Oil Demand, Oil Prices, Economic Growth and the Resource Curse: An Empirical Analysis

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Abstract

It is generally accepted that oil has been vitally important to the global economy and the world has experienced growth in oil consumption for the majority of years since the early 1900s. In all probability, this trend will continue with the majority of the growth coming from the emerging economies - hence the global importance of oil is likely to continue. Against this backdrop, this thesis aims to analyse empirically the relationship between oil and the level of growth in economic output (or income) from a number of different angles.

The thesis begins by investigating oil demand; in particular, the relationship between oil consumption and income (as well as prices) across six regions of the world by applying the Structural Time Series Modelling (STSM) technique. Furthermore, the estimates are used to produce different forecast scenarios of oil demand for each of the regions up to 2030. According to the reference case assumption, global oil demand is projected to rise from about 87 mb/d in 2010 to 110.27 mb/d in 2030 consisting of strong growth in the Middle East, Africa and Asia Pacific, compared to a marginal growth in Europe and Eurasia while North American oil consumption is projected to decline.

The thesis also investigates the co-movements and causality relationship between oil prices and GDP of non-OECD countries, grouped depending on whether a country is a net oil exporter or net oil importer using both time-series and panel data models. The results suggest that there is a long-run cointegrating relationship between oil prices and GDP and that oil prices 'Granger-causes' GDP for the group of net oil exporting countries but fails to 'Granger-cause' GDP for the net oil importing countries. This implies that oil prices have a strong influence on economic output of net oil exporting countries with little or no influence on the economic output of net oil importing countries.

Finally, the research considers the resource curse hypothesis debate by employing recently developed heterogeneous panel analysis to investigate the long-term effect of oil abundance on economic growth. It is concluded that oil as a resource, cannot be attributed to the poor economic performance of most oil rich countries, but perhaps might have come about by weak institutional base and oil price volatility which usually has an adverse effect on long-term economic performance.

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Chapter 1

1 Introduction

Since the early discovery of oil in the 1800s, the product has been vitally important to the world economy. According to Painter (1986), the invention of the internal combustion engine was the major influence in the rise in the importance of oil. Hathaway (2009) noted that the importance of oil has risen to the extent that in a world suddenly without oil, all the major distribution systems that allow economic transactions on a more than local basis would fail and the world economy would collapse.

According to British Petroleum (BP, 2012), the average global oil consumption in 2011 was 88.03 million barrels per day, and with the 2011 world population figures reported in United Nations report (UN, 2012) at 7.022 billion people, it is roughly equivalent to every single person on the planet using two litres of oil a day. Along with this, the average nominal price of Brent crude for the first-half of 2012 stood at $113.45,[1] so the global consumption of oil cost almost $10 billion every single day or $1.42 for every person.

Of course, the global distribution of oil consumption is not evenly spread as the advanced countries of the Organisation of Economic Co-operation and Development (OECD) and oil rich countries consumes far more oil than less advanced countries and also, over the years, oil consumption has been declining

[1] Crude oil prices obtained from EIA (2012)

in the OECD countries.[2] Given oil demand is generally accepted as being one of the most important factors that determines oil prices, it is therefore important to understand current and future oil consumption patterns and how they affect the oil market.

Oil prices and its attendant consequence on economic output still remains an important issue confronting a growing number of world economies. The relationship between oil prices and the level of economic activity has been the subject of much attention for some time as there has been extensive empirical literature on the oil price-GDP relationship, covering the last three decades. Derby (1982) and Hamilton (1983) were among the early studies and they conclude that most economic recessions were preceded by a sharp rise in the price of oil. This notion over the years weakened as later empirical studies shows oil prices having lesser influence on economic output.

The mechanisms through which oil price changes affect economic activity include both supply and demand channels.[3] Despite the substantial research on the impact of oil prices on economic activity, the understanding of the transmission channels through which oil prices affect economic activity is far from a consensus. Moreover, the way oil prices influence the economy and the magnitude of their effects may have evolved through time. The mechanisms which were at work during the first two shocks in the 1970's are not necessary the same today (since the beginning of the 2000s). Indeed according to Hamilton (2009) the oil price hike of the 2000s, especially in 2007-08 was one of the biggest shocks to oil prices on record, however, the causes were quite

[2] See BP Statistical Review 2011

[3] The theoretical literature has been of a general equilibrium nature, with different authors assigning different weights for the supply and demand channels. See, for example Rotemberg and Woodford (1996)

different from the events of those of the 1970s. Moreover, Hamilton (2009) notes that the impact on the economy of both oil importing and exporting countries is somewhat less than previous oil price shocks. While the historical oil price shocks were primarily caused by significant disruption in crude oil production that were brought about by largely exogenous geopolitical events, Hamilton (2009) argued that the 2007-08 event has not been that of a reduction in supply but a failure of production to increase between 2005 and 2007. According to Kilian (2010), one of the reasons why the recent events has had low impact on the economy could be attributed to the fact that the 1970's were characterized by an increasing dependence of the economies on oil and poor macroeconomic performance but since 2000, economies (especially of the OECD countries) have tightened measures for controlling business shocks.

Furthermore, studies have shown that the consequence of oil price fluctuations are likely to be different in oil exporting and oil importing countries. According to Jimenez-Rodriguez and Sanchez (2004), it is generally believed that an oil price increase should be considered good news in oil exporting countries and bad news in oil importing countries. However, some studies on the macroeconomic implications of oil abundance on the economies of major oil exporting countries shows relatively different results. Gelb (1988) and Gylfason et al. (1999) all establish a strong negative correlation between resource abundance (oil) and economic growth. The reality has been that oil exporting countries have persistently experienced slow and, in some cases, volatile growth even in periods of consistent higher oil prices. This outcome negates normal macroeconomic expectations and is often tagged in the literature as the 'resource curse'.[4]

[4] A more detailed discussion of what is meant by the 'resource curse' is provided in

This thesis therefore explores the various links between oil resource, prices and the economy. It seeks to investigate the long-term effect of oil prices/oil abundance on economic growth of non-OECD countries. However, before analysing these effects, it is important to try and understand the key factors that drive crude oil prices. The supply-side of the oil market is mainly concerned with crude oil reserve and the challenges involved in making them available in the market. As indicated earlier, geopolitical factors can easily disrupt crude oil supply - a factor that is quite difficult to anticipate. Nevertheless, most recent oil price shocks are demand induced as stated by Hamilton (2009). Therefore, the thesis also focuses on estimating oil demand relationships which can serve as a useful tool for analysing long-term activities in the oil industry. As outlined in Energy Information Administration report (EIA, 2012), oil demand has been declining in the advanced regions mainly due to efficiency improvements - hence, it is important to capture the impact of energy efficiency when estimating oil demand relationships.

The empirical literature on the impact of oil prices and economic output has been extensive; however, most of the studies investigate the relationship in a time series context on the US and other countries of the OECD. This thesis seeks to add to the oil price/GDP literature by analysing the relationship on groups of non-OECD countries in both a time-series and a panel data context.

As indicated earlier, empirical studies on the impact of oil abundance on economic growth have shown that oil rich countries experience slower growth even in the face of higher oil prices. These studies mostly follow the Sachs and Warner (1995) cross sectional estimation technique which has been criti-

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cised due to numerous problems associated with the technique.[5] van der Ploeg (2011) suggested that future empirical work on natural resource curse should apply panel estimation techniques to avoid problems of omitted variable bias associated with cross-sectional estimation. Cavalcanti et al. (2011) further observed that panel approaches such as traditional fixed and random estimate and GMM estimators are also not appropriate since they impose high degree of homogeneity across the countries, suggesting the use of heterogeneous panel techniques.[6] This thesis therefore, in one of the core chapters, re-investigates the resource curse hypothesis by applying a heterogeneous panel estimation technique using oil production and oil reserve as measures for resource abundance.

In general, the thesis seeks to answer the following research questions.

1. How best can the impact of technical progress (TP) and other exogenous factors be captured when estimating time-series oil demand relationships?

2. What are the long-term effects of price and income on global oil demand, and what is the possible pattern of future oil consumption?

3. What is the long-run Granger-causality relationship between oil prices and GDP for various groups of non-OECD countries and does the impact for the net oil exporting countries differ from that of the net oil importing countries?

[5] See Brunnschweiler and Bulte (2008), Koedijk et al. (2011) and Cavalcanti et al. (2011) among others

[6] This is discussed further in Chapter 3

4. Does oil abundance lead to lower economic performance in oil rich exporting countries, and what are the long-term effects of oil abundance on the levels of per-capita output?

These research questions are addressed in three key chapters of this thesis; research questions 1 and 2 are addressed in Chapter 2, research question 3 is addressed in Chapter 3 while research question 4 is addressed in Chapter 4.

Before going any further, it is important to clarify the country groupings used in this thesis and why. The first key chapter (Chapter 2) analyses global oil demand for the six geo-political regions as classified by BP (2011) (i.e 'North America', 'South and Central America', 'Europe and Eurasia', 'Middle East', 'Africa' and 'Asia Pacific') given BP (2011) is the major source of data for the analysis. Given the research questions 3 and 4, Chapters 3 and 4 employ a different classification. These chapters, which investigate the long-term effects of oil prices/oil abundance on economic growth for non-OECD countries, are generally grouped into two broad categories - net oil exporting and net oil importing countries.

It is also useful before proceeding to the main part of the thesis, to give a general overview on global economic growth and the oil market. The next subsections therefore provide information on the nature of oil and the oil market; oil supply, demand and prices in the long-term; oil price history and analysis and finally global population and economic growth.

1.1 Nature of Oil and the Oil Market

Crude oil is a naturally occurring substance which is found in widely differing amounts in various countries throughout the world. Oil is not used directly for any important purpose, rather it is refined and split into different products which are either used directly for final consumption or are in turn further processed. Different crude oils yield different proportions of these refined products, and since the value is related to the end uses, those crude oils yielding higher proportions of valuable by-products (petroleum motor spirit, diesel fuels, jet fuels, petroleum gas etc) will tend to sell at a premium relative to other crude oils. According to EIA (2010), heavy crudes tend to sell at a discount because of the negative effects on the efficiency of refining process.

A given crude oil price determined on a particular day varies by location and date of delivery. Since crude oil is expensive to transport (long distance trade has to take place since most of the major consumers produce little or no crude oil), the price at the point of production and at the point of import are quite different. Nakamura (2008), in a study of oil refining and markets, shows that the margin for transport cost, insurance and handling cost can be substantial as long hauls may take several weeks and holding large inventories can be very expensive. Therefore, firms facing uncertain future demand often wish to purchase 'forward' that is, to pay a price determined now for delivery later (e.g in one month's time). Such a price can be quite different from the price for immediate delivery (spot) in the same market. However, over lengthy periods (using quarterly or annual average prices) the whole term structure of prices tends to move closely together.[7]

[7] See Kaufmann and Ullman (2009)

Conventionally oil prices are quoted in US dollars per barrel whatever the point of delivery. According to Fattouh (2007), the oil pricing regime is based on formula pricing, in which the price of certain crude is set as a differential to a certain reference price. He outlined three crudes that have tended to be the reference points, which are explained below.

I. Arab Light (API 34^0)[8] : This is crude produced in Saudi Arabia, the world's largest producer/exporter of crude oil. Ghanwar, is the primary producing field for Arab Light Crude and according to EIA (2011), Ghanwar is the world's largest onshore oil field with estimated remaining reserve of over 70 billion barrels. Since Saudi Arabia is a dominant producer, the price of this crude was seen as a key variable in the pricing strategy of the Organisation of Petroleum Exporting Countries (OPEC)[9] and a representative of Middle-Eastern production. According to Fattouh (2011), Arab Light prices have tended to be replaced by those of the similar Dubai Light (API 32^0) since the early 1990's as a representative crude price for Middle-Eastern production. In June 2005, the new OPEC reference basket was introduced. It is currently made up of the following: Saharan Blend (Algeria), Girassol (Angola), Oriente (Ecuador), Iran Heavy (Islamic Republic of Iran), Basra Light (Iraq), Kuwait Export (Kuwait), Es-Sider (Libya), Bonny Light (Nigeria), Qatar Marine (Qatar), Arab Light (Saudi Arabia), Murban (UAE) and Merey (Venezuela).

