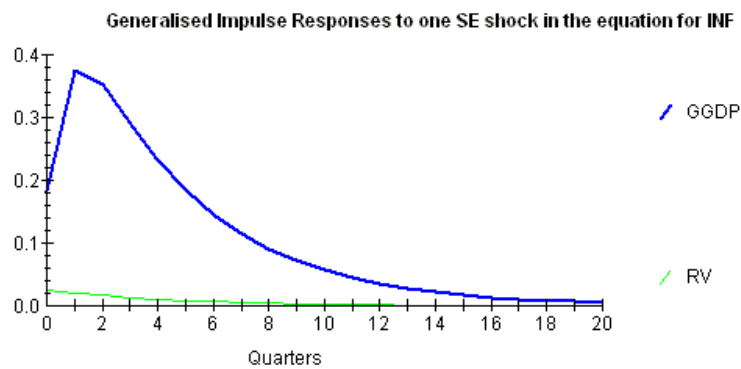
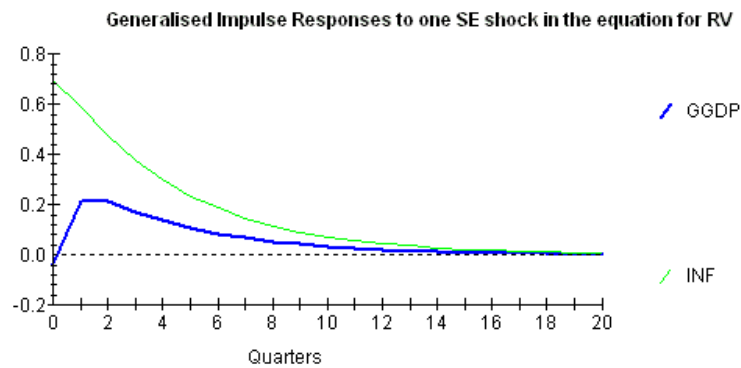
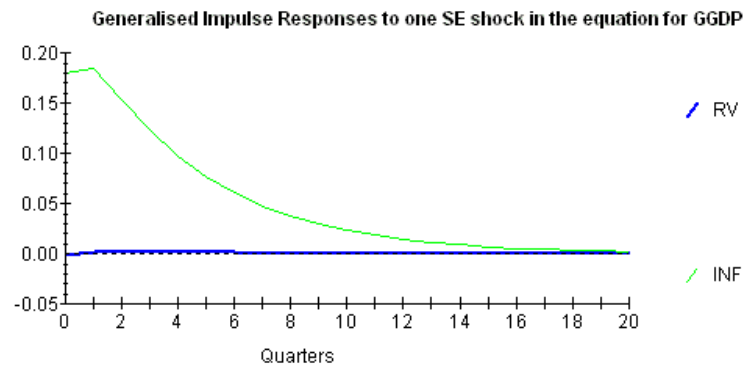
Null Hypotheses	$\chi^2$	D.F.	Probability
RV does not Granger causes GGDP	0.042	1	0.837
INF does not Granger causes GGDP	7.681	1	0.019
GGDP does not Granger causes RV	0.661	1	0.416
INF does not Granger causes RV	3.652	1	0.091
GGDP does not Granger causes INF	6.107	1	0.014
RV does not Granger causes INF	4.013	1	0.072

**Note:** Here RV is dependent variable.

Impulse response functions are presented in Figure 6.8 (overleaf). Inflation responds positively to one S.E. shocks in both GDP growth and oil price volatility. The positive impacts on GDP growth in response to the shocks in inflation and RV appear to die down after sixteen and thirteen quarter time horizons, respectively. GDP growth's response to a one S.E. shock in inflation is positive and it dies down after eighteen quarters time horizon.

The results of the variance decomposition tests are reported in Table 6.13. After five quarters inflation explains 18.90% of variations in GDP growth, while at the end of twenty quarters inflation explains 20.80%. Inflation also explains a fair portion of variations in oil price volatility. At the end of twenty quarters 49.70% of variations in realized volatility can be explained by inflation. Both GDP growth and oil price volatility explain the variations in inflation. After five quarters GDP growth explains 29.60% and RV explains 22.70% of variation in inflation. At the end of twenty quarters, GDP growth and oil price volatility explain 29.80% and 22.70% of variations in inflation, respectively. Thus, in Philippines oil price volatility impacts inflation; and GDP growth and inflation are closely related in the short run.

**Figure-6.8: Findings from Generalized Impulse Response Function for Philippines**



**Table 6.14: Findings from Generalized Forecast Error Variance Decomposition  
for Philippines**

Quarters	Variance Decomposition of GGDP			Variance Decomposition of RV			Variance Decomposition of INF		
	GGDP	RV	INF	GGDP	RV	INF	GGDP	RV	INF
1	0.949	0.022	0.080	0.001	0.944	0.366	0.279	0.122	0.898
5	0.841	0.061	0.189	0.006	0.841	0.481	0.296	0.227	0.795
10	0.824	0.067	0.206	0.007	0.826	0.496	0.298	0.227	0.795
15	0.823	0.067	0.208	0.007	0.825	0.497	0.298	0.227	0.795
20	0.823	0.068	0.208	0.007	0.825	0.497	0.298	0.227	0.795

Note: All the figures are estimates rounded to three decimal places.

#### 4.5.6 Impact analysis for Thailand

Since the Thai economy has also been severely affected by the Asian financial crisis and as the data suggests a spike during the crisis period, like Indonesia and Malaysia, this study implements two different VARs for Thailand in a similar fashion. VAR (1) output for the whole period of Thailand is shown in Appendix Table 6.8h and according to the coefficient and t-statistic for RV in GDP growth equation it can be inferred that in the Thai economy GDP growth is significantly impacted negatively by oil price volatility.

**Table-6.15: Granger Causality Test for Thailand from 1993:2 to 2008:1**

Null Hypotheses	$\chi^2$	D.F.	Probability
RV does not Granger causes GGDP	17.945	1	0.000
INF does not Granger causes GGDP	11.701	1	0.001
GGDP does not Granger causes RV	0.009	1	0.924
INF does not Granger causes RV	6.694	1	0.009
GGDP does not Granger causes INF	0.318	1	0.573
RV does not Granger causes INF	0.152	1	0.696

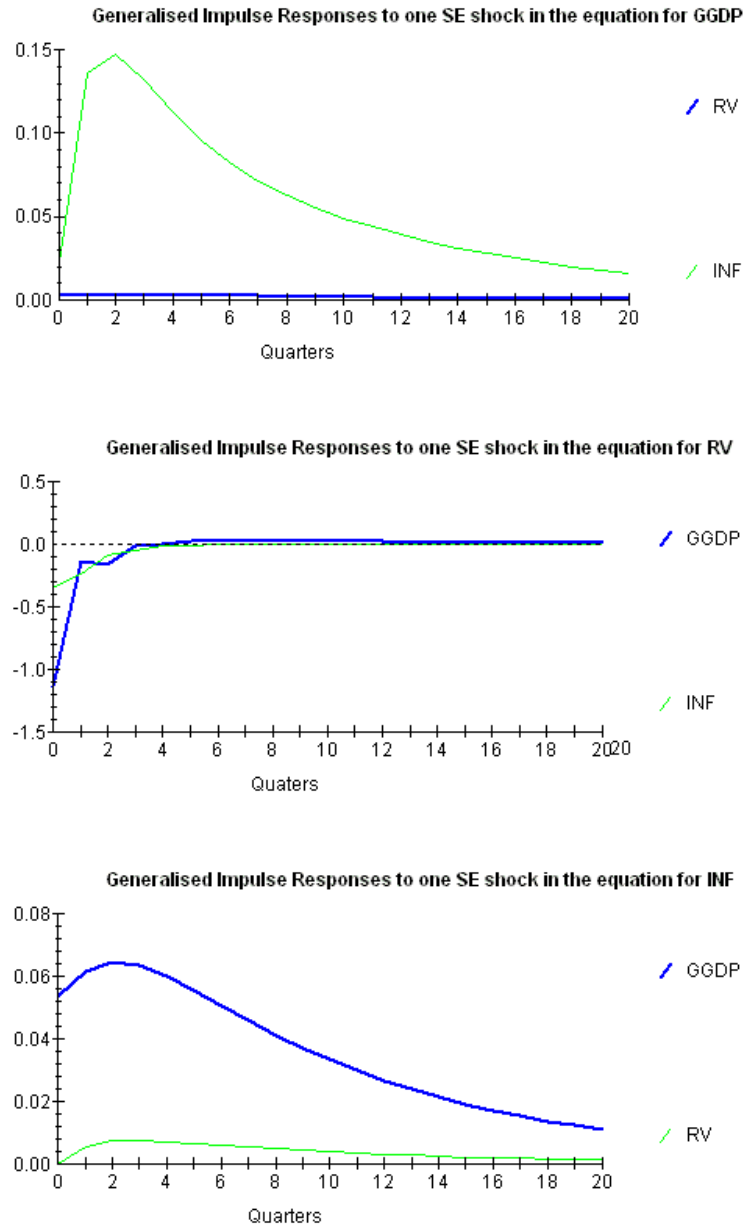
Note: Here RV is dependent variable.

The causality test findings for the whole data set are reported in Table 6.14. The causality test results indicate that in Thailand, oil price volatility Granger causes GDP growth and inflation Granger cause both oil price volatility and GDP growth.

The impulse response functions for the whole time period for Thailand are presented in Figure 6.9 (overleaf). The response of inflation to a one S.E. shock to GDP growth is positive and appears to die out sharply after twenty quarters time horizon. GDP growth's response to a one S.E. shock in oil price volatility is negative initially and after three quarters time horizon the negative impact eases away. GDP growth's

response to a one S.E. shock in inflation is positive and dies out over the twenty quarters time horizon.

**Figure-6.9: Findings from Generalized Impulse Response Function for Thailand from 1993:2 to 2008:1**



**Table 6.16: Findings from Generalized Forecast Error Variance  
Decomposition for Thailand from 1993:2 to 2008:1**

Quarters	Variance Decomposition of GGDP			Variance Decomposition of RV			Variance Decomposition of INF		
	GGDP	RV	INF	GGDP	RV	INF	GGDP	RV	INF
1	0.969	0.045	0.051	0.037	0.947	0.053	0.021	0.030	0.961
5	0.894	0.152	0.104	0.046	0.786	0.213	0.058	0.044	0.834
10	0.891	0.154	0.106	0.055	0.735	0.261	0.065	0.088	0.789
15	0.889	0.154	0.106	0.057	0.721	0.273	0.066	0.101	0.776
20	0.889	0.155	0.107	0.058	0.717	0.276	0.067	0.105	0.772

Note: All the figures are estimates rounded to three decimal places.

The results from variance decomposition analysis are reported in Table 6.15. The variance decomposition analysis reveals that in the fifth quarter RV and inflation explain 15.20% and 10.40% of variations in GDP growth, respectively. At the end of twenty quarters RV explains 15.50% and inflation explains 10.70% of variations in the GDP growth rate, respectively. 21.30% of variation in RV is explained by inflation after five quarters, while after twenty quarters inflation explains 27.60% variations in volatility. Thus, for the whole period, in the Thai economy, all the tests within the VAR framework suggest that oil price volatility impacts GDP growth. Now, this study performs a separate VAR analysis for the period after the Asian financial crisis.