II. Brent Crude (API 38^0): Brent crude is sourced from the North

[8] API is a scale devised by the American Petroleum Institute to measure the specific gravity of crude oil

[9] OPEC's mission as stated in its website is to coordinate and unify petroleum policies of its member countries and ensure the stabilization of oil market in order to ensure an efficient, economic and regular supply of petroleum to consumers, steady income to producers and a fair return on capital to those investing in the petroleum industry

Sea. It is used to price two-thirds of the world's internationally traded crude oil supplies.[10] According to Platts (2012), the current API gravity for Brent crude is estimated at 38 degrees and the sulphur content at 0.45%, hence it is classified as sweet crude. The nearness of the North Sea to major refining industries and large market of North West Europe, has given this crude a central role over the past two decades.

III. West Texas Intermediate (API 40^0): This crude commonly referred to as WTI, serves as the reference point for the US market. WTI is light crude, lighter than Brent crude. According to Platts (2012), WTI contains about 0.3% sulphur and is rated as a sweet crude. WTI is expected to command a higher price than Brent crude - however, starting from late 2010, WTI began to sell at a discount due to rapid increases in crude oil production from tight oil formation.[11] It is further reported that Brent has become more representative in the marginal cost of crude oil which led to the EIA in July 2012 to begin to publish Brent crude spot price forecast as against the WTI it normally used.

Fattouh (2007) argued that the oil market has undergone structural transformation that has placed oil prices on a new high path, which according to Fattouh (2007), is due to the emergence of new large consumers (such as China and India) and the geopolitical uncertainties in the Middle East - hence, the reaction of the oil market is generally in response to market fundamentals of supply and demand.

[10] See Bacon and Tordo (2005)

[11] See EIA (2012)

1.2 Oil Supply, Demand and Prices in the Long-term

Oil prices are influenced by a number factors, including some such as speculation, that are mainly short-term impacts. Other factors such as OPEC production decisions and expectation about future world demand for oil affects prices in the longer term. Supply and demand in the world oil market are balanced through responses to price movements, and the factors underlying supply and demand expectations are numerous and complex. According to EIA (2012), the key factors determining long-term supply, demand and prices for petroleum and other liquids[12] can be summarized in four broad categories: the economics of non-OPEC supply; OPEC investment and production decisions; the economics of other liquids supply; and world demand for petroleum and other liquids. OPEC's role is a critical factor in determining long-term oil supply because oil resource is only available in limited amount within a particular geographical distribution, and more than 70% of proved oil reserves are concentrated in the OPEC countries. Table 1.1 reports proved world oil reserves by regions, as it stands by the end of 1990, end of 2000 and end of 2010.

In 2010, almost 55% of global oil reserve is concentrated in the Middle East which makes the region quite essential, and of strategic importance for the future oil supply requirements of the industrialized and other emerging economies. Out of the 752.5 billion barrels of oil reserve available in the Middle East in 2010, 264.5 billion barrels (or 35%) is situated in Saudi Arabia. Other countries with huge oil reserve in the region include Iran, Iraq and Kuwait -

[12] According to the EIA (2012) report, the term 'petroleum' refers to crude oil, condensate, natural gas liquids and refinery gain while the term 'other liquids' refers to bio-fuels, bitumen (oil sands), coal-to-liquids (CTL), biomass-to-liquids (BTL), gas-to-liquids (GTL) and oil shale.

all with a proved reserve of over 100 billion barrels of oil (See Appendix 1.2 for the individual country's oil reserve and oil consumption).

Table 1.1

Proved Oil Reserves (Thousand million barrels)

Region	End of 1990	End of 2000	End of 2010
North America	96.3	68.9	74.3
South and Cen. America	71.5	97.9	239.4
Europe and Eurasia	80.8	107.9	139.7
Middle East	659.6	696.7	752.5
Africa	58.7	93.4	132.1
Asia Pacific	36.3	40.1	45.2
World Total	**1,003.2**	**1,104.9**	**1,383.2**
OPEC	763.4	849.7	1,068.4
Non-OPEC[13]	176.5	168.2	188.7
Former Soviet Union	63.3	87.1	126.1

Source: BP Statistical Review 2011

South and Central America experience a huge growth in oil reserve from 97.9 billion barrels at the end of the year 2000 to 239.4 billion barrels by the end of 2010, making it the second largest oil reserve region in the world. The growth in oil reserve within the period was driven by huge oil discovery in Venezuela over the period - Venezuelan oil reserve grew from 76.8 billion barrels in 2000 to 211.2 billion barrels by the end of 2010,[14] representing a rise of 175%.

[13] Excludes Former Soviet Union

[14] According to Schenker (2011), Venezuela's oil reserve have apparently grown by including more of the country's unconventional extra heavy crude, which is much more difficult and expensive to extract from the ground and process than oil found elsewhere.

By the end of 2010, Europe/Eurasia and Africa have a proved reserve reserve of 139.7 billion barrels and 132.1 billion barrels respectively; with 55% of the total reserve from Europe/Eurasia held by the Russian Federation. Libya and Nigeria are the two countries with huge reserves from Africa, together accounting for almost 65% of total oil reserve from the region. North America and Asia Pacific holds a reserve of 74.3 billion barrels and 45.2 billion barrels respectively.

More than three-quarters (77.24%) of global oil reserve is concentrated in the OPEC countries. This, in all probability, makes OPEC's investment and production decisions a critical factor in determining long-term global energy security.

While Asia Pacific and North America have the lowest oil reserve, the two regions have the highest oil consumption in 2010, accounting for 58% of global oil consumption. Total oil consumption for Asia Pacific and North America in 2010 are 27.24 mb/d and 23.42 mb/d respectively. Over the past two decades, Asia Pacific's oil consumption almost doubled from 13.81 mb/d in 1990 to 27.24 mb/d in 2010, mainly driven by economic growth in the region, particularly from China and India. China, with 9.057 mb/d accounts for one-thirds (33.25%) of total oil consumption in the region in 2010 while India's oil consumption is 3.319 mb/d.

United States is by far the largest crude oil consumer with a daily oil consumption of 19.148 mb/d in 2010. However, oil consumption has peaked sometime between 2000 and 2010 as total oil consumption in 2000 (19.701 mb/d) is slightly more than 2010 which is also the case with so many other advanced countries of the OECD. Multinational organisations such the International Energy Agency (IEA) and the EIA have suggested that the decline in oil consumption is partly due to efficiency improvements (or in other words efficiency gains).[15]

Table 1.2

Oil Consumption (Thousand of barrels daily)

Region	End of 1990	End of 2000	End of 2010
North America	20,316	23,574	23,418
South and Cen. America	3,623	4,855	6,104
Europe and Eurasia	23,247	19,582	19,510
Middle East	3,559	5,021	7,821
Africa	1,943	2,439	3,291
Asia Pacific	13,814	21,135	27,237
World Total	**66,503**	**76,605**	**87,382**
OECD	41,667	48,128	46,438
Non-OECD	24,836	28,477	40,944

Source: BP Statistical Review 2011

Europe and Eurasia presents a very interesting trend in oil consumption over the past two decades. The region has the highest oil consumption (23.24 mb/d) in 1990 before declining to 19.582 mb/d in 2000 and 19.510 mb/d in 2010. While the slight decline between 2000 and 2010 could be attributed to efficiency gains, the drastic fall between 1990 and 2000 was mainly due to fuel switching from oil to other sources for electricity generation in the Former Soviet Union.

Oil consumption has doubled in the Middle East between 1990 and 2010 and almost doubled in South/Central America and Africa. The 2010 figures

[15] See IEA (2012)

stood at 6.104 mb/d, 7.821 mb/d and 3.291 mb/d for South/Central America, Middle east and Africa respectively. Generally, growth in oil consumption over the past decade is mainly supported by the developing regions as oil consumption declined by 3.51% in the OECD between 2000 and 2010, while it rose by 43.78% in the non-OECD.

1.3 Oil Price History and Analysis

Oil has by far the greatest value of traded primary commodities, making it of interest to exporters and importers alike (Bacon 1991). It is a key primary energy source and it is often argued that no other fuel can compete for many of its uses in terms of price and convenience. The price of oil even at an annual average basis has experienced enormous movements in the past.

Crude oil prices behave much as any other commodity with wide price swings in times of shortage or oversupply. In norminal terms, oil prices ranged between $1.71 and $2.00 from 1950 through to the end of 1960s. When viewed in real terms (2011 dollar), the price of crude oil fluctuated between $11 and $14 during the period (BP 2011). As a whole, the price of oil was relatively stable during this period.

OPEC was established in 1960 with five founding members Iran, Iraq, Saudi Arabia, Kuwait and Venezuela. By the end of 1971, six other nations joined the group: Qatar, Nigeria, United Arab Emirates, Algeria, Indonesia and Libya. From the formation of OPEC through to 1972, the price of oil experienced steady decline. However, a little over two years later, OPEC through the unintended consequence of war asserted its power to influence prices. According to Seymour (1980), the significant oil price increases of the 1970s convinced many observers that OPEC had become a cartel that its founders envisioned.

1.3.1 First Oil Price Shock 1973 - 1977

The Yom Kippur War between Israel and Egypt which started in October 1973 quadrupled the price of oil from \$2.48 per barrel in 1972 to over \$11.58 per barrel[16] in 1974. The United States and many countries in the Western world showed support for Israel. Several Arab exporting nations including Iran imposed an embargo on the countries supporting Israel. OPEC success showed at the beginning of the 70's, as the rising oil demand exceeded production. Moreover, oil producing countries began to even ask for more concessions. Muammar-al-Gaddafi, taking over power after a military coup in Libya obtained a 20% due increase and an agreement to split profits 55-45% (Yergin 1990). During this period, production was cut by 4.3 million barrels per day (OPEC 2008) and the embargo contributed to economic recession during the period[17]. After the embargo, considerable efforts were made to preserve energy and pass from oil to alternative energy sources. According to Irawan (2012), the IEA was created in 1974 within the framework of the OECD in reaction to the oil crisis of 1973 when OPEC launched an embargo over the selling of their crude oil as a protest against US decision for supporting Israel in the Yon Kippur War.

The first oil price shock was an important economic and political event,

[16] All crude oil prices quoted in this Chapter are nominal prices of Europe Brent Crude unless otherwise stated

[17] According to Jones et al. (2004), US GDP decreased by 6% in the next two years; Japanese economy contracted for the first time after the Second World War

which led to controversies and debates in the years and decades that followed. Livia (2006) identified the many point of view and theories on the first oil price shock into three different categories; the Traditional point of view regarding the oil crisis, Dependence theories regarding the oil crisis and Conspiracy theories regarding the oil crisis. According to Livia (2006), the traditionalists point of view to the crisis often refer to the oligopolistic structures of the oil companies, collective decision of OPEC and to the demand and supply interaction on the international oil market. The dependence theories considered the oil crisis as a form of manifestation of economic nationalism in Third World states, in order to gain an equality position in the relationship with industrial powers. The conspiracy theories however, are based on the idea according to which the American Government, in collaboration with the oil companies and OPEC, intentionally started the crisis. The argument is based on the effects the crisis had which were negligible for the American economy, as compared to the effects on European and Japanese economy.

1.3.2 Second Oil Price Shock 1978 - 1982

From 1974 – 1978, the world crude oil price was relatively flat ranging from \$11.58 to \$14.02 per barrel. In 1979 and 1980, events in Iran and Iraq led to another round of crude oil price increases. According to OPEC (2005), the Iranian revolution resulted in the loss of 2 to 2.5 million barrels per day of oil production between November 1978 and June 1979. In September 1980, Iran was invaded by Iraq. The combined production of both countries was only a million barrels per day compared to 7.5 million barrels per day the previous year. The combination of the Iranian revolution and the Iraq–Iran War caused crude oil prices to more than double increasing from $14 in 1978 to $35 per barrel in 1981 (BP 2008).

1.3.3 Price Collapse, Sideways with a Spike 1983 - 1995

Higher prices also results in increased exploration and production outside of OPEC. From 1983 to 1986 non OPEC production increased by 10 million barrels per day. OPEC was faced with weakening demand and higher supply from outside the organisation. OPEC attempted to set production quotas low enough to stabilize prices but minimal success was achieved as various member countries produced beyond their quotas so that crude oil prices collapsed, reaching as low as $8 in May 1986 (WTRG 2010).[18] Temporary agreements were reached to cut production in August, some non-OPEC members also pledged production cuts. There was relative stability at around $18 per barrel between 1987 and 1989, the price remained stable until 1990 when the price of oil spiked to $35/barrel due to lower production and uncertainty associated with the Iraqi invasion of Kuwait and the ensuing Gulf War. Following the War, oil prices entered a period of steady decline with the spot price falling to $14.74 per barrel in 1994. The price then turned up mainly due to a strong US economy and a booming Asian Pacific region. From 1990 to 1997, world oil consumption increased by 6.2 million barrels per day which contributed to a price recovery that extended into 1997.

[18] WTRG Economics undertake analysis, planning, forecast and data services for energy producers and consumers

1.3.4 Collapse and Recovery 1997 - 2003

The price increase came to rapid end in 1997 and 1998 when the impact of the economic crisis in Asia was severely underestimated by OPEC. In December 1997, OPEC increased its quota by 2.5 million barrels per day (10 percent) with effect from January 1998. In 1998, Asian Pacific oil consumption declined for the first time since 1982. The combination of lower consumption and higher OPEC production send prices into a downward spiral. In response, OPEC cut production by 1.2 mb/d in April and another 1.33 mb/d in July.[19] Price continued to go down through December 1998. Prices began to recover in early 1999 as OPEC reduced production by another 1.71 mb/d in March, joined by non-OPEC production cut. By mid 1999, OPEC production dropped by about 3 million barrels per day and was sufficient to move prices above $25 per barrel. With growing US and world economies, the price continued to rise throughout 2000. Between April and October 2000, three successive OPEC quota increases totalling 3.2 million barrels per day were not able to stem the oil price increases. Prices finally started falling down following another quota increase of 500,000 barrels effective November 2000.

Russian production increases dominated non-OPEC production growth from 2000 and was responsible for most of the non-OPEC increase. In 2001, the weakened US economy and increases in non-OPEC production put downward pressure on prices. In response, OPEC cut production by 3.5 million barrels in September, 2001. In the wake of the September 11, 2001 attack, crude oil prices plummeted. Spot price of the US benchmark West Texas Intermediate

[19] Details of OPEC production cut/production increase were extracted from summary notes on Member Country's Crude Oil Production Allocations (1982-2007) as agreed at the various (Extraordinary) Meetings of the OPEC Conference, contained in the OPEC Annual Statistical Bulletin 2008.

was down 35% by the middle of November. OPEC delayed additional cuts until January 2002 when it reduces its quota by 1.5 million barrels per day and was joined by several other non-OPEC producers including Russia. Oil price moved up to $25 range by March, 2002. The non-OPEC members restored their production cuts by mid-year but prices continued to rise while US inventories reached a 20 year low later in the year. Furthermore, strike in Venezuela caused Venezuelan production to plummet. OPEC increased quotas by 2.8 million barrels per day in January and February 2003.

1.3.5 Ramp-up and Price Spike 2003 - 2009

On March 19, 2003, just as some Venezuelan production was beginning to return, military action commenced in Iraq. Meanwhile, inventories remained low in the US and other OECD countries. With an improved economy, US demand was increasing while Asian demand was also growing rapidly. The loss of production capacity in Iraq and Venezuela combined with increased OPEC production to meet international demand led to the erosion of excess oil production capacity. In mid 2002, there was over 6 million barrels per day of excess production capacity but by mid-2003, the excess was below 2 million barrels. The 2004 rise was caused by unexpectedly strong demand growth (China) and supply problems. According to EIA (2009), non-OPEC production also failed to grow and during much of 2004 and 2005, the spare capacity to produce oil was under a million barrels per day. This added a significant risk in a world that consumes over 80 million barrels per day and is largely responsible for crude oil prices in excess of $40-$50 per barrel (WTRG 2010). Further oil price rises in 2006, but then falling back quite sharply into

2007. OPEC took action to reduce stock overhang and market tightened again. There was fear of supply not keeping up with growing demand.

Oil price reached record high levels in July 2008, both in nominal and real terms, with the bench mark of Europe Brent crude reaching $147/bbl. Oil price rose steadily from early 2004 but the 18 month period beginning January 2007 saw price surge of more than 150%. The situation subsequently changed dramatically, oil price collapsed by more than 75% by the end of the year, from $147/bbl in July to $36/bbl in December 2008 before rallying up to around $70/bbl in early June 2009 and remained so throughout the year.

By any measure, this episode qualifies as one of the biggest shocks to oil price on record. However, the causes were quite different from those associated with the other episodes above. Hamilton (2009) argued that the big story is not a dramatic reduction in supply but a failure of production to increase between 2005 and 2007. Even as global supply stagnated, global demand was growing strongly, particularly, oil consumption growth in China. Chinese consumption was 870,000 barrels a day higher than just two years earlier. The underlying fear that supply could not keep up with growing demand, rapidly rising costs outside OPEC, growing concern over the end of cheap oil increased demand for inventory as well as the role of speculation accelerated the movements of prices (EIA, 2009). According to OPEC (2010), the weakening of the US dollars also greatly contributed to the record high prices.

It is generally believed that one of the major factors that led to the collapse of the oil price was the widening economic downturn which sharply erodes oil demand in the OECD countries as well as undermines growth in the emerging economies. The G-20 summit in April 2009 was instrumental in calming financial markets and supporting the recovery of equities. Furthermore, massive government fiscal and monetary support on a global scale was able to stabilize economic output and gradually optimism began to spread on signs pointing to a recovery before the end of the year. Oil prices were supported by these resulting improvements.

1.3.6 Price Rise 2010 - 2012

On the back of improved economic growth and colder weather in the Northern Hemisphere, crude oil price surged from $70.7/bbl in mid-December 2009 to $80.29/bbl on January 7, the highest since early October 2008 (EIA, 2011). For most of 2010, the monthly average price fluctuates between $72 and $82/bbl, reaching $91.45/bbl in December. The world economy experienced significant recovery in 2010; growing at a monthly average of 4.32% according to World Bank (2010). This has been an impressive reversal from the recession in 2009 which, to a large extent explains the increase in oil price recorded in 2010.

In 2011, oil price began with a strong surge following geo-political events in the MENA region. From February to December 2011, oil price fluctuated in a range of between $103 and $123/bbl. According to OPEC (2011b), the price of oil in 2011 generally moved in tandem with macro economic sentiments - rising positively on positive data before falling again when economic uncertaities reasserted themselves. For the first time ever, the annual average norminal price of Europe Brent crude went above $100, to stay at $111.26/bbl.

The first quarter of 2012 witnessed significant increase in the price of oil; with the monthly average price for the first three months of the year being

$110.69, $119.33 and $125.45 respectively. According to OPEC (2012b), the upward push was driven by a number of factors including supply disruption in the North Sea and some countries in West and East Africa, supply fears due to geo-political tensions, and increasing speculative activities in the crude oil futures markets. In the second quarter, prices fell below $100 which, according to OPEC (2012b) is due to gloomy economic outlook, particularly in the Euro zone. The price of oil bounced back to around $110 in the third quarter. The annual average price for 2012 stood at $111.63/bbl, almost the same as the annual average price recorded in 2011.

The episodes of oil price history beginning from the first price shock in 1973 – 1974 to the most recent shock explain why oil price changes receive important consideration for their presumed role on macroeconomic variables. As indicated earlier, several models have credited oil price shocks with affecting the natural rate of unemployment (Phelps 1994; Caruth et al., 1998), affecting business cycle (Davis 1986), contributing to recession (Hamilton 1983). Thus, from a theoretical point of view, there are different reasons why an oil price shock should affect macroeconomic variables, some studies suggesting that this would be a non-linear relationship.

Market fundamentals, as explained earlier, are the major factors that affect oil prices in the long-term. While Chapter 2 explores (in greater detail) the role of price, income and population in determining long-term oil demand, it is important to provide a background analysis of global population and economic growth trends over the years.

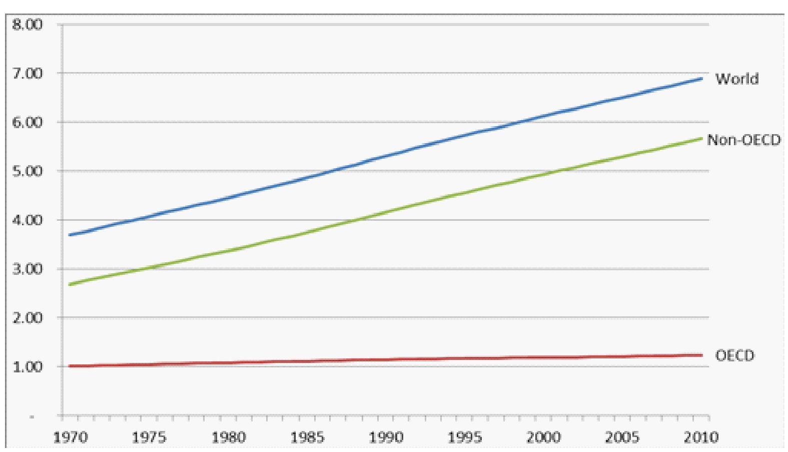
1.4 Overview of Population and Economic Growth Performance

This section provides an overview of global population and economic growth trends - both of which are important factors in analysing long-term economic performance. The analysis is conducted in the global context as well as OECD and non-OECD groups of countries.

1.4.1 Global Population Growth

According to UN (2010), global population nearly doubled over the past four decades from 3.69 billion in 1970 to 6.90 billion in 2010 as shown in Figure 1.1a. The annual average growth rate over the period was 1.57%. The growth in population was mainly driven by the non-OECD countries which grew an annual average rate of 1.88% while population in the OECD countries grew at an average rate of 0.51% per annum.

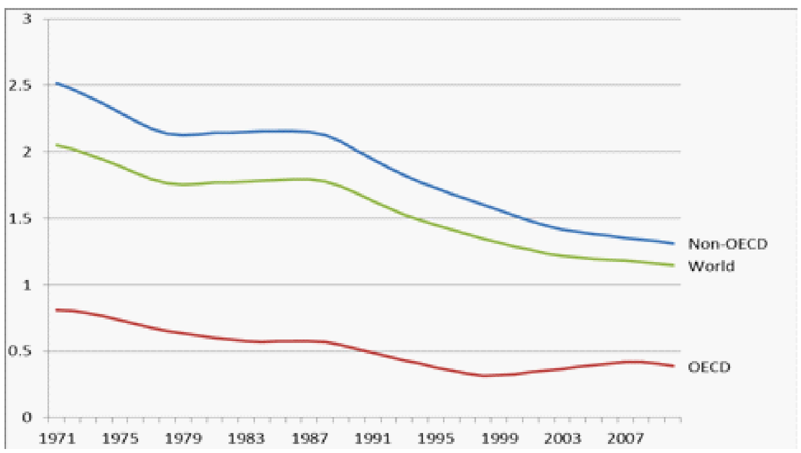
Figure 1.1a: Global Population (Billion)



Source: UN (2010)

Generally, population growth has been declining in both regions as shown in Figure 1.1b. Population growth declined from 2.51% in 1970 to 1.31% in 2010 for the developing region while it declined from 0.81% in 1970 to 0.38% in 2010 for the developed region. OECD's share of world population fell from 27.22% in 1970 to 19.72% in 2010 while the share of non-OECD increased from 72.77% in 1970 to 82.08% in 2010. According to UN (2010), world population is expected to reach 9.3 billion in 2050 and 10.1 billion in 2100.