The VAR (2) estimation results for the period from 1998:4 to 2008:1 are presented in Appendix Table 6.8i. From the coefficients and t-statistics of RV in the GDP growth equation it seems that the impact of RV in GDP growth becomes insignificant after the financial crisis. The Granger causality test within this time frame is reported in Table 6.16 (overleaf). Most of the causal relationship found for the whole period are absent in these causality test results for the period after the financial crisis, except the causality tests find that there is a bi-directional causality running from inflation to output growth. Furthermore, realized volatility seems to be exogenous to this system.

**Table-6.17: Granger Causality Test for Thailand from 1998:4 to 2008:1**

Null Hypotheses	$\chi^2$	D.F.	Probability
RV does not Granger causes GGDP	3.774	2	0.152
INF does not Granger causes GGDP	5.609	2	0.074
GGDP does not Granger causes RV	1.568	2	0.114
INF does not Granger causes RV	0.446	2	0.800
GGDP does not Granger causes INF	17.655	2	0.000
RV does not Granger causes INF	4.159	2	0.125

**Note:** Here RV is dependent variable.

The impulse response functions for this period after the financial crisis are presented in Figure 6.10. As the figure implies, inflation's response to a one S.E. shock in GDP growth is positive and there seems to be a decreasing trend in this impact in the future. GDP growth's response to the shock in inflation is also positive and it is declining as the window of horizon moves to the longer horizon. However, the GDP growth response to a one S.E. shock in RV is very minimal for the time period after 1998.

The results from the variance decomposition analysis are reported in Table 6.17. After five quarters inflation explains 30.10% of variations in GDP growth, while at the end of twenty quarters 36.90% of variations in GDP growth can be explained by inflation. 20.30% of the variations in inflation can be explained by GDP growth after five quarters and the figure increases to 23.70% at the end of twenty quarters.

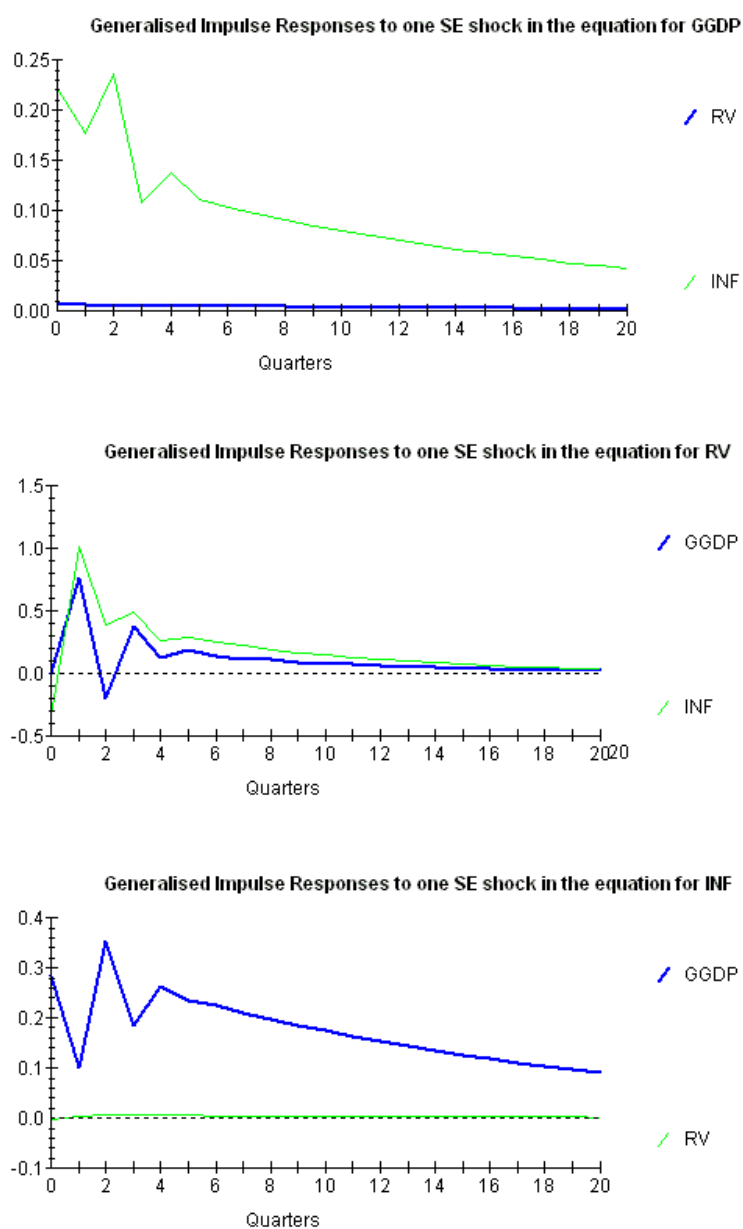
**Table-6.18: Findings from Generalized Forecast Error Variance  
Decomposition for Thailand from 1998:4 to 2008:1**

Quarters	Variance Decomposition of GGDP			Variance Decomposition of RV			Variance Decomposition of INF		
	GGDP	RV	INF	GGDP	RV	INF	GGDP	RV	INF
1	0.986	0.058	0.182	0.037	0.985	0.032	0.109	0.016	0.979
5	0.867	0.069	0.301	0.118	0.945	0.114	0.203	0.060	0.885
10	0.891	0.077	0.345	0.129	0.933	0.163	0.224	0.105	0.835
15	0.863	0.078	0.361	0.103	0.944	0.180	0.233	0.124	0.813
20	0.850	0.075	0.369	0.108	0.934	0.188	0.237	0.134	0.802

**Note:** All the figures are estimates rounded to three decimal places.

From the VAR analyses for Thailand it can be inferred that oil price volatility impacts output growth for the whole period, however after the Asian financial crisis the impact seems to disappear. This finding is consistent with Rafiq, Salim & Bloch (2009) where the authors find that impact of oil price volatility no longer exists in the Thai economy after the financial crisis.

**Figure-6.10: Findings from Generalized Impulse Response Function for Thailand from 1998:4 to 2008:1**



## 6.5 Summary

This chapter investigates the short-term impact of oil price volatility in the concerned economies. One of the unique features of this chapter is that, here the oil price volatility for each country is calculated using a non-parametric approach namely realized oil price variance. Furthermore, to the author's knowledge this is the first study that analyses the impact of oil price volatility on developing economies. Since Indonesia, Malaysia and Thailand were severely affected by the Asian financial crisis and as the data in hand portrays spikes during this period, this study implements two different VAR systems for these countries trying to compare between the impact channels for the whole period and for the period after the crisis.

For China, according to the VAR analysis along with the Granger causality test, impulse response functions and variance decompositions, it can be inferred that oil price volatility impacts output growth in the short run. For India oil price volatility impacts both GDP growth and inflation. In Philippines oil price volatility impacts inflation. Furthermore, for all these economies GDP growth and inflation are closely related in the short run. Another important feature of the results from these three countries is that for all the VAR models, oil price volatility seems to be slightly endogenous. This may be caused by the use of exchange rates in constructing the realized volatility measure.

Based on two different VAR analyses for Indonesia, it can be inferred that for the Indonesian economy oil price volatility impacts both GDP growth and inflation for both of the time periods, for the whole sample period and for the period after the Asian financial crisis. Furthermore, the link between GDP growth and inflation is bi-directional for both of the VAR systems. However, one significant difference in results from the two VARs is that, oil price volatility seems to become exogenous to the economy after the financial crisis.

There is not much difference between the two VAR analyses performed for the Malaysian economy. In both of the VAR systems, oil price volatility impacts GDP growth, while there is a very little feedback from the opposite side. Furthermore, like all the other economies analysed so far, GDP growth and inflation seems to be strongly tied in the Malaysian economy.



From the VAR analyses for Thailand, it can be inferred that oil price volatility impacts output growth for the whole period. However, after the Asian financial crisis the impact seems to disappear. This finding is consistent with Rafiq, Salim & Bloch (2009) where the authors find that impact of oil price volatility no longer exists in the Thai economy after the financial crisis. Thus, the results after the financial crisis show that adverse effect of oil price volatility has been mitigated to some extent. It seems that oil subsidization of the Thai Government by introduction of the oil fund plays a significant role in improving economic performance by lessening the adverse effect of oil price volatility on macroeconomic indicators. The policy implication of this result is that the government should keep pursuing its policy to stabilize domestic oil price through subsidization and thus help stabilize economic growth.

It is to be noted here that for all the countries, the impact of oil price volatility on macroeconomic variables is short run. The next chapter concludes the thesis with a comprehensive summary of the thesis, a presentation of some policy recommendations and a discussion about the contributions and limitations of this study.

## Appendix to Chapter 6

**Appendix Table 6.1: Realized Oil Price Variance (RV) for Different Countries**

**a. China**

Quarter	RV
1999Q2	0.03107
1999Q3	0.01900
1999Q4	0.03182
2000Q1	0.03434
2000Q2	0.03638
2000Q3	0.02984
2000Q4	0.06689
2001Q1	0.04788
2001Q2	0.01735
2001Q3	0.04057
2001Q4	0.06318
2002Q1	0.03638
2002Q2	0.01982
2002Q3	0.01491
2002Q4	0.01997
2003Q1	0.03846
2003Q2	0.02700
2003Q3	0.01729
2003Q4	0.02602
2004Q1	0.01983
2004Q2	0.02689
2004Q3	0.02646
2004Q4	0.04880
2005Q1	0.01971
2005Q2	0.02353
2005Q3	0.01883
2005Q4	0.01418
2006Q1	0.01377
2006Q2	0.01993
2006Q3	0.01676
2006Q4	0.01791
2007Q1	0.02667
2007Q2	0.01080
2007Q3	0.00865
2007Q4	0.02126
2008Q1	0.01645

Note: RV stands for realized volatility of oil prices which is calculated as the variance of oil price returns.

**b. India**

Quarter	RV
1996Q4	0.02376
1997Q1	0.02394
1997Q2	0.02180
1997Q3	0.01346
1997Q4	0.02072
1998Q1	0.08280
1998Q2	0.04280
1998Q3	0.04600
1998Q4	0.08164
1999Q1	0.05221
1999Q2	0.03169
1999Q3	0.01922
1999Q4	0.03240
2000Q1	0.03420
2000Q2	0.03620
2000Q3	0.03025
2000Q4	0.06707
2001Q1	0.04787
2001Q2	0.01822
2001Q3	0.04128
2001Q4	0.06395
2002Q1	0.03626
2002Q2	0.02005
2002Q3	0.01505
2002Q4	0.01988
2003Q1	0.03894
2003Q2	0.02842
2003Q3	0.01656
2003Q4	0.02612
2004Q1	0.02008
2004Q2	0.02643
2004Q3	0.02664
2004Q4	0.04991
2005Q1	0.02017
2005Q2	0.02320
2005Q3	0.01836
2005Q4	0.01664
2006Q1	0.01411
2006Q2	0.01877
2006Q3	0.01715
2006Q4	0.01777
2007Q1	0.02632
2007Q2	0.01158
2007Q3	0.00905
2007Q4	0.02230
2008Q1	0.01842

Note: RV stands for realized volatility of oil prices which is calculated as the variance of oil price returns.