Figure 1.1b: Population Growth Rates

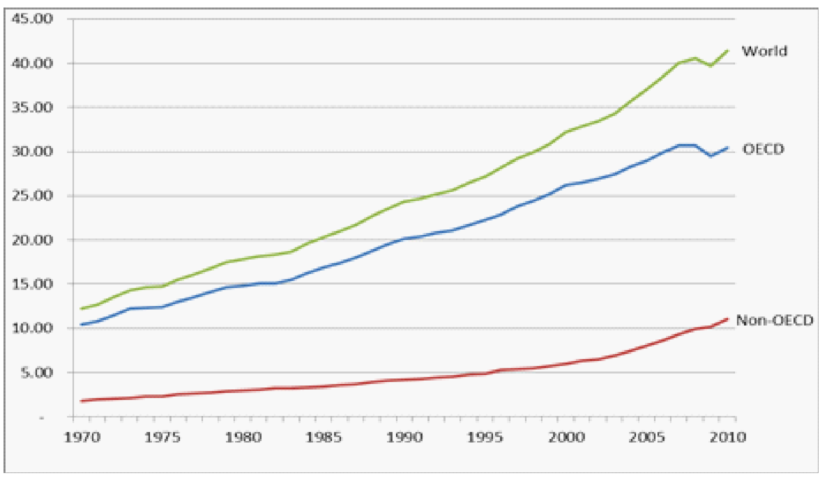


Source: UN (2010)

1.4.2 Global Economic Growth

According to World Bank (2012), global real GDP (at 2000 prices) grew from $12.20 trillion in 1970 to $41.40 in 2010, representing a rise of 239% over the period, and an average growth rate of 3.11% per year. In 2010, the share of OECD in global GDP was 73.49%, down from 85.24% in 1970. Emerging economies such as China and India have experienced unprecedented growth rates over the past decade which helped bridge the gap between the developed and developing regions. As shown in Figure 1.2a, GDP in the OECD increased from \$10.4 trillion in 1970 to \$30.40 trillion in 2010; an average increase of 2.73% per year while GDP in the non-OECD expanded from \$1.80 trillion in 1970 to \$11 trillion in 2010, an average annual increase of 4.65% over the period.

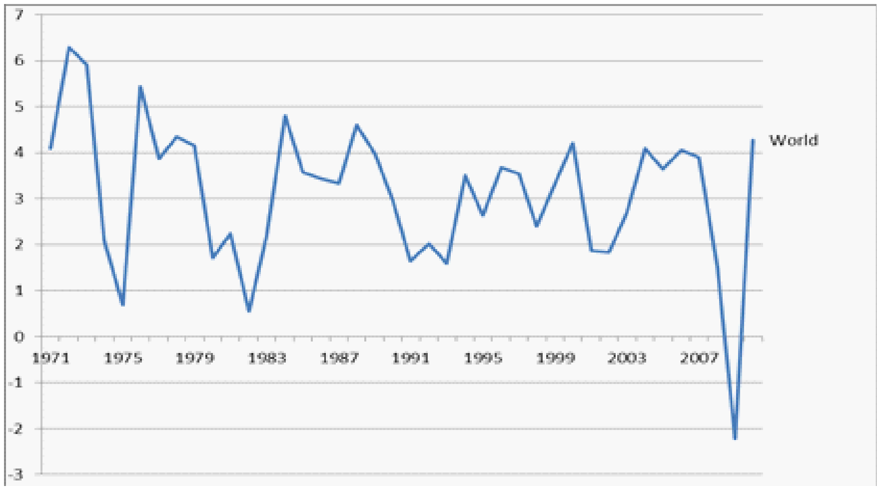
Figure 1.2a: Global GDP (\$Trillion)



Source: World Bank (2012)

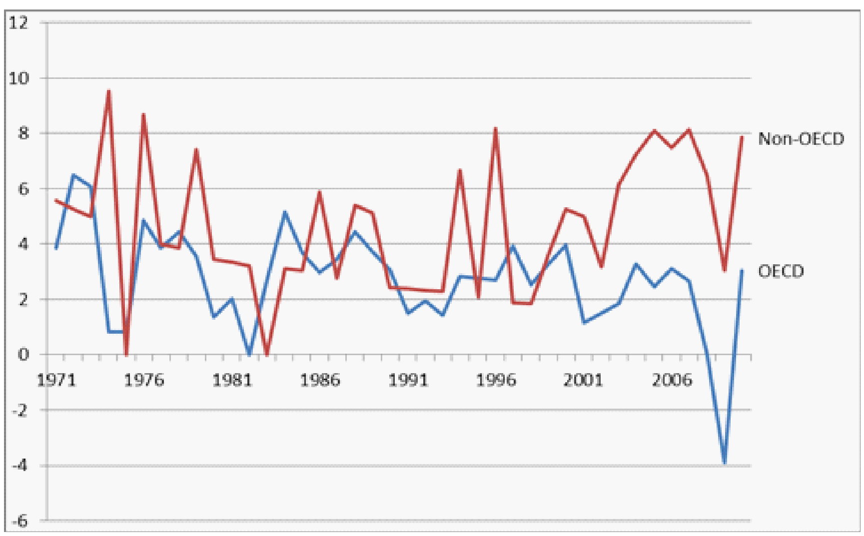
Global GDP growth rates has been volatile over the past three decades as dipicted in the charts below. Figures 1.2b and 1.2c shows the annual GDP growth rates for the world, and also OECD and non-OECD respectively. Due to the volatile nature of the growth rates, the charts are separeted in order to provide a clearer picture.

Figure 1.2b: World GDP Growth Rates



Source: World Bank (2012)

Figure 1.2c: OECD and Non-OECD GDP Growth Rates



Source: World Bank (2012)

Both the OECD and non-OECD regions have experienced volatile growth over the period, with the OECD being slightly less volatile as depicted in Figure 1.2c. The 1970s was particularly more volatile for both regions around the time of the first and second oil price shocks and also, the average growth rate (for both the OECD and non-OECD) is very similar between 1970 and 1999 as shown by the overlapping growth rates in Figure 1.2c during the period. However, from 2000 to 2010, non-OECD growth rate is clearly above the OECD - according to Kuijs (2012), China and India dominated growth in the non-OECD during the period, with an average growth rate of 9% and 7.5% respectively. In general, even though the global economy experienced unprecedented growth (at levels) over the last four decades, the annual growth rates have been quite volatile. While GDP figures or GDP growth rates over time is a very useful indicator to measure economic output, Gutierrez et al. (2007) argued that it is not an appropriate indicator to measure standard of living of a country or region - but rather, per capita GDP which shows individual contribution or value.

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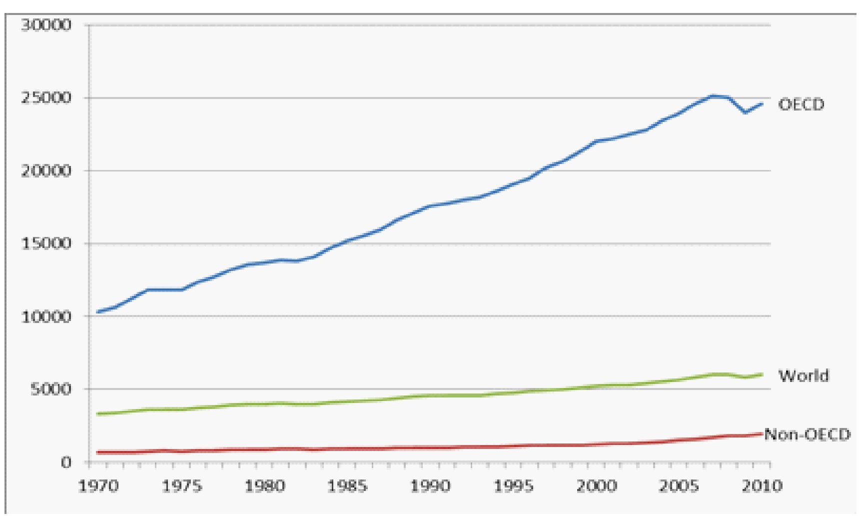
Figure 1.3: Per capita GDP (USD)



Source: UN (2010) and World Bank (2012)

World per capita GDP increased from $3,300 in 1970 to $6,003 in 2010. As shown in Figure 1.3, there is a wide disparity in per capita GDP between the OECD and non-OECD regions - average per capita GDP for the OECD over the period is $17,597 while it is $1,089 for the non-OECD.

The above background of the oil market, prices and economic growth provides a back drop to the long-term analysis of oil and economic growth. As outlined in the introduction, the thesis seek to empirically analyse the relationship using time-series and panel data techniques. The next section briefly explains the composition and methodology of the analysis undertaken in each chapter of the thesis.

1.5 The Thesis

The research questions outlined earlier are addressed in three core chapters; hence, the thesis comprises of five chapters with Chapters 1 and 5 being Introduction and Conclusion accordingly.

Chapter 2 applies the Structural Time Series Modelling (STSM) technique to investigate the relationship between aggregate oil consumption, income and prices across six regions of the world.[20] Following arguments in the energy economics literature on how to appropriately capture the impact of technical progress when modelling energy demand, the chapter incorporates asymmetric price responses (APR) and the Underlying Energy Demand Trend (UEDT) to capture endogenous and exogenous technical progress respectively. The estimates obtained are then used to produce future forecast scenarios of oil

[20] The reasons for using the STSM are explained in Chapter 2

demand for each of the six regions up to 2030, based on different assumptions about future path of key variables that drive oil consumption.

Chapter 3 analyses the co-movements and causality relationship between oil prices and economic growth, covering 28 countries. The chapter mainly focuses on non-OECD countries and applies both time-series and panel estimation technique. Estimating causality relationship, whether in a time-series or panel context involves four different stages; firstly, unit root test is applied to confirm the order of integration of the variables. If the variables are found to be integrated of the same order, the long-run cointegrating relationship is estimated at the second stage of the process. If cointegration is found, the long-run cointegrating relationship is estimated before finally testing for the direction of causality.

While initial researches assumes a symmetric model, contemporary time-series studies of oil price-GDP relationship almost always focus on studying both symmetric and asymmetric impacts of oil prices on the macro economy. Even though the main aim of the chapter is to investigate long-run impact of oil prices on economic growth, the study also seek to investigate whether the impact of oil prices on net oil exporting countries is different from net oil importing countries. Therefore, the panel groupings are done according to whether a country is a net oil exporter or a net oil importer.

Chapter 4 addresses the last research question relating to the resource curse hypothesis. The chapter investigates the hypothesis by applying a heterogeneous panel analysis to investigate the effect of natural resource abundance on economic growth, using oil production and oil reserve as proxies of natural resource abundance. As is the case in Chapter 3, the country groupings are done according to whether a country is a net oil exporter or net oil importer and the estimation process also followed the similar stages. However, for this chapter, only heterogeneous tests are applied at every stage. The recent heterogeneous error correction model based on Canning and Pedroni (2008) is utilized to estimate the short-run impact of resource abundance, and how fast it reverts to a long-run equilibrium following a shock in the system.

1.6 Appendix to Chapter 1

1.6.1 Appendix 1.1: Proved Oil Reserves by Country

In order to provide a clearer picture of the individual countries that make-up the regional proved oil reserve figures reported in Table 1.1, the individual countries' proved oil reserve as at the end of 1990, 2000 and 2010 are reported in Appendix 1.1. According to BP (2012), Canada has the highest proved oil reserve in North America in 2010 with 32.1 billion barrels of oil followed by the United States and Mexico with 30.9 and 11.4 billion barrels respectively. According to EIA (2010), Canadian oil reserve grew tremendously due to huge discovery of heavy oil in the early 2000s.

Table A1.1

Proved Oil Reserves (Billion Barrels)

Country	End of 1990	End of 2000	End of 2010
United States	33.8	30.4	30.9
Canada	11.2	18.3	32.1
Mexico	51.3	20.2	11.4
Total North Ame.	96.3	68.9	74.3
Argentina	1.4	3.0	2.5
Brazil	4.5	8.5	14.2
Colombia	2.0	2.0	1.9
Ecuador	1.4	4.6	6.2
Venezuela	60.1	76.8	211.2
Other S. & C. Ame.	2.0	3.1	3.4
Total S. & C. Ame.	71.5	97.9	239.4
Azerbidjan	n/a	1.2	7.0
Khazakhtan	n/a	25.0	39.8
Norway	8.6	11.4	6.7
Russian Fed.	n/a	59.0	77.4
United Kingdom	4.0	4.7	2.8
Other Eur. & Eurasia	68.2	6.6	6.0
Total Eur. & Eurasia	80.8	107.9	139.7

Source: BP Statistical Review 2012

According to BP (2012), almost 90% of the total proved oil reserve in South and Central America is located in Venezuela. This is also as a result of huge discovery of heavy oil in the early 2000s as reported in EIA (2010). Europe and Eurasia's oil reserve is mostly located in Russia and Kazakhtan which respectively accounts for 55.4% and 28.4% of total oil reserve in the region.

Table A1.2

Proved Oil Reserves (Billion Barrels)

Country	End of 1990	End of 2000	End of 2010
Iran	92.9	99.5	137.0
Iraq	100.0	112.5	115.0
Kuwait	97.0	96.5	101.5
Oman	4.4	5.8	5.5
Qatar	3.0	16.9	25.9
Saudi Arabia	260.3	262.8	264.5
Syria	1.9	2.3	2.5
UAE	98.1	97.8	97.8
Yemen	2.0	2.4	2.7
Other Middle East	0.1	0.2	0.1
Total Middle East	659.6	696.7	752.5
Algeria	9.2	11.3	12.2
Angola	1.6	6.0	13.5
Egypt	3.5	3.6	4.5
Gabon	0.9	2.4	3.7
Libya	22.8	36.0	46.4
Nigeria	17.1	29.0	37.2
Sudan	0.3	0.6	6.7
Other Africa	3.4	2.8	7.8
Total Africa	58.7	93.4	132.1

Source: BP Statistical Review 2012

The Middle East is by far the region with the highest oil reserve - the region has 4 countries with more than 100 billion barrels of oil reserve by the end of 2010. According to BP (2010), Saudi Arabia accounts for 35.1% of proved oil reserve in the Middle East with 264.5 billion barrels. The other 3 countries are Iran, Iraq and Kuwait with 137, 115 and 101 billion barrels respectively.

Libya has the largest proved oil reserve in Africa with 46.4 billion barrels followed by Nigeria and Algeria with 37.2 and 12.2 billion barrels respectively.

Table A1.3

Proved Oil Reserves (Billion Barrels)

Country	End of 1990	End of 2000	End of 2010
Australia	3.2	4.9	4.1
China	16.0	15.2	14.8
India	5.6	5.3	9.0
Indonesia	5.4	5.1	4.2
Malaysia	3.6	4.5	5.8
Vietnam	0.2	2.0	4.4
Other Asia Pac.	2.4	3.0	2.8
Total Asia Pac.	36.3	40.1	45.2

Source: BP Statistical Review 2012

According to BP (2012), Asia Pacific is the region with the least proved oil reserve with a total of 45.2 billion barrels by the end of 2010. All the oil abindant countries in the region have a proved reserve of less than 10 billion barrels except China which is reported to have 14.8 billion barrels.

1.6.2 Appendix 1.2: Individual Country Oil Consumption

Appendix 1.2 reports the individual countries that make-up the regional totals of oil consumption reported in Table 1.2. According to BP (2012), United States accounts for 82% (almost 20 mb/d) of total oil consumption in North

America by the end of 2010. The breakdown for South and Central America shows that Brazil accounts for 43% of oil consumption in the region with 2.60mb/d followed by Venezuela and Argentina with 0.77 mb/d and 0.56 mb/d respectively.

Oil consumption in the Middle East is mainly supported by two countries; Saudi Arabia and Iran - both of which accounts for around 60% of oil consumption in the region.

Table A1.4

Oil Consumption (thousand of barrels daily)

Country	End of 1990	End of 2000	End of 2010
United States	16,988	19,701	19,148
Canada	1,747	1,922	2,276
Mexico	1,580	1,950	1,994
Total North Ame.	20,316	23,574	23,418
Argentina	398	434	557
Brazil	1,432	2,018	2,604
Chile	141	233	314
Colombia	204	235	238
Ecuador	92	128	226
Venezuela	417	559	765
Other S. & C. Ame.	944	1,249	1,401
Total S. & C. Ame.	3,623	4,855	6,104
Iran	947	1,304	1,799
Israel	177	279	242
Kuwait	106	249	413
Qatar	43	60	220
Saudi Arabia	1,175	1,578	2,812
UAE	304	369	682
Other Middle East	808	1,155	1,653
Total Middle East	3,559	5,021	7,821

Source: BP Statistical Review 2012

Seven countries within Europe and Eurasia consumes more than 1 mb/d, among which Russia is the largest consumer with 3.2 mb/d followed by Germany with 2.4 mb/d. Others are France, UK, Italy, Spain and Netherland with 1.74, 1.59, 1.53, 1.51 and 1.06 mb/d respectively.

Table A1.5

Oil Consumption (thousand of barrels daily)

Country	End of 1990	End of 2000	End of 2010
Austria	222	242	269
Belg. and Lux.	500	694	715
Finland	226	220	219
France	1,895	1,994	1,744
Germany	2,689	2,746	2,441
Greece	314	398	372
Italy	1,924	1,930	1,532
Kazakhstan	442	162	262
Netherland	748	879	1,057
Norway	200	204	239
Porland	325	426	568
Portugal	225	318	261
Russia	5,049	2,698	3,199
Spain	1,026	1,425	1,505
Sweden	364	339	305
Switzerland	271	260	242
Turkey	464	668	624
Ukraine	1,272	253	256
United Kingdom	1,754	1,704	1,590
Other Eur & Eurasia	3,336	1,971	2,110
Total Euro & Eurasia	23,247	19,582	19,510

Source: BP Statistical Review 2012

Africa is the region with the least oil consumption and three countries mainly contributes to the region's figures - Egypt, South Africa and Algeria with a daily oil consumption of 0.76, 0.53 and 0.32 million barrels respectively.

Table A1.6

Oil Consumption (thousand of barrels daily)

Country	End of 1990	End of 2000	End of 2010
Algeria	213	191	327
Egypt	466	552	757
South Africa	349	457	531
Other Africa	915	1,238	1,676
Total Africa	1,943	2,439	3,291
Australia	688	831	941
China	2,320	4,766	9,057
China H.K	130	201	324
India	1,213	2,261	3,319
Indonesia	644	1,143	1,304
Japan	5,234	5,530	4,451
Malaysia	269	460	556
Pakistan	217	371	410
Philippines	233	347	282
Singapore	444	645	1,185
South Korea	1,042	2,252	2,384
Taiwan	576	882	1,026
Thailand	422	835	1,128
Vietnam	60	171	338
Other Asia Pac.	322	438	534
Total Asia Pac.	13,814	21,135	27,237

Source: BP Statistical Review 2012

According to BP (2012), by the end of 2010, Asia Pacific region has the highest oil consumption. China is by far the largest oil consumer in the region with over 9 mb/d. Others are Japan (4.5 mb/d), India (3.3 mb/d), South Korea (2.4 mb/d), Indonesia (1.3 mb/d), Singapore (1.2 mb/d), Thailand (1.1 mb/d) and Taiwan (1.0 mb/d).

Chapter 2[21]

2 Modelling and Forecasting World Oil Demand

2.1 Introduction

Since the early 1970s, world crude oil prices have experienced sharp fluctuations brought about by supply/demand fluctuations due to a number of factors. For example, geopolitical factors related to the destabilization of the Middle East on one hand, and the growth in the world economy, particularly from the emerging economies, on the other. Nevertheless, despite considerable uncertainty surrounding the world oil market, global oil consumption increased at an annual average rate of 2.86%, 0.80%, 1.42% and 1.29% for the periods 1971-1980, 1981-1990, 1991-2000 and 2001-2010 respectively (BP, 2011).

Over the whole period, 1971 to 2010, global oil consumption increased by an average of 1.59% per annum; however, the growth varied between regions. In the North America and Europe/Eurasia regions (which together accounted for well above 60% of world oil consumption over the period), the average annual growth rate in oil consumption was limited to 0.81% and 0.13% respectively. Whereas, the average annual growth in the other regions was somewhat higher; 4.61% for the Middle-East, 3.70% for Africa, 3.39% for Asia Pacific, 2.61% for South and Central America.

[21]Earlier preliminary work for this chapter was presented at the 35th Annual IAEE International Conference, Perth, Australia. June, 2012.

According to BP (2012), one of the major factors that constrain oil consumption growth is technological advances, particularly in the advanced region of the OECD.[22] Nevertheless, there has been a debate in the economics literature about the impact of energy efficiency improvements or technological progress (TP) on energy demand. Some studies, such as - Beenstock and Willcoks (1981; 1983) and Hunt et al. (2003a; 2003b) argue that when modelling energy demand the specification should allow for TP to be exogenous in nature and unrelated to price development. However, others, such as Kouris (1983a and 1983b) argue that prices induce technical change so when modelling energy demand the specification should just allow for TP to be endogenous in nature via price variable. Furthermore, in separate strand of the oil and energy demand literature others, such as Dagay and Gately (1995), Gately and Huntington (2002) and Dagay et al. (2007), support the view (albeit implicitly) that energy demand specification should allow for TP to be endogenous in nature by allowing the demand to respond asymmetrically to price rises and price falls.

Furthermore, when TP is exogenously included in an energy or oil demand specification, it has been argued by some, such as Hunt et al. (2003a, 2003b) and, Adeyemi and Hunt (2007 and 2013), that TP should be captured by allowing the trend component to be stochastic in a time series context or time dummies in a panel context. This being referred to as the Underlying Energy Demand Trend (UEDT) given it should capture technical advances as well as other important exogenous influences. Several studies, such as Hunt and Ninomiya (2003), Dimitropoulos et al. (2005), and Dilaver and Hunt (2011)

[22] According to the outlook, energy efficiency will continue to improve globally at an accelerating rate of 2.0% per annum as against 1.2% per annum over the past 20 years.

have applied this model with symmetrical price responses. Whereas, Adeyemi et al. (2010) and Adeyemi and Hunt (2013) have considered both endogenous and exogenous TP captured through asymmetric price responses (APR) and the UEDT respectively and any restrictions placed on the model (such as symmetric price responses and/or non-linear trends) only applied if suggested by data.

Against this background, the STSM is used to estimate oil demand functions for the six regions of the world identified in Chapter 1, based on the modelling procedure suggested by Adeyemi and Hunt (2013). The aim is to provide robust estimates of price and income elasticities as well as the UEDT that explains the different oil demand relationships and illustrate how they differ across various regions of the world. In addition, to use these estimates to produce future forecast scenarios for the various regions of the world based on different assumptions about the future path of key variables that drive oil consumption.

The rest of the chapter is organised as follows. Section 2.2 reviews the literature and Section 2.3 outlines the methodology applied in this study. Section 2.4 discusses the data and reports the estimation results. Section 2.5 outlines details of the forecast scenarios of oil demand up to 2030 for each of the regions and Section 2.6 concludes.

2.2 Literature Review

2.2.1 Review onTechnical Progress and the Underlying Energy Demand Trend

Several studies have used different estimation techniques to arrive at estimates of price and income elasticities in energy demand modelling.[23] While the early studies applied the simple OLS technique without any role for TP, most of the recent energy demand literature (discussed below) recognises the importance of capturing the impact of TP in building energy demand models whether endogenously and/or exogenously.

One strand of the literature argues that there is good reason to believe that prices provide a key motivation for the development of new technology; consequently, technical change is seen as being price induced; hence it should be captured endogenously in the model. According to Kouris (1983a and 1983b), a simple deterministic trend cannot adequately capture the underlying process unless certain engineering data could be found to proxy technical progress. If not, then it is better to model endogenously through prices without allowance for exogenous technical progress. As introduced above, connected to this is a strand of literature on asymmetric price responses, which was initially analysed through the observed imperfect price-reversibility. Dargay and Gately (1995) argued that higher energy price induced investment in more energy efficient equipment but when prices fell, the response is not reversed symmetrically. Therefore, they concluded that symmetric energy demand specification would not provide an adequate description of an energy demand relationship, which

[23] See Dahl (1993) and Atkinson and Manning (1995) for a survey of international energy elasticities

may lead to misrepresentative estimates of the price and income elasticities. In line with the above argument, Gately and Huntington (2002), henceforth GH, decomposed the price variable into price-maximum, price-recovery and price-cut to capture TP endogenously. Several studies in the energy economics literature have applied similar decomposition approach.[24] However, Griffin and Schulman (2005) argued that the price decomposition approach adopted by GH was only a proxy for energy saving technical progress. They suggested a simple symmetric price specification that accounts for technical change via time dummies.