### c. Indonesia

Quarter	RV
1993Q2	0.00784
1993Q3	0.02687
1993Q4	0.02828
1994Q1	0.03015
1994Q2	0.02313
1994Q3	0.01919
1994Q4	0.01259
1995Q1	0.00781
1995Q2	0.01129
1995Q3	0.00767
1995Q4	0.00827
1996Q1	0.02147
1996Q2	0.02691
1996Q3	0.02350
1996Q4	0.02322
1997Q1	0.02286
1997Q2	0.02185
1997Q3	0.04071
1997Q4	0.16046
1998Q1	0.59143
1998Q2	0.29482
1998Q3	0.07245
1998Q4	0.14654
1999Q1	0.06619
1999Q2	0.04567
1999Q3	0.06143
1999Q4	0.04368
2000Q1	0.03534
2000Q2	0.04766
2000Q3	0.03567
2000Q4	0.07444
2001Q1	0.05532
2001Q2	0.02273
2001Q3	0.06104
2001Q4	0.07036
2002Q1	0.03447
2002Q2	0.02856
2002Q3	0.01635
2002Q4	0.02170
2003Q1	0.03823
2003Q2	0.02775
2003Q3	0.01728
2003Q4	0.02709
2004Q1	0.01952
2004Q2	0.02821
2004Q3	0.02901
2004Q4	0.04980
2005Q1	0.01982
2005Q2	0.02517

*Continued.*

Quarter	RV
2005Q3	0.03005
2005Q4	0.01492
2006Q1	0.01480
2006Q2	0.01895
2006Q3	0.01807
2006Q4	0.01834
2007Q1	0.02532
2007Q2	0.01329
2007Q3	0.01043
2007Q4	0.02266
2008Q1	0.01650

RV stands for realized volatility of oil prices which is calculated as the variance of oil price returns.

#### d. Malaysia

Quarter	RV
1991Q2	0.01108
1991Q3	0.01819
1991Q4	0.01932
1992Q1	0.02223
1992Q2	0.01170
1992Q3	0.00558
1992Q4	0.01289
1993Q1	0.01935
1993Q2	0.00756
1993Q3	0.02699
1993Q4	0.02918
1994Q1	0.03112
1994Q2	0.02148
1994Q3	0.01954
1994Q4	0.01232
1995Q1	0.00811
1995Q2	0.01157
1995Q3	0.00823
1995Q4	0.00838
1996Q1	0.01998
1996Q2	0.02626
1996Q3	0.02341
1996Q4	0.02336
1997Q1	0.02418
1997Q2	0.02153
1997Q3	0.02117
1997Q4	0.03312
1998Q1	0.10722
1998Q2	0.04827
1998Q3	0.05234
1998Q4	0.03108
1999Q1	0.05238
1999Q2	0.03110
1999Q3	0.01917
1999Q4	0.03183
2000Q1	0.03435
2000Q2	0.03638
2000Q3	0.02987
2000Q4	0.06685
2001Q1	0.04789
2001Q2	0.01738
2001Q3	0.04049
2001Q4	0.06320
2002Q1	0.03638
2002Q2	0.01993
2002Q3	0.01504
2002Q4	0.02008
2003Q1	0.03852
2003Q2	0.02685

*Continued.*

Quarter	RV
2003Q3	0.01704
2003Q4	0.02502
2004Q1	0.01978
2004Q2	0.02678
2004Q3	0.02647
2004Q4	0.04869
2005Q1	0.01976
2005Q2	0.02352
2005Q3	0.01892
2005Q4	0.01402
2006Q1	0.01541
2006Q2	0.01969
2006Q3	0.01678
2006Q4	0.01791
2007Q1	0.02689
2007Q2	0.01125
2007Q3	0.00828
2007Q4	0.02136
2008Q1	0.01673

RV stands for realized volatility of oil prices which is calculated as the variance of oil price returns.

# **e. Philippines**

Quarter	RV
1986Q1	0.18053
1986Q2	0.00938
1986Q3	0.00011
1986Q4	0.00004
1987Q1	0.17003
1987Q2	0.00086
1987Q3	0.00951
1987Q4	0.03054
1988Q1	0.02494
1988Q2	0.01846
1988Q3	0.04259
1988Q4	0.11140
1989Q1	0.03380
1989Q2	0.03286
1989Q3	0.01745
1989Q4	0.00653
1990Q1	0.01902
1990Q2	0.03046
1990Q3	0.18399
1990Q4	0.17337
1991Q1	0.36062
1991Q2	0.01153
1991Q3	0.01622
1991Q4	0.02036
1992Q1	0.02232
1992Q2	0.01276
1992Q3	0.01443
1992Q4	0.01743
1993Q1	0.01662
1993Q2	0.00915
1993Q3	0.02804
1993Q4	0.03485
1994Q1	0.02891
1994Q2	0.02370
1994Q3	0.01706
1994Q4	0.01420
1995Q1	0.01229
1995Q2	0.01117
1995Q3	0.00760
1995Q4	0.00852
1996Q1	0.02070
1996Q2	0.02718
1996Q3	0.02339
1996Q4	0.02337
1997Q1	0.02378
1997Q2	0.02204
1997Q3	0.03908
1997Q4	0.03822
1998Q1	0.09444

*Continued.*



Quarter	RV
1998Q2	0.05514
1998Q3	0.04824
1998Q4	0.08786
1999Q1	0.05037
1999Q2	0.03124
1999Q3	0.02122
1999Q4	0.03200
2000Q1	0.03718
2000Q2	0.03879
2000Q3	0.02975
2000Q4	0.07397
2001Q1	0.04909
2001Q2	0.02041
2001Q3	0.04125
2001Q4	0.06351
2002Q1	0.03598
2002Q2	0.02148
2002Q3	0.01656
2002Q4	0.02246
2003Q1	0.04032
2003Q2	0.02690
2003Q3	0.01731
2003Q4	0.02585
2004Q1	0.01993
2004Q2	0.02729
2004Q3	0.02635
2004Q4	0.04906
2005Q1	0.01977
2005Q2	0.02269
2005Q3	0.01829
2005Q4	0.01465
2006Q1	0.01436
2006Q2	0.01791
2006Q3	0.01806
2006Q4	0.02055
2007Q1	0.02632
2007Q2	0.01185
2007Q3	0.01181
2007Q4	0.02343
2008Q1	0.01758

RV stands for realized volatility of oil prices which is calculated as the variance of oil price returns.

**f. Thailand**

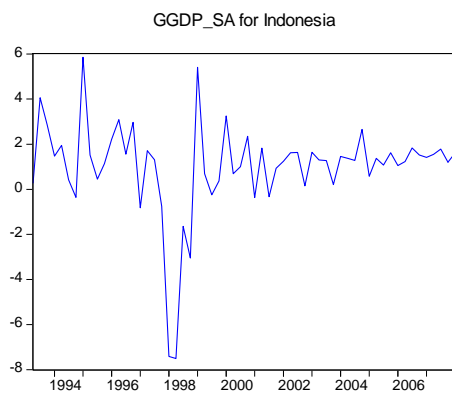
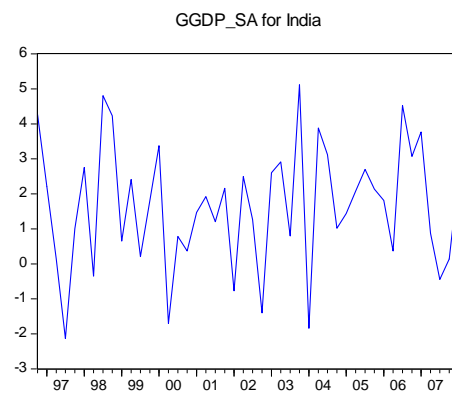
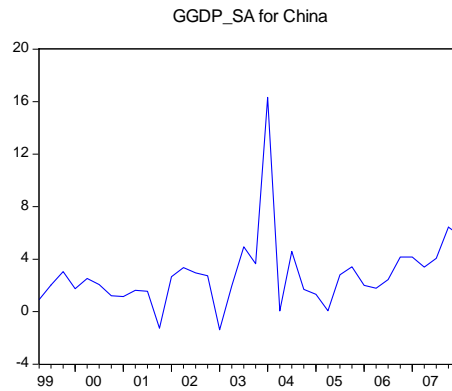
Quarter	RV
1993Q2	0.00915
1993Q3	0.02804
1993Q4	0.03485
1994Q1	0.02891
1994Q2	0.02370
1994Q3	0.01706
1994Q4	0.01420
1995Q1	0.01229
1995Q2	0.01117
1995Q3	0.00760
1995Q4	0.00852
1996Q1	0.02070
1996Q2	0.02718
1996Q3	0.02339
1996Q4	0.02337
1997Q1	0.02378
1997Q2	0.02204
1997Q3	0.03908
1997Q4	0.03822
1998Q1	0.09444
1998Q2	0.05514
1998Q3	0.04824
1998Q4	0.08786
1999Q1	0.05037
1999Q2	0.03124
1999Q3	0.02122
1999Q4	0.03200
2000Q1	0.03718
2000Q2	0.03879
2000Q3	0.02975
2000Q4	0.07397
2001Q1	0.04909
2001Q2	0.02041
2001Q3	0.04125
2001Q4	0.06351
2002Q1	0.03598
2002Q2	0.02148
2002Q3	0.01656
2002Q4	0.02246
2003Q1	0.04032
2003Q2	0.02690
2003Q3	0.01731
2003Q4	0.02585
2004Q1	0.01993
2004Q2	0.02729
2004Q3	0.02635
2004Q4	0.04906
2005Q1	0.01977
2005Q2	0.02269

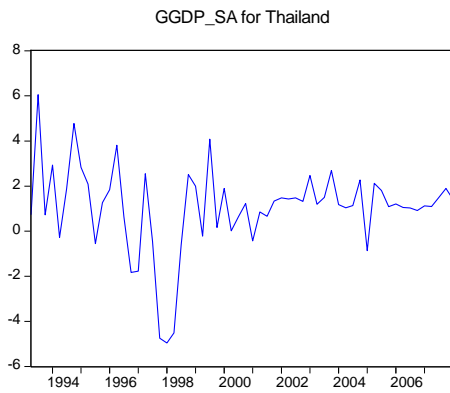
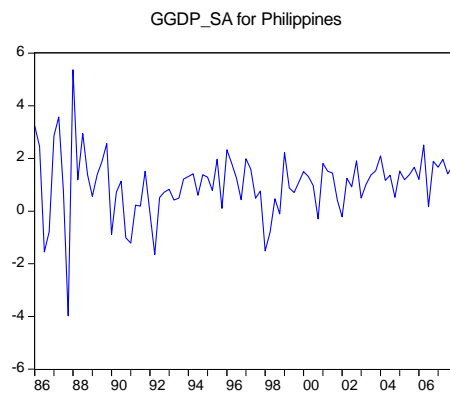
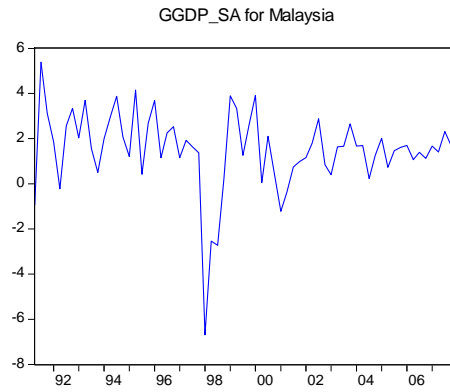
*Continued*

Quarter	RV
2005Q3	0.01829
2005Q4	0.01465
2006Q1	0.01436
2006Q2	0.01791
2006Q3	0.01806
2006Q4	0.02055
2007Q1	0.02632
2007Q2	0.01185
2007Q3	0.01181
2007Q4	0.02343
2008Q1	0.01758

RV stands for realized volatility of oil prices which is calculated as the variance of oil price returns.