As also introduced briefly above, in a parallel strand of the literature it has been argued that technical progress should be incorporated exogenously in energy demand models. Beenstock and Willcocks (1981, 1983) recognised the role of TP but argued that it is mainly dependent on exogenous factors which can be captured with a simple deterministic trend. Despite the argument by Kouris (1983a and 1983b) that a simple linear trend is inadequate to capture TP, Beenstock and Willcocks (1983) responded that using a simple time trend is better than ignoring the issue. Hunt et al (2003a, 2003b) went further to argue that a linear deterministic trend is an inadequate way to capture TP but there is still a need to capture other exogenous effects[25] that can be achieved by a stochastic trend in energy demand modelling or as Hunt et al. (2003a and 2003b) call it the UEDT.

Developing out of the studies above is the argument that TP might be

[24] See for instance, Griffin and Shulman (2005), Adeyemi and Hunt (2007), Adeyemi et. al. (2010) and Adeyemi and Hunt (2013)

[25] According to Hunt et al. (2003), apart from technical progress or advancement in technology other exogenous effects that can be captured by the stochastic trend include consumer preference, habit persistence, changes in values and lifestyles, changes in economic structure etc.

incorporated both exogenously and endogenously in oil and energy demand models. Huntington (2006) challenged Griffin and Schulman's (2005) view that asymmetric price responses (APR) are just a proxy of energy saving TP showing statistically[26] that there may be a role for both endogenous TP via asymmetric prices and exogenous TP via time dummies. Adeyemi and Hunt (2007) (for the OECD industrial energy demand) and subsequently Adeyemi et al. (2010) (for OECD whole economy aggregate energy demand) carried out a series of statistical tests on both time-series and panel data and concluded that in general, statistically there is role for both exogenous and endogenous technical progress.[27] Adeyemi and Hunt (2013) integrates both exogenous and endogenous TP in a time-series context by applying the 'general to specific' philosophy which initially incorporates both APR and a stochastic UEDT, and restrictions imposed only if suggested by the data. This work therefore builds on this approach, by modelling world oil demand by regions using the structural time-series model (STSM). The technical details of this procedure are outlined in the methodology section.

2.2.2 Review of Previous Oil Demand Studies

There have been numerous econometric studies considering the response of world/regional oil demand to price and income changes - some considering overall oil demand or oil demand by sectors, while others disaggregate by oil use; residual, transport and other uses. According to Pedrogal et al. (2009),

[26] Huntington (2006) tested restrictions of symmetric and no time dummies in a panel data context and found that statistically there may be role for both asymmetric price response and technical progress

[27] A role for exogenous technical progress via stochastic trend in a time-series context and time-dummies in a panel context. With endogenous technical progress via asymmetric price response

the specific nature of demand functions is generally constrained by information available or economic theory; in most studies, the specification for the dependent variable is consumption which is frequently considered either in physical units or per-capita terms while the explanatory variables[28] usually considered are real prices, real income, technology or changes in capital efficiency, climatic differences among others. Most of the earlier studies that estimate energy or oil demand functions applied symmetric models using the simple OLS technique without accounting for the role of technical progress. As indicated in the previous section, later studies came to recognise the role of technical change and attempted to capture it endogenously via asymmetric price responses (and exogenously via a trend).

In estimating oil demand relationship, it is important that significant coefficients of price and income elasticities are obtained since, as Dahl (1993) indicated, models that do not include both price and income are mis-specified. While most studies used GDP for the income variable, decision on the price variable is a bit mixed. Dargay and Gately (2010), henceforth DG, maintain that it would be better to use real end-user prices but these are generally only available for a few large OECD countries; consequently, the global market can only be analysed using crude oil prices. DG suggest that the use of crude oil prices makes the model less suitable in analysing demand in individual countries but provides a reasonable description of how demand for group of countries responds to price of crude oil.

Some of the earlier studies have shown that the response of oil demand to either prices or income differs depending on whether industrialized or develop-

[28] Pedrogal et al. (2009) used the term 'exogenous variables' because exogeneity test has been conducted on the explanatory variables

ing countries are considered. Dahl (1993) in a survey of oil demand elasticities for developing countries found that the demand for oil is income elastic and greater than 1.32, implying that with stable prices, oil demand will grow faster than income. Dargay and Gately (1995) compared oil demand elasticities for industrialized and less developed countries (LDC) and found the LDCs oil demand to be more responsive to income and less responsive to prices while the industrialized countries are more responsive to prices.

GH estimated the effect of price and income on oil demand by considering imperfect price and income reversibility. Using pooled cross-section/time series data for various groups of countries, the study conclude that oil demand responds more to increases in prices and income than decreases. DG used similar methodology and country groupings to estimate changes in prices and income on world oil demand and made projections to 2030. They argued that it would be more difficult to restrain oil demand growth in the future as factors that led to reduced oil demand cannot be repeated since most countries have switched away from the use of oil in electricity generation. Their projection for 2030 is around 30mb/d greater than what is projected by DOE, IEA and OPEC.

While all the above studies only consider price induced technical progress, Huntington (2009) differentiates the role of price induced and other exogenous TP that may affect oil demand growth. As indicated in Section 2.1, the study uses a simple deterministic trend to capture exogenous TP and confirms the influence of both exogenous and endogenous TP in oil demand growth. Asali (2011) also used a deterministic trend to capture exogenous TP, in a study that applied dynamic time-series modelling to estimate income and price elasticities of demand for oil in G7 and BRIC countries. Evidence of deterministic trend was found for some countries while it was found to be only price induced for others.

As shown in Table 2.1, GH and DG applied asymmetric specification on both price and income variable[29] while Huntington (2010) applied only price asymmetry, allowing the income variable to be symmetric. The long-run income elasticity for the various sub-groups ranges between 0.24 and 0.90 in GH and 0.43 and 1.03 in DG. While the former has a relatively lower income elasticity of 0.56 for the OECD, the latter has a higher elasticity of 0.80 for the same group. Furthermore, Huntington's (2009) study which analysed only the OECD group shows a long-run income elasticity of 0.81. Asali (2011) with a symmetric model and time trend shows a much higher long-run income elasticity of 1.24 for the group of advanced economies.

The long-run price elasticity generally ranges between -0.06 and -0.64 across the various studies discussed above.[30] The studies also reveal that the price variables are not significant for some groups such as: the group of oil exporters in GH; and China, the group of oil exporters, and the former Soviet Union (FSU) in DG consistent with Dahl (1993), which arguably means the models for these groups are mis-specified. On a general note, based on the studies, it could be argued that the notion of less advanced countries being more income responsive than the advanced countries, as Dahl (1993) observed, no longer

[29] The asymmetric income specification was rejected for some groups; OECD in GH and all the groups except oil exporters in DG

[30] Some of the variations in long-run elasticities is likely to be due to different sample period used

Table 2.1

Long-run Income and Price Elasticity Estimates from Previous Oil Demand Studies

Author	Country/ Groupings	Period	Data	Model	LR Income Elasticities				LR Price Elasticities			
					Y	Ymax	Yrec	Ycut	P	Pmax	Prec	Pcut
Gately and Huntington (2002)	5 Groups	1971-1997	Pooled Time-series	Asymmetric								
	OECD				0.56	n/a	n/a	n/a	n/a	-0.67	-0.33	-0.42
	Non-OECD				n/a	0.53	0.46	0.07	n/a	-0.19	-0.06	-
	Oil Exporters				n/a	0.91	0.23	-	n/a	-	-	-
	Income Growers				n/a	0.95	-	0.29	n/a	-0.12	-	-
	Others				n/a	-	0.70	0.16	n/a	-0.29	-	-
Huntington (2010)	OECD	1971-2005		Asymmeric^{Trd}	0.81	n/a	n/a	n/a	n/a	-0.07	-0.01	-
Dagay and Gately (2010)	6 Groups	1971-2008		Asymmetric								
	OECD				0.80	n/a	n/a	n/a	n/a	-0.60	-0.29	-0.2
	Income Growers				0.87	n/a	n/a	n/a	-0.07	n/a	n/a	n/a
	China				0.74	n/a	n/a	n/a	-	n/a	n/a	n/a
	Oil Exporters				n/a	1.0	0.7	0.34	n/a	-	-	-
	FSU				0.43	n/a	n/a	n/a	-	n/a	n/a	n/a
	Others				n/a	1.0	0.39	1.03	n/a	-0.12	-0.01	-0.04
Asali (2011)	2 Groups	1990-2010	Pooled Time-series	Symmeric^{Trd}								
	G7				1.24	n/a	n/a	n/a	-0.05	n/a	n/a	n/a
	BRIC				0.70	n/a	n/a	n/a	-0.06	n/a	n/a	n/a

Note: ^{Trd} = Time trend included in the model to capture exogenous technical progress necessarily still holds since the more recent literature seems to suggest higher income elasticities for the more advanced group of countries.

It can also be concluded from the literature that most of the recent studies recognize the need to capture technical efficiency when modelling oil demand, which they attempt to capture via asymmetric prices and/or a non-linear time trend. However, as far as is known, the STSM (allowing for a stochastic UEDT along with APR) has not been applied before to model oil demand for the various regions of the world; hence, the research undertaken here. The details of this technique are therefore outlined in the next section.

2.3 Methodology

It is assumed that the oil demand function for each world region can generally be represented by:

$$e_t = f(y_t, p_t, UEDT_t) \tag{2.1}$$

where e_t is the natural logarithm of per-capita oil consumption, y_t is natural logarithm of real per-capita GDP, and $UEDT_t$ (the properties of this are explained later in this section) is the Underlying Energy Demand Trend. The price variable, p_t, is the natural logarithm of the real oil price which is decomposed into, $p_{\max,t}$ the cumulative increases in the historical maximum of p_t, $p_{rec,t}$ the cumulative sub maximum increase in p_t, and $p_{cut,t}$ the cumulative decreases in p_t. The oil demand specification outlined here, which generally identifies a simple long-run equilibrum relationship between oil consumption, economic activity and real oil prices, is similar to previous studies of energy and oil demand relationships and assumes that both y_t and p_t are exogenous, consistent with Pedrogal et al. (2009). According to Pesaran et al. (1998), this simple specification generally outperforms specifications that are more complex. Amarawickrama and Hunt (2008) in a related study of electricity demand noted that these kind of specifications can be interpreted as 'market relations' that link consumption/usage to prices and hence termed long-run equilibrum 'consumption functions' rather than 'demand functions'. Going by this, the term 'demand' as noted by Amarawickrama and Hunt (2008) is used for simplicity and consistency with previous studies as it would not alter the analysis or conclusions of the work.

2.3.1 Estimation Technique

Following Adeyemi and Hunt (2013), one of four general models of asymmetry/symmetry will be applied depending on which is best accepted by the data. The models are; Full Asymmetry (FA), Restricted Asymmetry I (RAI), Restricted Asymmetry II (RAII), and Symmetry (S). Details of these models are described below.[31]

Full Asymmetric (FA) Model The FA model incorporates both a stochastic UEDT and asymmetric price response (APR) within the ARDL model. The estimated model is therefore represented as follows:[32]

[31] The general energy demand function is a log log specification in line with the majority of studies in the area.