**Appendix Figure 6.1: GGDP after Seasonal Adjustment**





Note: GGDP\_SA represents seasonally adjusted GDP growth.

**Appendix Table-6.2: Summary Statistics**

**a. China**

**Descriptive Statistics**

Variables	Mean	Std. Deviation	Observation
RV	0.0269	0.0135	36
GGDP	2.9387	20.5930	36
INF	0.2549	0.8505	36

**Correlations**

Variables	RV	GGDP	INF
RV	1.000 (0.000)		
GGDP	-0.037 (0.831)	1.000 (0.000)	
INF	0.336 (0.049)	0.050 (0.776)	1.000 (0.00)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 33.

**a. India**

**Descriptive Statistics**

Variables	Mean	Std. Deviation	Observation
RV	0.0302	0.0174	46
GGDP	1.6468	1.7895	46
INF	1.3075	1.5394	46

**Correlations**

Variables	RV	GGDP	INF
RV	1.000 (0.000)		
GGDP	-0.226 (0.136)	1.000 (0.000)	
INF	0.060 (0.696)	0.241 (0.111)	1.000 (0.00)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 43.

**b. Indonesia****Descriptive Statistics**

Variables	Mean	Std. Deviation	Observation
RV	0.04720	0.0174	60
GGDP	1.0101	1.7895	60
INF	2.8391	1.5394	60

**Correlations**

Variables	RV	GGDP	INF
RV	1.000 (0.000)		
GGDP	-0.749 (0.001)	1.000 (0.000)	
INF	0.701 (0.001)	0.637 (0.000)	1.000 (0.00)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 57.

**c. Malaysia****Descriptive Statistics**

Variables	Mean	Std. Deviation	Observation
RV	0.0259	0.0164	68
GGDP	1.4940	1.7512	68
INF	0.7092	0.5121	68

**Correlations**

Variables	RV	GGDP	INF
RV	1.000 (0.000)		
GGDP	-0.573 (0.000)	1.000 (0.000)	
INF	0.289 (0.018)	0.372 (0.002)	1.000 (0.00)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 65.

#### d. Philippines

##### Descriptive Statistics

Variables	Mean	Std. Deviation	Observation
RV	0.0376	0.0503	89
GGDP	1.0189	1.2435	89
INF	1.6911	1.3334	89

##### Correlations

Variables	RV	GGDP	INF
RV	1.000 (0.000)		
GGDP	-0.120 (0.265)	1.000 (0.000)	
INF	0.432 (0.000)	0.128 (0.234)	1.000 (0.00)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 86.

#### e. Thailand

##### Descriptive Statistics

Variables	Mean	Std. Deviation	Observation
RV	0.0305	0.0202	60
GGDP	1.0289	1.9181	60
INF	0.9059	0.8413	60

##### Correlations

Variables	RV	GGDP	INF
RV	1.000 (0.000)		
GGDP	-0.348 (0.007)	1.000 (0.000)	
INF	0.115 (0.387)	0.293 (0.024)	1.000 (0.00)

Note: Significance levels are in bracket. This is based on two tailed tests. Time is taken as a controlled variable. Degrees of freedom is 57.



**Appendix Table-6.3: Augmented Dickey-Fuller (ADF) Unit Root Test Results  
for GGDP, RV, and INF**

Country	Series	Level		First Difference	
		Intercept	Intercept & Trend	Intercept	Intercept & Trend
China	GGDP	-5.485[0] (0.000)	-5.852[0] (0.000)	-11.334[0] (0.000)	-11.174[0] (0.000)
	RV	-3.787[0] (0.007)	-5.416[1] (0.001)	-7.658[1] (0.000)	-5.839[2] (0.000)
	INF	-4.596[7] (0.001)	-4.582[7] (0.006)	-10.519[0] (0.000)	-10.364[0] (0.000)
India	GGDP	-7.629[0] (0.000)	-7.679[0] (0.000)	-6.089[3] (0.000)	-6.097[3] (0.000)
	RV	-4.238[3] (0.001)	-4.895[1] (0.001)	-5.527[2] (0.000)	5.581[2] (0.000)
	INF	-2.724[3] (0.079)	-4.790[3] (0.029)	-7.638[2] (0.000)	-7.537[2] (0.000)
Indonesia	GGDP	-5.162[0] (0.000)	-5.119[0] (0.000)	-11.224[0] (0.000)	-11.134[0] (0.000)
	RV	-3.996[0] (0.003)	-4.035[0] (0.013)	-8.101[1] (0.000)	-8.036[1] (0.000)
	INF	-3.681[0] (0.007)	-3.672[0] (0.032)	-8.655[0] (0.000)	-8.579[0] (0.000)
Malaysia	GGDP	-5.878[0] (0.000)	-6.003[0] (0.000)	-12.088[0] (0.000)	-11.989[0] (0.000)
	RV	-4.968[0] (0.000)	-4.921[0] (0.001)	-7.851[2] (0.000)	-7.826[2] (0.000)
	INF	-6.519[0] (0.000)	-6.828[0] (0.000)	-9.741[2] (0.000)	-9.680[2] (0.000)
Philippines	GGDP	-9.454[0] (0.000)	-9.551[0] (0.000)	-10.744[3] (0.000)	-10.684[3] (0.000)
	RV	-7.291[0] (0.000)	-7.351[0] (0.000)	-14.200[0] (0.000)	-14.103[0] (0.000)
	INF	-5.847[0] (0.000)	-6.068[0] (0.000)	-15.348[0] (0.000)	-15.286[0] (0.000)
Thailand	GGDP	-5.079[0] (0.000)	-5.036[0] (0.001)	-11.480[0] (0.000)	-11.429[0] (0.000)
	RV	-4.749[0] (0.000)	-4.749[0] (0.002)	-9.119[1] (0.000)	-9.037[1] (0.000)
	INF	-4.666[0] (0.000)	-4.739[0] (0.002)	-9.962[0] (0.000)	-9.897[0] (0.000)

**Notes:** Figures in the parentheses indicate p-values while figures in brackets are optimum lag length determined by Schwarz Information Criteria (SIC). GGDP, RV and INF stand for GDP growth, oil price volatility and inflation, respectively.

**Appendix Table-6.4: Phillips Perron (PP) Unit Root Test Results for GGDP, RV, and INF**

Country	Series	Level		First Difference	
		Intercept	Intercept & Trend	Intercept	Intercept & Trend
China	GGDP	-5.482[1] (0.000)	-5.852[0] (0.000)	-18.245[9] (0.000)	-18.198[9] (0.000)
	RV	-3.818[1] (0.006)	-5.035[9] (0.001)	-13.393[19] (0.000)	-13.749[18] (0.000)
	INF	-4.833[4] (0.000)	-4.856[4] (0.002)	-11.123[1] (0.000)	-10.997[1] (0.000)
India	GGDP	-7.629[0] (0.000)	-7.712[1] (0.000)	-22.923[8] (0.000)	-22.261[8] (0.000)
	RV	-4.158[2] (0.002)	-4.989[3] (0.001)	-14.432[16] (0.000)	-16.474[19] (0.000)
	INF	-6.092[6] (0.000)	-6.098[7] (0.000)	-19.757[16] (0.000)	-18.808[16] (0.000)
Indonesia	GGDP	-5.145[1] (0.000)	-5.119[0] (0.000)	-21.064[21] (0.000)	-23.684[22] (0.000)
	RV	-3.996[0] (0.003)	-4.035[0] (0.013)	-11.101[11] (0.000)	-11.319[12] (0.000)
	INF	-3.796[3] (0.005)	-3.783[3] (0.024)	-10.654[9] (0.000)	-10.547[9] (0.000)
Malaysia	GGDP	-5.967[2] (0.000)	-6.096[2] (0.000)	-15.136[5] (0.000)	-15.076[5] (0.000)
	RV	-4.922[1] (0.000)	-4.874[1] (0.001)	-31.404[65] (0.000)	-39.624[61] (0.000)
	INF	-6.547[1] (0.000)	-6.784[3] (0.000)	-28.074[23] (0.000)	-28.337[23] (0.000)
Philippines	GGDP	-9.491[3] (0.000)	-9.589[4] (0.000)	-34.351[18] (0.000)	-35.649[18] (0.000)
	RV	-7.308[1] (0.000)	-7.454[2] (0.000)	-30.406[19] (0.000)	-30.109[19] (0.000)
	INF	-5.847[0] (0.000)	-5.957[1] (0.000)	-21.160[16] (0.000)	-21.963[18] (0.000)
Thailand	GGDP	-5.119[2] (0.000)	-5.074[2] (0.001)	-22.006[52] (0.000)	-27.752[43] (0.000)
	RV	-4.941[4] (0.000)	-4.933[4] (0.001)	-14.419[6] (0.000)	-14.307[6] (0.000)
	INF	-4.666[0] (0.000)	-4.749[1] (0.002)	-20.678[38] (0.000)	-26.932[42] (0.000)

**Notes:** Figures in the parentheses indicate optimum bandwidth determined by Newey-West using Bartlett kernel while figures in brackets are p-values from Mackinnon (1996). Optimal lag length is determined by Schwartz Information Criteria. GGDP, RV and INF stand for GDP growth, oil price volatility and inflation, respectively.

**Appendix Table-6.5: Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Unit Root  
Test Results for GGDP, RV, and INF**

Country	Series	Level		First Difference	
		Intercept	Intercept & Trend	Intercept	Intercept & Trend
China	GGDP	0.337[1]	0.058[1]	0.241[15]	0.233[15]
	RV	0.324[3]	0.067[4]	0.225[16]	0.214[17]
	INF	0.142[4]	0.082[3]	0.092[4]	0.089[4]
India	GGDP	0.106[2]	0.058[3]	0.045[1]	0.042[2]
	RV	0.218[4]	0.084[2]	0.195[16]	0.185[18]
	INF	0.144[5]	0.114[6]	0.215[15]	0.115[15]
Indonesia	GGDP	0.121[3]	0.112[3]	0.278[21]	0.277[31]
	RV	0.168[4]	0.113[4]	0.116[11]	0.096[11]
	INF	0.094[4]	0.066[4]	0.127[13]	0.126[13]
Malaysia	GGDP	0.174[3]	0.095[3]	0.125[10]	0.104[10]
	RV	0.229[5]	0.212[5]	0.244[25]	0.197[24]
	INF	0.587[3]	0.158[0]	0.202[17]	0.104[17]
Philippines	GGDP	0.185[5]	0.102[6]	0.166[19]	0.123[19]
	RV	0.296[2]	0.052[1]	0.338[36]	0.098[60]
	INF	0.376[5]	0.104[4]	0.233[47]	0.227[57]
Thailand	GGDP	0.137[3]	0.131[3]	0.182[22]	0.182[22]
	RV	0.174[5]	0.160[5]	0.101[7]	0.077[7]
	INF	0.308[4]	0.147[4]	0.341[38]	0.091[36]
Critical Values					
1%		0.739	0.216	0.739	0.216
5%		0.463	0.146	0.463	0.146
10%		0.347	0.119	0.347	0.119

**Notes:** Figures in brackets are optimum bandwidth determined by Newey-West using Bartlett kernel. GGDP, RV and INF stand for GDP growth, oil price volatility and inflation, respectively.

**Appendix Table-6.6: Lag Exclusion Wald Test****a. China**

VAR Lag Exclusion Wald Tests

Sample: 1999Q2 2008Q1

Included observations: 30

Chi-squared test statistics for lag exclusion:

Numbers in [ ] are p-values

	GGDP	RV	INF	Joint
Lag 1	5.665499 [ 0.129068]	5.244857 [ 0.154721]	5.985669 [ 0.112310]	17.62768 [ 0.118551]
Lag 2	0.219896 [ 0.974315]	4.218254 [ 0.238841]	7.877173 [ 0.048620]	12.51173 [ 0.185973]
Lag 3	6.913202 [ 0.074716]	7.705473 [ 0.052507]	10.95509 [ 0.011971]	23.82039 [ 0.004594]
Lag 4	4.266671 [ 0.234071]	2.401906 [ 0.493280]	1.115511 [ 0.773331]	9.183374 [ 0.420522]
Lag 5	2.877056 [ 0.410972]	1.046552 [ 0.789990]	3.994516 [ 0.262057]	15.5332 [ 0.077293]
Lag 6	0.346284 [ 0.951101]	1.26933 [ 0.736428]	2.464254 [ 0.481786]	5.331171 [ 0.804537]
df	3	3	3	9

**b. India**

VAR Lag Exclusion Wald Tests

Sample: 1996Q4 2008Q1

Included observations: 40

Chi-squared test statistics for lag exclusion:

Numbers in [ ] are p-values

	GGDP	RV	INF	Joint
Lag 1	2.824239 [ 0.419525]	5.034346 [ 0.169299]	1.952148 [ 0.582398]	8.23656 [ 0.484640]
Lag 2	6.980618 [ 0.072518]	9.055207 [ 0.028566]	12.03020 [ 0.007280]	21.03896 [ 0.012479]
Lag 3	0.978252 [ 0.806514]	4.177778 [ 0.242896]	1.796579 [ 0.615680]	7.126158 [ 0.623986]
Lag 4	5.120834 [ 0.163160]	0.496972 [ 0.919556]	9.624283 [ 0.022045]	15.87776 [ 0.069479]
Lag 5	1.636995 [ 0.651031]	7.94743 [ 0.047111]	0.123618 [ 0.988860]	10.47741 [ 0.313235]
Lag 6	0.668705 [ 0.880539]	1.389398 [ 0.708022]	0.187151 [ 0.979636]	2.300884 [ 0.985768]
df	3	3	3	9

**c. Indonesia from 1993:2 to 2008:1**

VAR Lag Exclusion Wald Tests

Sample: 1993Q2 2008Q1

Included observations: 54

Chi-squared test statistics for lag exclusion:

Numbers in [ ] are p-values

	GGDP	RV	INF	Joint
Lag 1	6.633973 [ 0.084526]	5.126465 [ 0.162768]	1.140443 [ 0.767321]	16.6541 [ 0.054416]
Lag 2	2.665298 [ 0.446157]	4.253136 [ 0.235395]	5.451047 [ 0.141596]	39.90915 [ 7.89e-06]
Lag 3	11.1656 [ 0.010863]	6.807595 [ 0.078290]	0.183726 [ 0.980173]	26.07546 [ 0.001986]
Lag 4	37.20843 [ 4.16e-08]	24.03122 [ 2.46e-05]	24.24374 [ 2.22e-05]	50.18238 [ 9.95e-08]
Lag 5	1.126622 [ 0.770652]	1.211842 [ 0.750166]	1.044893 [ 0.790391]	6.793664 [ 0.658592]
Lag 6	1.839413 [ 0.606396]	0.779535 [ 0.854355]	1.159955 [ 0.762624]	2.778016 [ 0.972450]
df	3	3	3	9

**d. Indonesia from 1998:4 to 2008:1**

VAR Lag Exclusion Wald Tests

Sample: 1998Q4 2008Q1

Included observations: 38

Chi-squared test statistics for lag exclusion:

Numbers in [ ] are p-values

	GGDP	RV	INF	Joint
Lag 1	5.438028 [ 0.142393]	4.311444 [ 0.229738]	0.097849 [ 0.992094]	9.958999 [ 0.353815]
Lag 2	2.907248 [ 0.406148]	4.104894 [ 0.250358]	0.990549 [ 0.803539]	8.169331 [ 0.517176]
Lag 3	6.955963 [ 0.073315]	2.341927 [ 0.504536]	3.771933 [ 0.287168]	13.56024 [ 0.138851]
Lag 4	9.634735 [ 0.021940]	6.312107 [ 0.097374]	6.302125 [ 0.0972869]	23.28996 [ 0.011955]
Lag 5	4.496105 [ 0.212638]	5.684381 [ 0.128017]	1.487552 [ 0.685146]	11.16341 [ 0.264674]
Lag 6	3.916728 [ 0.270598]	7.064649 [ 0.069865]	2.605176 [ 0.456583]	14.74377 [ 0.098219]
df	3	3	3	9

**e. Malaysia from 1991:2 to 2008:1**

VAR Lag Exclusion Wald Tests

Sample: 1991Q2 2008Q1

Included observations: 64

Chi-squared test statistics for lag exclusion:

Numbers in [ ] are p-values

	GGDP	RV	INF	Joint
Lag 1	1.093940 [ 0.778537]	5.350212 [ 0.147877]	1.217237 [ 0.748873]	12.44994 [ 0.189116]
Lag 2	8.438489 [ 0.037768]	7.996027 [ 0.046094]	7.071422 [ 0.069656]	14.98293 [ 0.091406]
Lag 3	0.819664 [ 0.844758]	0.738169 [ 0.864192]	2.872172 [ 0.411756]	4.887031 [ 0.844043]
Lag 4	2.119035 [ 0.548072]	1.831857 [ 0.608027]	6.008459 [ 0.111199]	15.06167 [ 0.089256]
Lag 5	0.993724 [ 0.802771]	3.473258 [ 0.324247]	0.8449 [ 0.838700]	10.65244 [ 0.300287]
Lag 6	2.759441 [ 0.430220]	0.523869 [ 0.913617]	2.399485 [ 0.493731]	10.09338 [ 0.342979]
df	3	3	3	9



**f. Malaysia from 1998:4 to 2008:1**

VAR Lag Exclusion Wald Tests

Sample: 1998Q4 2008Q1

Included observations: 38

Chi-squared test statistics for lag exclusion:

Numbers in [ ] are p-values

	GGDP	RV	INF	Joint
Lag 1	4.852813 [ 0.182898]	3.251000 [ 0.354521]	4.166094 [ 0.244078]	12.12175 [ 0.206533]
Lag 2	7.418009 [ 0.056498]	9.234939 [ 0.026325]	11.694779 [ 0.0138095]	29.65374 [ 0.00733541]
Lag 3	4.161678 [ 0.244527]	4.279854 [ 0.232788]	2.638098 [ 0.450850]	11.35712 [ 0.252022]
Lag 4	10.34584 [ 0.015844]	4.312653 [ 0.229622]	1.574991 [ 0.665074]	14.90743 [ 0.093510]
Lag 5	0.935741 [ 0.816795]	0.134857 [ 0.987349]	2.557622 [ 0.464967]	3.679499 [ 0.931214]
Lag 6	0.184999 [ 0.979974]	5.915385 [ 0.115800]	0.930655 [ 0.818024]	7.195718 [ 0.616750]
df	3	3	3	9

**g. Philippines**

VAR Lag Exclusion Wald Tests

Sample: 1986Q1 2008Q1

Included observations: 83

Chi-squared test statistics for lag exclusion:

Numbers in [ ] are p-values

	GGDP	RV	INF	Joint
Lag 1	7.006176 [ 0.071701]	12.07382 [ 0.007135]	13.43954 [ 0.003776]	31.52723 [ 0.007504]
Lag 2	2.253923 [ 0.521405]	3.883633 [ 0.274307]	6.945608 [ 0.073652]	14.74685 [ 0.098128]
Lag 3	3.675394 [ 0.298716]	5.291512 [ 0.151654]	3.676193 [ 0.298619]	10.71904 [ 0.295460]
Lag 4	15.89426 [ 0.001192]	2.277374 [ 0.516869]	1.088669 [ 0.779810]	19.01002 [ 0.022606]
Lag 5	14.3765 [ 0.002435]	5.224643 [ 0.156068]	2.657924 [ 0.447425]	25.94864 [ 0.002083]
Lag 6	2.527949 [ 0.470261]	4.524955 [ 0.210075]	3.380715 [ 0.336566]	11.57755 [ 0.238186]
df	3	3	3	9

## h. Thailand from 1993Q2 to 2008Q1

VAR Lag Exclusion Wald Tests

Sample: 1993Q2 2008Q1

Included observations: 54

Chi-squared test statistics for lag exclusion:

Numbers in [ ] are p-values

	GGDP	RV	INF	Joint
Lag 1	24.40198 [ 2.06e-05]	6.935141 [ 0.073994]	8.416633 [ 0.038142]	37.51728 [ 2.13e-05]
Lag 2	0.222537 [ 0.973872]	7.159658 [ 0.066979]	1.115932 [ 0.773230]	10.13073 [ 0.340006]
Lag 3	2.049505 [ 0.562196]	0.870859 [ 0.832454]	0.832925 [ 0.841577]	3.596871 [ 0.935890]
Lag 4	2.773174 [ 0.427935]	13.20962 [ 0.004205]	3.431666 [ 0.329733]	18.41055 [ 0.030698]
Lag 5	6.283658 [ 0.098596]	2.276936 [ 0.516954]	2.909576 [ 0.405778]	9.340882 [ 0.406421]
Lag 6	2.111976 [ 0.549494]	2.511035 [ 0.473300]	0.76969 [ 0.856702]	6.230336 [ 0.716662]
df	3	3	3	9

**i. Thailand from 1998Q4 to 2008Q1**

VAR Lag Exclusion Wald Tests

Sample: 1998Q4 2008Q1

Included observations: 38

Chi-squared test statistics for lag exclusion:

Numbers in [ ] are p-values

	GGDP	RV	INF	Joint
Lag 1	1.076006 [ 0.782869]	0.656859 [ 0.883301]	0.151130 [ 0.985064]	3.75137 [ 0.731448]
Lag 2	11.59199 [ 0.008920]	7.922358 [ 0.047644]	9.722283 [ 0.021081]	27.56934 [ 0.0080349]
Lag 3	0.865399 [ 0.833769]	1.619024 [ 0.655084]	1.236166 [ 0.744344]	3.391825 [ 0.946718]
Lag 4	3.519548 [ 0.318236]	4.922926 [ 0.177529]	3.686130 [ 0.297412]	11.02831 [ 0.273774]
Lag 5	2.373459 [ 0.498594]	0.891456 [ 0.827489]	0.798048 [ 0.849934]	4.283042 [ 0.891816]
Lag 6	2.538368 [ 0.468397]	1.508228 [ 0.680373]	1.303622 [ 0.728273]	5.45419 [ 0.793056]
df	3	3	3	9

## Appendix Table-6.7: VAR Stability Condition Check

### a. China

Roots of Characteristic Polynomial  
 Endogenous variables: GGDP RV INF  
 Exogenous variables: C  
 Lag specification: 1 3  
 Date: 01/25/09 Time: 16:30

Root	Modulus
0.791757 - 0.364753i	0.871736
0.791757 + 0.364753i	0.871736
-0.136790 - 0.750517i	0.762881
-0.136790 + 0.750517i	0.762881
-0.614194 - 0.427115i	0.748105
-0.614194 + 0.427115i	0.748105
0.236846	0.236846
0.192165 - 0.130502i	0.232289
0.192165 + 0.130502i	0.232289

No root lies outside the unit circle.  
 VAR satisfies the stability condition.