[32] Given the length of the annual data set, an initial lag length of two years was thought to be adequate, leaving an appropriate number of degrees of freedom for the modelling exercise.

$$\begin{aligned} e_t &= UEDT_t + \beta_0 y_t + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \gamma_0 p_{\max,t} + \gamma_1 p_{\max,t-1} \\ &\quad + \gamma_2 p_{\max,t-2} + \pi_0 p_{rec,t} + \pi_1 p_{rec,t-1} + \pi_2 p_{rec,t-2} \\ &\quad + \delta_0 p_{cut,t} + \delta_1 p_{cut,t-1} + \delta_2 p_{cut,t-2} + \lambda_1 e_{t-1} + \lambda_2 e_{t-2} + \varepsilon_t \end{aligned} \qquad (2.2)$$

where e_t, y_t, $p_{\max,t}$, $p_{rec,t}$, and $p_{cut,t}$ are as defined above. $UEDT_t$ is the underlying energy demand trend (discussed further below); $t = 1970 - 2010$; $\beta_i = y_{t-i}\ coefficients,\ i = 0,1,2$; $\gamma_i = p_{\max,t-i}\ coefficients,\ i = 0,1,2$; $\pi_i = p_{rec,t-i}\ coefficients,\ i = 0,1,2$; $\delta_i = p_{cut,t-i}\ coefficients,\ i = 0,1,2$; $\lambda_i = e_{t-i}\ coefficients, i = 1,2$.

$$\beta* = \frac{\beta_0 + \beta_1 + \beta_2}{1 - \lambda_1 - \lambda_2} = \textit{long-run income elasticity};$$

$$\gamma* = \frac{\gamma_0 + \gamma_1 + \gamma_2}{1 - \lambda_1 - \lambda_2} = \textit{long-run price-}\max\ \textit{elasticity};$$

$$\pi* = \frac{\pi_0 + \pi_1 + \pi_2}{1 - \lambda_1 - \lambda_2} = \textit{long-run price-rec elasticity};\ \textit{and}$$

$$\delta* = \frac{\delta_0 + \delta_1 + \delta_2}{1 - \lambda_1 - \lambda_2} = \textit{long-run price-cut elasticity.}$$

Restricted Asymmetry I (RAI) Model When it proves difficult to find statistically significant coefficients and/or the estimated long-run coefficients do not conform to the a-priori expectation that $|\gamma*| \succeq |\pi*| \succeq |\delta*|$[33] from the

[33] DG notes that an increase in prices that has previously been experienced should have a lesser demand response than when that event occurs occurs for the first time. In other

full asymmetric model above, then a simpler model is explored where decomposittion consists of only price rises and price cuts. Therefore the restriction placed is that, $\theta_0 = \gamma_0 = \pi_0$, $\theta_1 = \gamma_1 = \pi_1$ and $\theta_2 = \gamma_2 = \pi_2$ so that the general ARDL(2) model in equation 2.2 becomes:

$$\begin{aligned} e_t &= UEDT_t + \beta_0 y_t + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \theta_0 p_{rise,t} + \theta_1 p_{rise,t-1} + \theta_2 p_{rise,t-2} \\ &\quad + \delta_0 p_{cut,t} + \delta_1 p_{cut,t-1} + \delta_2 p_{cut,t-2} + \lambda_1 e_{t-1} + \lambda_2 e_{t-2} + \varepsilon_t \qquad (2.3) \end{aligned}$$

where e_t, y_t, $p_{cut,t}$, $UEDT_t$, β_i, δ_i, $\lambda_{i,}$ ε_t, t, $\beta*$ and $\delta*$ are as defined above. $p_{rise,t} = p_{\max,t} + p_{rec,t}$ which is the cummulative rise in the natural logarithm of historical real oil prises in year t. $\theta_i = p_{rise,t-i}$, $i = 0, 1, 2;$ *and*

$$\theta* = \frac{\theta_0 + \theta_1 + \theta_2}{1 - \lambda_1 - \lambda_2} = \textit{long-run price-rise elasticity}$$

Restricted Asymmetry II (RAII) Model In a situation where the RAI model proves difficult to find statistically significant coefficients and/or where the estimated long-run coefficients do not conform to the a-priori expectation that $|\theta*| \succeq |\delta*|$, then a more simpler model is explored where the price decomposition consists of price-max and price changes. The restriction placed therefore is that, $\psi_0 = \pi_0 = \delta_0$, $\psi_1 = \pi_1 = \delta_1$and $\psi_2 = \pi_2 = \delta_2$ so that the general ARDL(2) model becomes:

---

words, the long-run price recovery elasticity is expected to be no greater (in absolute terms) than the long-run price-max elasticity. It is further assumed that the long-run price-cut elasticity will be no greater (in absolute terms) than the long-run price-recovery elasticity. Hence the a-priori expectation that $|\gamma*| \succeq |\pi*| \succeq |\delta*|$

$$e_t = UEDT_t + \beta_0 y_t + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \gamma_0 p_{\max,t} + \gamma_1 p_{\max,t-1} + \gamma_2 p_{\max,t-2} + \psi_0 p_{change,t} + \psi_1 p_{change,t-1} + \psi_2 p_{change,t-2} + \lambda_1 e_{t-1} + \lambda_2 e_{t-2} + \varepsilon_t \quad (2.4)$$

where e_t, y_t, $p_{\max,t}$, $UEDT_t$, β_i, γ_i, λ_i, ε_t, t, β^* and γ^* are as defined above. $p_{change,t} = p_{rec,t} + p_{cut,t}$ which is the cummulative decrease and rise in the natural logarithm of historical real oil prises below the previous maximum in year t. $\psi_i = p_{change,t-i}$, $i = 0, 1, 2$; *and*

$$\psi^* = \frac{\psi_0 + \psi_1 + \psi_2}{1 - \lambda_1 - \lambda_2} = \textit{long-run price-change elasticity}$$

Symmetric (S) Model Where none of the above asymmetric specifications was able to find statistically significant coefficient, a more restrictive general symmetric price response is utilized. The price variable is therefore no longer decomposed, with restrictions $\varphi_0 = \gamma_0 = \pi_0 = \delta_0$, $\varphi_1 = \gamma_1 = \pi_1 = \delta_1$ and $\varphi_2 = \gamma_2 = \pi_2 = \delta_2$ so that the general ARDL(2) model becomes:

$$e_t = UEDT_t + \beta_0 y_t + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \varphi_0 p_t + \varphi_1 p_{t-1} + \varphi_2 p_{t-2} + \lambda_1 e_{t-1} + \lambda_2 e_{t-2} + \varepsilon_t \quad (2.5)$$

where e_t, y_t, $UEDT_t$, β_i, λ_i, ε_t, t, and β^* are as defined above. $p_t = p_{\max,t} + p_{rec,t} + p_{cut,t}$; *and*

$$\varphi^* = \frac{\varphi_0 + \varphi_1 + \varphi_2}{1 - \lambda_1 - \lambda_2} = \textit{long-run (symmetric) price elasticity}$$

2.3.2 Nature of the Underlying Energy Demand Trend (UEDT)

The STSM which is used to estimate the relationship, allows the UEDT to vary stochastically over time. The UEDT depends upon level (μ_t) and slope (β_t) components with the following formulation:

$$\begin{aligned} \mu_t &= \mu_{t-1} + \beta_{t-1} + \eta_t; \quad \eta_t \sim NID(0, \sigma_\eta^2) \\ \beta_t &= \beta_{t-1} + \xi_t; \qquad \xi_t \sim NID(0, \sigma_\xi^2) \end{aligned}$$

The hyper parameters η_t and ξ_t are mutually uncorrelated white noise disturbances with zero means and variances. The nature of the estimated UEDT therefore depends upon zero restrictions imposed on the level, slope and the hyper parameters. For the most restrictive case $\sigma_\eta^2 = \sigma_\xi^2 = 0$ the model reduces to the traditional regression model with a constant and a linear trend.[34]

Estimation of the model parameters and hyper-parameters is by maximum likelihood using Kalman filter. The equation residuals and auxiliary residuals are also estimated to evaluate the model. As indicated by Harvey and Koopman (1992), normality of the auxiliary residuals can be maintained by identifying irregular, slope and level interventions. Dilaver and Hunt (2011) further highlighted that these interventions give important information about breaks and other structural changes at certain points during the estimation

[34] According to Harvey (1997), the STSM permits a more flexible approach to modelling the trend component and it is worth noting that this removes any concern about the stationarity process of the data.

period. The irregular interventions have a temporary effect on the UEDT as it captures unexpected events or shocks while the level and slope intervention has a more lasting effect on the UEDT. Where there are no interventions, the estimated UEDT is given by the level (μ_t), however where intervention are present, as Dilaver and Hunt (2011) demonstrate, the UEDT is given by:

UEDT = μ_t + irregular interventions + level interventions + slope interventions

Using a data driven general to specific approach starting from a lag of 2 (as shown in the equations 2.2 - 2.5), the coefficient of insignificant variables and hyper-parameters are eliminated ensuring that a number of diagnostic tests and normality tests on the auxiliary residuals are passed in order to arrive at the preferred specification. In searching for the preferred specification, the most general model (FA model with a stochastic trend) is explored first and the restrictive versions chosen only accepted if they are accepted by the data and conform to the economic theory; as explained earlier in this section. The software package STAMP 8.3 (Koopman et al., 2009) is used to estimate the model. The results obtained are reported in the next section, before then, the sources and other useful information about the data used for this study are explained.

2.4 Data and Estimation Results

2.4.1 Data

The aim of this chapter is to model global oil demand along geographical regional classification and produce future forecast scenarios. As indicated in

Chapter 1, the six geographical regions analysed are those as classified in BP (2011): 'North America', 'South and Central America', 'Europe and Eurasia', 'Middle East', 'Africa', and 'Asia Pacific'. Each region is therefore considered as a block thus allowing time-series estimation for each. As often argued, for long-term growth potential and prospects for future energy needs, it is essential to consider demographic trends as growth patterns will vary across regions. This classification is therefore adopted in order to analyse differences in oil demand relationships across regions and also examine the relative pattern of future oil consumption for regions (such as Middle East, Africa and Asia Pacific) that have experienced significant increase over the past decade.

Annual time-series data from 1970 to 2010 for regional oil consumption (in thousand barrels per day) and the international real crude oil price (internationally traded UK Brent crude price in $2010) were obtained from the BP (2011). Real GDP (at US$ 2000 prices) and population (in millions) were obtained from WDI, World Bank (available at www.esds.ac.uk).

2.4.2 Estimation Results

Table 2.2 presents estimates of price and income elasticities after eliminating insignificant variables and including interventions in order to maintain the normality of the residuals and auxiliary residuals. Statistically, the existence of interventions in the STSM might be a sign of structural break or instability over the estimation period. The preferred models for each region appear to fit the data well and are free from mis-specification problems, passing all diagnostic tests. The FA model is the preferred specification for all the regions except for Africa and Asia Pacific where the RAI is the preferred specification. A stochastic trend is preferred for all regions except Africa, which exhibits a deterministic trend. Discussions on the result of the various regions are provided below.