### b. India

Roots of Characteristic Polynomial  
 Endogenous variables: GGDP RV INF  
 Exogenous variables: C  
 Lag specification: 1 2  
 Date: 01/25/09 Time: 17:35

Root	Modulus
0.100320 - 0.678296i	0.685675
0.100320 + 0.678296i	0.685675
-0.440409 - 0.390357i	0.588506
-0.440409 + 0.390357i	0.588506
0.488580 - 0.075182i	0.494331
0.488580 + 0.075182i	0.494331

No root lies outside the unit circle.  
 VAR satisfies the stability condition.

**c. Indonesia from 1993:2 to 2008:1**

Roots of Characteristic Polynomial  
Endogenous variables: GGD<sub>P</sub> RV INF  
Exogenous variables: C  
Lag specification: 1 4  
Date: 01/26/09 Time: 12:25

Root	Modulus
-0.273739 - 0.750910i	0.799249
-0.273739 + 0.750910i	0.799249
0.250537 - 0.738128i	0.779488
0.250537 + 0.738128i	0.779488
0.702450 - 0.211525i	0.733607
0.702450 + 0.211525i	0.733607
0.521296 - 0.499137i	0.721725
0.521296 + 0.499137i	0.721725
-0.598661 - 0.357170i	0.697112
-0.598661 + 0.357170i	0.697112
-0.426804 - 0.253868i	0.496599
-0.426804 + 0.253868i	0.496599

No root lies outside the unit circle.  
VAR satisfies the stability condition.

**d. Indonesia from 1998:4 to 2008:1**

Roots of Characteristic Polynomial  
Endogenous variables: GGD<sub>P</sub> RV INF  
Exogenous variables: C  
Lag specification: 1 4  
Date: 01/26/09 Time: 13:05

Root	Modulus
-0.722404	0.722404
0.051313 - 0.710129i	0.711980
0.051313 + 0.710129i	0.711980
0.689991	0.689991
-0.380780 - 0.544659i	0.664565
-0.380780 + 0.544659i	0.664565
0.525725 - 0.379303i	0.648273
0.525725 + 0.379303i	0.648273
-0.383400 - 0.405319i	0.557924
-0.383400 + 0.405319i	0.557924
0.208256 - 0.159213i	0.262144
0.208256 + 0.159213i	0.262144

No root lies outside the unit circle.  
VAR satisfies the stability condition.

**e. Malaysia from 1991:2 to 2008:1**

Roots of Characteristic Polynomial  
Endogenous variables: GGDP RV INF  
Exogenous variables: C  
Lag specification: 1 2  
Date: 01/26/09 Time: 14:36

Root	Modulus
0.799949	0.799949
0.029033 - 0.556192i	0.556949
0.029033 + 0.556192i	0.556949
-0.365826	0.365826
0.135227 - 0.133652i	0.190129
0.135227 + 0.133652i	0.190129

No root lies outside the unit circle.  
VAR satisfies the stability condition.

**f. Malaysia from 1998:4 to 2008:1**

Roots of Characteristic Polynomial  
Endogenous variables: GGDP RV INF  
Exogenous variables: C  
Lag specification: 1 2  
Date: 01/26/09 Time: 15:08

Root	Modulus
0.773530	0.773530
0.003592 - 0.631663i	0.631673
0.003592 + 0.631663i	0.631673
0.160747 - 0.376102i	0.409014
0.160747 + 0.376102i	0.409014
-0.217016	0.217016

No root lies outside the unit circle.  
VAR satisfies the stability condition.

#### g. Philippines from 1986:1 to 2008:1

Roots of Characteristic Polynomial  
Endogenous variables: GGDP RV INF  
Exogenous variables: C  
Lag specification: 1 1  
Date: 01/26/09 Time: 16:17

Root	Modulus
0.448059	0.448059
0.235234	0.235234
-0.073921	0.073921

No root lies outside the unit circle.  
VAR satisfies the stability condition.

#### h. Thailand from 1993Q2 to 2008Q1

Roots of Characteristic Polynomial  
Endogenous variables: GGDP RV INF  
Exogenous variables: C  
Lag specification: 1 1  
Date: 01/26/09 Time: 18:04

Root	Modulus
0.641259	0.641259
0.444234	0.444234
-0.246647	0.246647

No root lies outside the unit circle.  
VAR satisfies the stability condition.

#### i. Thailand from 1998Q4 to 2008Q1

Roots of Characteristic Polynomial  
Endogenous variables: GGDP RV INF  
Exogenous variables: C  
Lag specification: 1 2  
Date: 01/26/09 Time: 18:18

Root	Modulus
-0.087764 - 0.482928i	0.490838
-0.087764 + 0.482928i	0.490838
-0.217661 - 0.402185i	0.457306
-0.217661 + 0.402185i	0.457306
0.367447 - 0.264133i	0.452530
0.367447 + 0.264133i	0.452530

No root lies outside the unit circle.  
VAR satisfies the stability condition.



**Appendix Table-6.8: Vector Autoregressive Model Output for Different Countries**

**a. VAR (3) Output for China**

Vector Autoregression Estimates  
Sample (adjusted): 2000Q1 2008Q1  
Included observations: 33 after adjustments  
Standard errors in ( ) & t-statistics in [ ]

	GGDP	RV	INF
GGDP (-1)	-0.029060 (0.23912) [-0.12153]	- 0.000401 (0.00096) [- 0.41575]	0.042387 (0.04642) [ 0.91312]
GGDP (-2)	-0.001353 (0.24243) [-0.00558]	-0.001506 (0.00098) [-1.54193]	0.086460 (0.04706) [ 1.83709]
GGDP (-3)	-0.301211 (0.21583) [-1.39557]	- 0.001844 (0.00087) [- 2.12080]	-0.212812 (0.04190) [-5.07903]
RV(-1)	-52.4906 (7.919376) [-6.628123]	0.582865 (0.21149) [ 2.75595]	25.96305 (10.1901) [2.54787]
RV(-2)	6.958502 (58.6631) [ 0.11862]	-0.488507 (0.23636) [-2.06676]	25.41388 (11.3884) [ 2.23156]
RV(-3)	-35.52624 (9.0646) [-3.919229]	0.633598 (0.19769) [ 3.20502]	-25.80016 (9.52501) [-2.70867]
INF(-1)	1.914148 (0.76751) [ 2.49399]	0.002198 (0.00309) [ 0.71069]	0.148918 (0.14900) [ 0.99947]
INF(-2)	0.092253 (0.90936) [ 0.10145]	-0.001995 (0.00366) [-0.54461]	0.479603 (0.17654) [ 2.71674]
INF(-3)	-0.061534 (0.93478) [-0.06583]	0.006320 (0.00377) [ 1.67811]	-0.078716 (0.18147) [-0.43377]
C	4.331041 (2.41706) [ 1.79186]	0.003701 (0.00974) [ 0.38004]	1.057926 (0.46923) [ 2.25460]

## b. VAR (2) Output for India

Vector Autoregression Estimates  
Sample (adjusted): 1997Q2 2008Q1  
Included observations: 44 after adjustments  
Standard errors in ( ) & t-statistics in [ ]

	GGDP	RV	INF
GGDP (-1)	-0.160571 (0.16076) [-0.99882]	-0.001224 (0.00127) [-0.96324]	-0.004060 (0.12121) [-0.03350]
GGDP (-2)	-0.162641 (0.15764) [-1.03170]	-0.003448 (0.00125) [-2.76775]	-0.312397 (0.11886) [-2.62833]
RV(-1)	-30.27972 (19.3455) [-1.56521]	0.218361 (0.15288) [ 1.42834]	39.12552 (14.5857) [2.68245]
RV(-2)	-28.74552 (8.3954) [- 3.423961]	0.189011 (0.14537) [ 1.30021]	41.51209 (13.8694) [ 2.99306]
INF(-1)	0.241663 (0.18766) [ 1.28779]	0.004984 (0.00148) [ 3.36060]	0.239191 (0.14149) [ 1.69056]
INF(-2)	0.307543 (0.19643) [ 1.56566]	0.002932 (0.00155) [ 1.88858]	-0.108176 (0.14810) [-0.73042]
C	1.420634 (0.74155) [ 1.91575]	0.015289 (0.00586) [ 2.60890]	1.596499 (0.55910) [ 2.85546]

### c. VAR (4) Output for Indonesia for 1993Q2 to 2008Q1

Vector Autoregression Estimates  
Sample (adjusted): 1994Q2 2008Q1  
Included observations: 56 after adjustments  
Standard errors in ( ) & t-statistics in [ ]

	GGDP	RV	INF
GGDP (-1)	-0.360913 (0.20069) [-1.79838]	-0.009027 (0.01002) [-0.90105]	-0.411515 (0.34946) [-1.17756]
GGDP (-2)	-0.158094 (0.20544) [-0.76952]	-0.014922 (0.01026) [-1.45503]	-0.506371 (0.35775) [-1.41545]
GGDP (-3)	-0.090945 (0.18585) [-0.48934]	-0.013060 (0.00928) [-1.40770]	-0.190839 (0.32363) [-0.58968]
GGDP (-4)	0.159918 (0.16930) [ 0.94461]	-0.017944 (0.00845) [-2.12335]	0.016901 (0.29480) [ 0.05733]
RV(-1)	-24.94635 (4.91190) [-5.07875]	0.748105 (0.24519) [ 3.05114]	22.84461 (8.55325) [ 2.67087]
RV(-2)	-1.166810 (5.39185) [-0.21640]	-0.485249 (0.26915) [-1.80292]	1.876389 (9.38899) [ 0.19985]
RV(-3)	-15.34970 (5.05925) [-3.03398]	0.279776 (0.25254) [ 1.10783]	-10.13683 (8.80984) [-1.15063]
RV(-4)	15.01557 (6.03036) [ 2.48999]	-0.642142 (0.30102) [-2.13323]	-4.212239 (10.5009) [-0.40113]
INF(-1)	0.048445 (0.12136) [ 0.39918]	-0.006849 (0.00606) [-1.13049]	-0.037035 (0.21133) [-0.17525]
INF(-2)	0.066169 (0.10696) [ 0.61866]	-0.004181 (0.00534) [-0.78305]	0.097752 (0.18625) [ 0.52485]
INF(-3)	-0.046450 (0.10415) [-0.44599]	-0.001164 (0.00520) [-0.22381]	-0.081049 (0.18136) [-0.44689]

*Continued.*

	GGDP	RV	INF
INF(-4)	0.018939 (0.08251) [ 0.22954]	-0.000536 (0.00412) [-0.13020]	-0.085036 (0.14368) [-0.59185]
C	2.396929 (1.25120) [ 1.91570]	0.143907 (0.06246) [ 2.30412]	3.744154 (2.17875) [ 1.71849]

#### d. VAR (4) Output for Indonesia for 1998Q4 to 2008Q1

Vector Autoregression Estimates

Sample: 1998Q4 2008Q1

Included observations: 38

Standard errors in ( ) & t-statistics in [ ]

	GGDP	RV	INF
GGDP (-1)	-0.564836 (0.16911) [-3.34006]	0.001358 (0.00365) [ 0.37158]	-0.136843 (0.44619) [-0.30669]
GGDP (-2)	-0.299190 (0.16779) [-1.78315]	-9.48E-05 (0.00363) [-0.02615]	-0.049594 (0.44270) [-0.11203]
GGDP (-3)	-0.304037 (0.14728) [-2.06430]	0.002139 (0.00318) [ 0.67202]	0.082218 (0.38860) [ 0.21157]
GGDP (-4)	0.034310 (0.13392) [ 0.25619]	-0.000539 (0.00289) [-0.18635]	0.530664 (0.35334) [ 1.50184]
RV(-1)	-14.54729 (9.16206) [-1.58778]	0.402670 (0.19798) [ 2.03390]	7.497047 (24.1735) [ 0.31013]
RV(-2)	2.196141 (7.32760) [ 0.29971]	0.010099 (0.15834) [ 0.06378]	22.323757 (7.3334) [3.044121]
RV(-3)	-18.80682 (4.24835) [-4.42685]	0.263224 (0.09180) [ 2.86734]	3.558666 (11.2090) [0.31748]
RV(-4)	9.414673 (4.80867) [ 1.95786]	-0.065286 (0.10391) [-0.62830]	13.36210 (12.6874) [ 1.05318]
INF(-1)	-0.068284 (0.07127) [-0.95816]	0.000328 (0.00154) [ 0.21286]	0.171984 (0.18803) [ 0.91465]
INF(-2)	0.038352 (0.07050) [ 0.54400]	-0.001306 (0.00152) [-0.85739]	0.020579 (0.18601) [ 0.11063]
INF(-3)	-0.072401 (0.06315) [-1.14647]	-0.000325 (0.00136) [-0.23791]	0.058718 (0.16662) [ 0.35240]

*Continued*

	GGDP	RV	INF
INF(-4)	0.000453 (0.04554) [ 0.00994]	0.000298 (0.00098) [ 0.30244]	-0.126745 (0.12014) [-1.05494]
C	3.569226 (0.99997) [ 3.56933]	0.009174 (0.02161) [ 0.42454]	0.871277 (2.63836) [ 0.33023]

### e. VAR (2) Output for Malaysia for 1991Q2 to 2008Q1

Vector Autoregression Estimates  
Sample (adjusted): 1991Q4 2008Q1  
Included observations: 66 after adjustments  
Standard errors in ( ) & t-statistics in [ ]

	GGDP	RV	INF
GGDP (-1)	0.170354 (0.14691) [ 1.15961]	-0.000343 (0.00134) [-0.25613]	-0.039463 (0.04692) [-0.84104]
GGDP(-2)	-0.054116 (0.13682) [-0.39552]	-0.002631 (0.00125) [-2.11068]	0.007773 (0.04370) [ 0.17787]
RV(-1)	-30.63755 (16.2672) [-1.88340]	0.374999 (0.14821) [ 2.53016]	0.564228 (5.19569) [ 0.10860]
RV(-2)	-9.277130 (16.1385) [-0.57485]	-0.004880 (0.14704) [-0.03319]	-8.693493 (5.15458) [-1.68656]
INF(-1)	-0.099140 (0.42476) [-0.23340]	-0.004320 (0.00387) [-1.11620]	0.217289 (0.13567) [ 1.60163]
INF(-2)	-0.031293 (0.42539) [-0.07356]	-0.008143 (0.00388) [-2.10097]	0.017378 (0.13587) [ 0.12790]
C	2.427706 (0.86875) [ 2.79448]	0.029668 (0.00792) [ 3.74819]	0.801016 (0.27748) [ 2.88679]

# **f. VAR (2) Output for Malaysia for 1998Q4 to 2008Q1**

Vector Autoregression Estimates

Sample: 1998Q4 2008Q1

Included observations: 38

Standard errors in ( ) & t-statistics in [ ]

	GGDP	RV	INF
GGDP (-1)	0.250787 (0.16191) [ 1.54892]	0.000176 (0.00174) [ 0.10155]	-0.063789 (0.05507) [-1.15836]
GGDP (-2)	-0.205308 (0.14229) [-1.44283]	-0.002863 (0.00153) [-1.87543]	-0.045654 (0.04840) [-0.94334]
RV(-1)	-22.80607 (14.6139) [-1.56057]	0.289024 (0.15676) [ 1.84376]	-3.253318 (4.97036) [-0.65454]
RV(-2)	-6.075688 (14.4552) [ -0.42031]	0.002099 (0.15506) [ 0.01354]	-6.031285 (4.91638) [-1.22677]
INF(-1)	0.345905 (0.53011) [ 0.65252]	-0.010534 (0.00569) [-1.85260]	0.345381 (0.18030) [ 1.91563]
INF(-2)	-0.397560 (0.49849) [-0.79753]	-0.013399 (0.00535) [-2.50573]	-0.129711 (0.16954) [-0.76506]
C	1.886315 (0.67387) [ 2.79924]	0.035128 (0.00723) [ 4.85975]	0.831267 (0.22919) [ 3.62697]



### g. VAR (1) Output for Philippines

Vector Autoregression Estimates  
Sample (adjusted): 1986Q2 2008Q1  
Included observations: 88 after adjustments  
Standard errors in ( ) & t-statistics in [ ]

	GGDP	RV	INF
GGDP (-1)	-0.017203 (0.10798) [-0.15932]	-0.006485 (0.00398) [-1.62846]	-0.255713 (0.10347) [-2.47129]
RV(-1)	-0.587822 (2.86085) [-0.20547]	0.221195 (0.11010) [ 2.00911]	2.337990 (0.98531) [2.372847]
INF(-1)	-0.093055 (0.11276) [-0.82524]	0.003381 (0.00416) [ 0.81300]	0.405381 (0.10806) [ 3.75145]
C	1.180745 (0.25474) [ 4.63508]	0.028509 (0.00939) [ 3.03464]	1.293268 (0.24412) [ 5.29766]

## h. VAR (1) Output for Thailand for 1993Q2 to 2008Q1

Vector Autoregression Estimates  
Sample (adjusted): 1993Q3 2008Q1  
Included observations: 59 after adjustments  
Standard errors in ( ) & t-statistics in [ ]

	GGDP	RV	INF
GGDP (-1)	0.095061 (0.11872) [ 0.80073]	-0.003487 (0.00135) [-2.58725]	-0.033901 (0.06013) [-0.56384]
RV(-1)	-45.76355 (10.8031) [-4.23613]	0.327087 (0.12263) [ 2.66718]	2.135271 (5.47124) [0.39027]
INF(-1)	-0.876349 (0.25620) [-3.42061]	-0.000277 (0.00291) [-0.09529]	0.416698 (0.12975) [ 3.21153]
C	3.111968 (0.54833) [ 5.67534]	0.024732 (0.00622) [ 3.97333]	0.624203 (0.27770) [ 2.24774]

# **i. VAR (2) Output for Thailand for 1998Q4 to 2008Q1**

Vector Autoregression Estimates

Sample: 1998Q4 2008Q1

Included observations: 38

Standard errors in ( ) & t-statistics in [ ]

	GGDP	RV	INF
GGDP (-1)	-0.344737 (0.16729) [-2.06073]	-0.005166 (0.00249) [-2.07513]	-0.101658 (0.14866) [-0.68384]
GGDP (-2)	-0.119956 (0.11645) [-1.03007]	-0.006624 (0.00173) [-3.82184]	0.037882 (0.10348) [ 0.36606]
RV(-1)	-20.11358 (11.0810) [-1.81514]	0.400447 (0.16491) [ 2.42830]	4.756463 (9.84691) [0.48304]
RV(-2)	2.175093 (11.0406) [ 0.19701]	-0.199222 (0.16431) [-1.21250]	-15.23698 (9.81101) [-1.55305]
INF(-1)	-0.267848 (0.21618) [-1.23902]	-0.001054 (0.00322) [-0.32756]	0.068336 (0.19210) [ 0.35573]
INF(-2)	-0.041093 (0.21206) [-0.19378]	-0.001768 (0.00316) [-0.56021]	-0.233554 (0.18844) [-1.23938]
C	2.586131 (0.63168) [ 4.09407]	0.039828 (0.00940) [ 4.23670]	1.392899 (0.56133) [ 2.48143]

# Chapter 7

## Conclusions and Policy Implications

### 7.1 Introduction

After two consecutive oil shocks of 1970's, literature on analysing the impact of oil prices on economic activities gained momentum. With major contributions from several seminal works in this field, now it is well established in the literature that oil price shocks exert considerable adverse effect on the economic activities. Similarly, oil price volatility may also impact the economic activities through increasing uncertainty and sectoral reallocation channels. However, the literature in this regard is very limited and almost non-existent in the context of developing economies.

Furthermore, with the emergence of the concept of 'peak oil' and energy conservation possibilities, a considerable body of empirical literature has been written with relation to many economies around the world. However, literature concerning impact of oil consumption on economic activities of developing countries and oil conservation possibilities thereof is very limited. In addition to that, empirical studies concerning energy consumption and economic activities are recently criticised for the incompleteness of their models in terms of omitted variable bias that may lead to imperfect policy implications regarding energy conservation possibilities. The theoretical literature does not provide a solid foundation for examining such an association between energy and/or oil consumption, and economic activities. It, thus, remains an empirical issue to be investigated in a greater detail.

In this thesis the contribution of oil in economic development is investigated with the help of two different models. The first model, termed as *production-side approach*, analyses the contribution of oil consumption in economic activities within the neoclassical production function framework. The second model, termed as *demand-side approach*, analyses the contribution of energy consumption in economic activities in two stages. In the first stage, oil consumption demand is identified by a tri-variate model having oil prices as the third variable in addition to oil consumption and real GDP. In the second stage, carbon emission output is

determined in a tri-variate model with carbon emission as the third variable along with oil consumption and output. Furthermore, this thesis also analyses the impact of volatility on world crude oil prices on the economic activities of developing countries.

This thesis makes several theoretical and empirical contributions to energy economic analyses and energy economic modelling in order to address the gaps identified in the literature regarding the oil-development relationship. The major contributions can be summarised as follows: (1) it develops a complete methodology to analyse the impact of oil consumption on economic activities by using three different models from both *demand-* and *supply-side* economics together; (2) it investigates the complete oil-development nexus in the context of comparatively rarely studied yet highly important emerging economies of the world; (3) to the author's knowledge, this is the first study to include carbon emission in the oil-economy relationship in the context of developing countries and above all; (4) this is the first study to investigate the impact of oil price volatility in the developing economies, let alone the economies considered in this study.

## **7.2 Major Findings**

This thesis empirically investigates the impact of oil consumption, oil prices, and oil price volatility on the economic activities of six emerging economies of Asia. The oil consumption-economy nexus is analyzed within both *supply-* and *demand-side* frameworks. In the *supply-* or *production-side* model, oil consumption is considered as an additional factor of input in the traditional Cobb-Douglas-type production function. Time-series analysis indicates that in China a long-run uni-directional causality is running from oil consumption to output, while there is no causality between oil consumption and output in the short run. This finding is consistent with the fixed price model, the stickiness of oil price is further ensured by the Chinese Government's oil price subsidization policy. For India, there is a bi-directional causality between oil consumption and output both in the short run and long run. The empirical results for Indonesia are similar to that of India indicating bi-directional causality between the variables both in the short and long run. Uni-directional causality from oil consumption to output is running in both the short run and long run for Malaysia. In both Thailand and Philippines, causality runs from output to oil

consumption both in the short and long run. Both generalized impulse responses and variance decomposition results are consistent with the causality directions for most of these countries. Furthermore, a simple panel data analysis taking all the economies together indicates that oil consumption contributes significantly in the production process under different effect specification scenarios. To be more specific, the long-run elasticities of output with respect to oil consumption in the three different specifications, namely without any effect, time fixed effect and both time and country fixed effects are 0.0218, 0.3452 and 0.2214, respectively.

The relationship between oil consumption and output is further investigated through two *demand-side* models consisting of output, CO<sub>2</sub> emissions, oil price, and oil consumption. The first model investigates oil consumption-output relationship in the light of an oil consumption demand framework, while the second model investigates the relationship in a carbon emission output framework. According to the analysis for China based on time-series data for the first model of oil consumption demand, there is a uni-directional short-run causality running from output to oil consumption, while in the long run there is a bi-directional causality between the variables. For India, oil consumption Granger causes output both in short run and long run. In Indonesia, the empirical results indicate a uni-directional causality running from output to oil consumption both in the short and long run. Oil consumption Granger causes output both in the short run and long run in Malaysia. For Philippines, there exists a uni-directional causality from output to oil consumption in both of the time horizons. For Thailand, the long-run causality between oil consumption and output is bi-directional, while in the short run there is a uni-directional causality running from output to oil consumption. In the long run oil price Granger causes output of China, India and Malaysia. Both impulse response functions and variance decompositions analyses confirm the robustness of these causality findings. As far as the demand for oil consumption is concerned, the panel data analysis shows output has significant impact on the oil consumption demand when all the economies are studied together.

With a few exceptions, the causality directions identified within the second model for carbon emission output are similar for most of the countries. For China, Indonesia, Malaysia, and Thailand bi-directional causality is found in the long run. In addition to that, one very important finding of the empirical analysis of this

chapter is that for all the countries, except Malaysia, output Granger causes pollutant emission ( $\text{CO}_2$ ) both in the short run and long run. Taking all the countries together the panel data analysis shows that both oil consumption and output have significant impacts on pollutant emission under all different effect specification scenarios.

This thesis also investigates the short-term impact of oil price volatility in the concerned economies. The variables considered for this purpose are oil price volatility, output and inflation. Moreover, since Indonesia, Malaysia and Thailand were severely affected by the Asian financial crisis and as the data in hand portrays spikes during this period, this study implements two different VAR systems for these countries trying to compare between the impact channels for the whole period and for the period after the crisis.

Empirical results indicate that oil price volatility impacts output growth in the short run in China. For India, oil price volatility impacts both GDP growth and inflation, while oil price volatility impacts inflation in Philippines. Based on two different VAR analyses for Indonesia it can be inferred that, for the Indonesian economy oil price volatility impacts both GDP growth and inflation for both of the time periods; for the whole sample period and for the period after the Asian financial crisis. Furthermore, the link between GDP growth and inflation is bi-directional for both of the VAR systems. In both of the VAR systems for Malaysia, oil price volatility impacts GDP growth, while there is a very little feedback from the opposite side. From both the VAR analyses for Thailand it can be inferred that oil price volatility impacts output growth for the whole period. However, after the Asian financial crisis the impact seems to disappear. Furthermore, for all these economies GDP growth and inflation are closely related in the short run.

### 7.3 Policy Implications

Several policy implications emerge from the empirical findings:

It is inappropriate to devise any energy conservation related policy based on just one single perspective, i.e. *supply-side* or *demand-side* or with only a few variables in the system<sup>35</sup>. Hence, this study performs both *production-* and *demand-side* analysis by

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<sup>35</sup> For further insight on the limitations of studies with few variables to make any conservation related policies please consult Karanfil (2009).

investigating three different models to identify a common causality dynamics between oil consumption and output for the concerned countries. Despite dissimilarities in the results for causality relationships between oil consumption and output for different countries, one similar or common result has emerged. Except for the Philippines, all the other countries are found to be oil dependent either from *supply-side* or *demand-side* or from both. These results imply that, for all the considered developing economies, except for the Philippines, oil conservation policies seem to be harder to implement as that may retard their economic growth. These findings are consistent with the results of Fatai, Oxley & Scrimgeour (2004), where the authors suggest that since there is more need for energy in energy intensive industries in developing countries, energy conservation policy may be more feasible to industrialized countries like Australia and new Zealand rather than for some developing Asian countries. From this common ground, some policy implications can be offered to the countries.

For the Philippines, where uni-directional causality from income to oil consumption is found, she may contribute to the fight against global warming directly implementing energy conservation measures. The direction of causality indicates that the oil conservation policies can be initiated with little or no effects on economic growth. Moreover, for the Philippines, energy conservation offers a practical means of achieving development goals. It enhances the international competitiveness of industries in world markets by reducing the cost of production. It optimizes the use of capital resources by diverting lesser amounts in conservation investments as against huge capital investment in power sector where oil is used to generate power. It helps environment in the short run by reducing pollution and in the long run by reducing the scope of global climatic changes. Oil conservation also implies the substitution of costly imported oil by cheaper and more plentiful indigenous sources to supplement conventional sources.

For the rest of the oil dependent countries where either bi-directional causality or uni-directional causality from oil consumption to output is found in any of the models, the policy implications can be as follows. Since oil is a critical determinant of economic growth in these countries, its shortage may retard economic growth. However, in order to achieve high economic growth rates, multidimensional policies



are required and these policies should not ignore the energy sector. To facilitate the availability of energy and balance of payments position, alternative sources of energy should also be developed. Hence, a balanced combination of alternative policies seems to be appropriate for these economies.

These developing countries aspire to transform the economies into fully industrialized nations in the near future, while economic growth is the outcome of growth in inputs and increases the productivity of inputs. Hence, rapid industrialization requires higher and/or more efficient consumption of energy products.

Regarding output-carbon emission relationship, one very important finding is that, for almost all the countries output Granger causes pollutant emission ( $\text{CO}_2$ ) both in the short run and long run, suggesting that economic growth proceeds degradation of environment. Thus, for most of these countries, economic growth induces an increase in pollution levels. This finding is not surprising given that in most of these emerging economies much energy have been consumed in the production process to promote heavy industrialization. However, despite these findings, the policymakers of these countries should be mindful that a persistent decline in environmental quality may exert a negative externality to the economy through affecting human health, and thereby reduce productivity in the long run.

Nevertheless, all of these countries may initiate environmental policies aimed at decreasing energy intensity, increasing energy efficiency, and developing a market for emission trading. These countries can invest in research and development (R&D) to innovate technology that makes alternative energy sources more feasible, thus mitigating pressure in environment. They can, furthermore, increase utilization of public transportation and establish a price mechanism which may encourage the use of renewable and environmental friendly energy sources. Finally, given the directions of causality between the variables it should be noted that the policy makers of different countries should design their energy policies in the light of individual country's demand structure and energy mix.

The results of oil price-output relationship do not find any significant impact of oil prices on output of the concerned countries in the short run, while oil price affect

output of China, India and Malaysia in the long run. This result is also not surprising as most of these developing countries subsidize oil prices to insulate the economies from any adverse effect from oil price shocks. However, in the long run such policy may impact the economy through persistent budget deficit, which may impact fiscal policies to promote industrialization. Furthermore, this short-run insulation may transmit to other sectors of the economy like terms of trade position, investment, etc.

In addition to the above, oil price volatility seems to impact all the economies in the short run. According to the results, oil price volatility affects GDP growth in China and Malaysia, GDP growth and inflation in India and Indonesia, and inflation in Philippines. In Thailand the impact channels are different for pre- and post-Asian financial crisis period. For Thailand, it can be inferred that oil price volatility impacts output growth for the whole period, but after the Asian financial crisis the impact seems to disappear. This finding is consistent with Rafiq, Salim & Bloch (2009), where the authors find that impact of oil price volatility does no longer exist in the Thai economy after the financial crisis. Hence, the results after the financial crisis show that adverse effect of oil price volatility has been mitigated to some extent. It seems that oil subsidization of the Thai government by introduction of the oil fund and the flexible exchange rate regime plays a significant role in improving economic performance by lessening the adverse effect of oil price volatility on macroeconomic indicators. From the above reasoning, it can be suggested that, the Thai policymakers should keep pursuing its policy to stabilize domestic oil price through subsidization and thus help boost economic growth.

For all other countries, the impact of oil price volatility is of short term. Hence, the impact of oil price volatility on GDP growth in China and Malaysia, inflation and growth in India and Indonesia, and on inflation in the Philippines may be exerted though the uncertainty borne by the fluctuations in the crude oil price in the world market. As far as the impact on GDP growth is concerned, the short-run impact may also be transmitted through the investment uncertainties resulting from increased volatility in oil prices. However, from the Thai experience it can be inferred that flexible exchange rate regime insulates the economy in the short run from any adverse impact on growth. Hence, it may suggest that good subsidization policy with considerable knowledge on international currency market, both spot and future, can

shield the economies from adverse consequences due to the fluctuation in oil prices in the short run. Nevertheless, this may lead to affects on other sectors of the economy like, inflation, interest rate, government budget deficit, etc. Hence, a balanced and careful policy leadership can ensure sustained growth for these oil dependent developing countries even in the time of higher oil price volatility and fear of ‘peak oil.’

#### **7.4 Research Limitations and Suggestions for Future Research**

The empirical findings of this thesis facilitate understanding of the oil-development relationship from a multifaceted analysis of the dynamics between oil consumption, oil price, oil price volatility, and economic activities in six major developing economies of Asia. However, this study is subject to some limitations which need to be considered in interpreting results as well as carrying out further empirical studies.

Similar to other studies in developing countries, this study is constrained by the size of available data. If longer data series were available, it could have led this study to include more macroeconomic indicators into the models so that more meaningful and stronger policy implications could be made. For example, subject to the availability of reliable data, variables like interest rate and exchange rate which may affect oil demand could be included in the *demand-side* analysis. Furthermore, if there were more quarterly macroeconomic data available, inclusion of other variables like stock market index, budget deficit, interest rate, trade balance etc., could used to investigate the economy-wide impact of oil price volatility on different economies. Furthermore, given the availability of required data general equilibrium models could be used to investigate the contribution of oil on different sectors like agriculture or trade of the concerned economies. More data on oil price may help this study to use other volatility measures like conditional (GARCH or ARCH-type) or implied volatility to measure volatility in oil prices. Hence, the primary limitation of this study comes from unavailability of reliable data.

Since the concerned countries vary across the socio-economic conditions and energy consumption scenarios, this study primarily employed time-series econometric techniques. However, in some empirical analysis sections this study uses a very simple form of panel data analysis under different specification situations without

making any judgement regarding the stationarity of the data or possible cointegrating relationship. The extreme assumption of similar country dataset may cause estimation bias. However, the simple panel data estimation enabled this study to make a very general inference on the importance of oil consumption in the production process of these economies as a whole.

### **7.5 Concluding Remarks**

Despite the limitations stated above, this study has made some important contributions in theoretical and empirical literature of oil-development relationship. With respect to developing economies, this is the first study to investigate the importance of oil consumption on economic activities through a combined investigation of both *production-* and *demand-side* framework, more importantly by including pollutant emission in the oil consumption-economy relationship. Additionally, it develops a new two step methodology to analyse the *demand-side* implications of oil consumption on developing economies, more importantly this method helps to investigate the contribution of output and oil consumption in the environmental degradation mechanism in the development process. Furthermore, this is the first study to investigate the effects of oil price volatility in developing economies.

Finally, for policy makers and government of the concerned countries, the results of this study may serve as a guide for future planning, budgeting, and policy formulation in relation to the use of oil for the sustainable economic growth.

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