Table 2.2A

Parameter Estimates

	N. America	*S. & Cen. Ame.*	*Eur. & Eurasia*	*Middle East*	*Africa*	*Asia Pacific*
Model	*FA*	*FA*	*FA*	*FA*	*RAI*	*RAI*
Estimated Coefficients						
λ_1	-0.228***	0.638***	0.408***	0.227**	0.426***	0.280**
β_0	1.302***	0.316***	0.571***	0.157***	0.326***	0.650***
γ_0	-	-	-0.050***	-	*n/a*	*n/a*
γ_1	-0.015*	-0.074***	-	-0.144***	*n/a*	*n/a*
θ_0	*n/a*	*n/a*	*n/a*	*n/a*	-0.039***	-
θ_1	*n/a*	*n/a*	*n/a*	*n/a*	-	-0.070***
LR elasticity estimates						
β^* (*income*)	1.06	0.87	0.96	0.20	0.57	0.90
γ^* (*price* − max)	-0.02	-0.20	-0.08	-0.19	-0.07	-0.10
π^* (*price* − *rec*)	0.00	0.00	0.00	0.00	-0.07	-0.10
δ^* (*price* − *cut*)	0.00	0.00	0.00	0.00	0.00	0.00
Hyper-parameters and Interventions						
Hyper-parameters						
Irregular	0.0000324	0.000179	0.0000960	0.000190	0.000132	0.0000852
Level	-	-	-	-	-	-
Slope	0.000161	0.0000153	0.0000687	0.0000327	-	0.000233
Nature of Trend						
	Stochastic Trend	*Stochastic Trend*	*Stochastic Trend*	*Stochastic Trend*	*Deterministic Trend*	*Stochastic Trend*
Interventions						
	Irr 1981	*Irr* 1974	*Irr* 1977	*Irr* 1974	*Irr* 1986	*Irr* 1998
	Irr 2008	*Irr* 2000	*Slp* 1979	*Irr* 1988	*Slp* 1982	*Lvl* 1974
	Slp 1978	*Slp* 1978		*Slp* 1984		

Note:
1. Model estimation and all tests are from the software package STAMP 8.3
2. *,**,*** denotes statistical significance at 10%, 5% and 1% respectively
3. For Africa and Asia Pacific, the long-run p-max and p-rec elasticities are identical given the restriction imposed

Table 2.2B

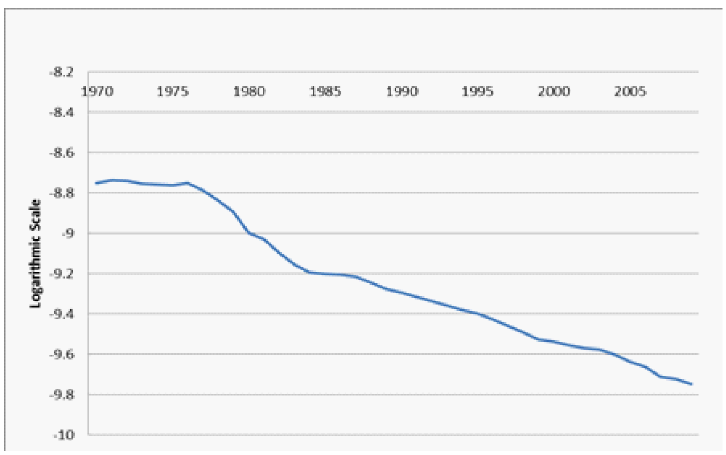
Diagnostic Tests

	N. America	*S. & Cen. Ame.*	*Eur. & Eurasia*	*Middle East*	*Africa*	*Asia Pacific*
Goodness of fit						
$p.e.v$	0.000144	0.000222	0.000304	0.000256	0.000109	0.000481
$p.e.v/m.d^2$	1.168	1.170	1.116	1.173	1.131	0.984
AIC	−8.399	−7.972	−7.706	−7.829	−8.728	−7.248
R^2	0.979	0.957	0.977	0.994	0.992	0.991
R_d^2	0.707	0.755	0.664	0.780	0.833	0.656
Re*sidual Diagnostics*						
Std Error	0.012	0.014	0.017	0.016	0.010	0.021
Normality	2.881	3.855	0.323	0.854	1.272	0.188
$H(11)$	0.861	1.129	0.809	0.408	1.066	0.428
$r(1)$	0.016	−0.177	0.157	−0.048	−0.228	−0.032
$r(2)$	−0.044	0.050	0.037	−0.127	−0.066	0.159
$r(3)$	−0.022	0.162	−0.328	−0.034	−0.009	−0.025
DW	1.936	2.231	1.604	1.982	2.304	1.998
$Q(q, q-p)$	7.718	6.455	9.118	2.127	2.925	3.657
Auxiliary residuals: Normality						
Irregular	1.601	0.069	0.111	0.465	0.668	1.963
Level	n/a	n/a	n/a	n/a	n/a	n/a
Slope	3.370	1.216	0.565	0.784	n/a	0.371
Pr*edictive test* 2005 − 2010						
Failure	5.404	6.704	4.930	1.963	9.486	4.262
Cusum $t(6)$	−0.718	−0.527	0.044	0.920	1.145	−0.171
LR Test	28.22***	6.09*	8.27**	9.61**	-	11.94***

Note: 1. *,**,*** denotes statistical significance at 10%, 5% and 1% respectively
2. Prediction error variance (p.e.v), prediction error mean deviation (p.e.v/m.d) and the coefficient of determination (R^2 and R_d^2) are all measures of goodness of fit;
3. Normality of Bowman-Shenton test, approximately distributed as $\chi^2_{(2)}$;
4. H(11) is Heteroscedasticity statistics distributed as $F_{(11,11)}$;
5. $r(\tau)$ is serial correlation at residual lags τ;
6. DW is the Durbin Watson statistics;
7. Q(p,d) is the Box-Ljung statistics distributed as $\chi^2_{(d)}$;
8. LR represents likelihood ratio test after imposing restriction either σ^2_η or σ^2_ξ is equal to zero, distributed as$\chi^2_{(1)}$;
9. The statistical significance of the residual diagnostic tests are above 10%, hence the models have passed all the diagnostic tests presented.

North America The preferred model for this region is the FA model with a stochastic trend. The model passes all diagnostic tests including the additional normality tests on the auxiliary residuals generated by the STSM. The estimated long-run income, price-max elasticities are 1.06 and -0.02 respectively, whereas the estimated price-rec and price-cut elasticities are zero given both variables were deleted given their statistical insignificance when testing down from the general to the build-up to the preferred model.

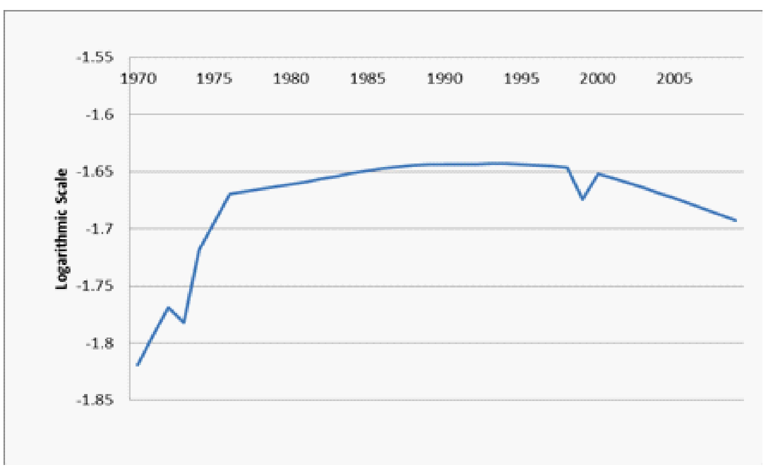
Figure 2.1: UEDT for North America



The log likelihood (LR) test result indicates that the stochastic specification of the trend is accepted by the data with fluctuations that would not be adequately captured by a linear trend. The UEDT is generally downward sloping as shown in Figure 2.1 which implies that holding price and income constant, aggregate oil demand for North America declined but not at a fixed rate as in the case of a deterministic trend. Furthermore, during this estimation process, it was found that irregular interventions (1981, 2008) and a slope intervention (1978) were required to ensure the normality of the residuals was maintained. The slope intervention might be because of the 1977/78 oil price shock while the irregular intervention of 1981 may be the resultant economic slowdown that followed. The irregular intervention of 2008 might have captured the recent financial crisis that began in August 2008.

South and Central America Similar to North America, the preferred model for this region is also the FA model with stochastic trend and the model passes all diagnostic tests. The estimated long-run income and price-max elasticities are 0.87 and -0.20 respectively whereas the estimated price-rec and price-cut elasticities are both zero given that like in North America both variables were deleted given their statistical insignificance.

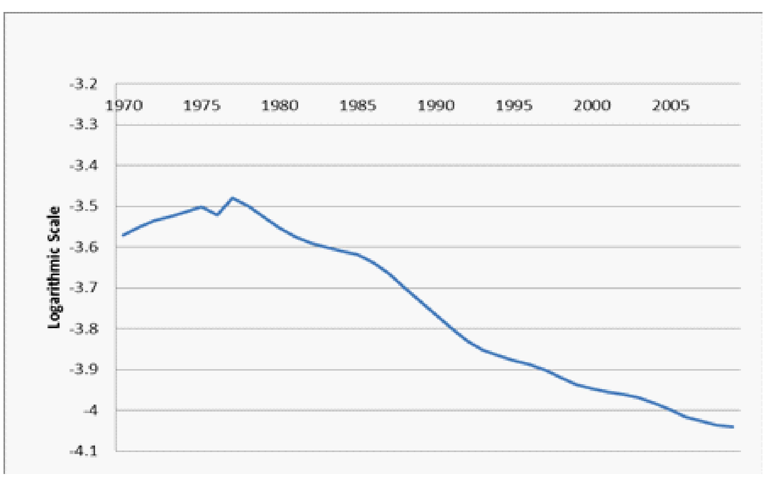
Figure 2.2: UEDT for South and Central America



The priori expecteation that $/\gamma^*/ \succeq /\pi^*/ \succeq /\delta^*/$ also holds and the LR suggests preference for a stochastic trend. The UEDT for South and Central America shown in Figure 2.2 is clearly non-linear, indicating periods of both upward and downward trend in oil demand within the sample period. It was also found that irregular intervention (1974, 2000) and slope intervention (1978) were required to ensure the normality of the residuals. The irregular intervention of 1974 and slope intervention of 1978 are likely to be related to the uncertainty around the 1970s oil price shocks that affected global economic activity at the period. The Economic Commission for Latin America and the Caribbean reported a significant shock in economic performance of the region in 1999/2000 due to weakening link between domestic prices and exchange rate during the period. This might have been the reason for the irregular intervention in the year 2000.

Europe and Eurasia The preferred model for this region is again the FA with stochastic trend and the model passed all diagnostic tests as required. The long-run income and price-max elasticities are 0.96 and -0.08 respectively whereas the estimated price-rec and price-cut elasticities are both zero.

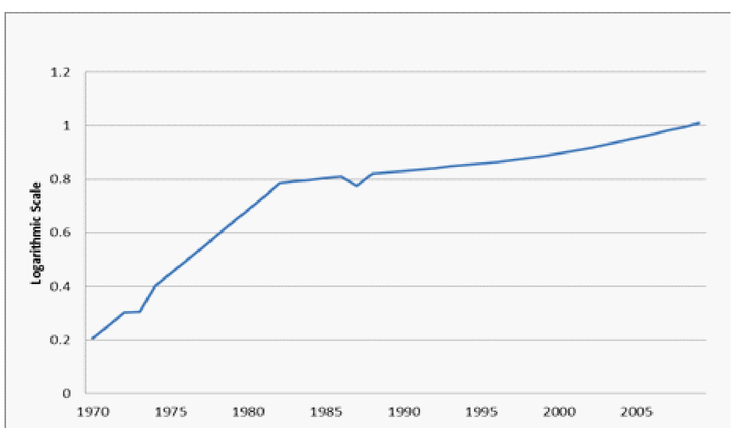
Figure 2.3: UEDT for Europe and Eurasia



The LR test result supports the stochastic nature of the trend. As in the case for North America, the UEDT for Europe and Eurasia shown in Figure 2.3 is generally downward sloping but with some fluctuations, implying that aggregate oil demand generally declined over the estimation period (holding income and price constant). Some interventions were required to maintain normality of the residuals; irregular intervention 1977 and a slope intervention 1979. Considering Europe is a highly industrialized region, it could be argued that both interventions are as a result of the oil price shock in the late 1970's, causing a temporary effect in 1977 and a more lasting effect from 1979.

Middle East The FA model with a stochastic trend is also the preferred model for the Middle East. The long-run income and price-max elasticities are 0.20 and -0.19 respectively. As was reported for the other regions, the estimated price-rec and price-cut elasticities are both zero given that both variables were deleted given their statistical insignificance.

Figure 2.4: UEDT for Middle East



The a-priori expectation for the asymmetric model holds and the LR suggests a preference for a stochastic trend. The UEDT for the Middle East shown in Figure 2.4 is generally upward sloping but the rate of increase slowed somewhat in the early 1980s. The stochastic element associated with the oil demand trend could be caused by the relative inefficiencies due to massive subsidies imposed on petroleum products by the governments of most countries in the Middle East. As noted by Fattouh and El-Katiri (2012), energy subsidies in the Middle East distort price signals with serious implications on efficiency and optimal allocation of resources.

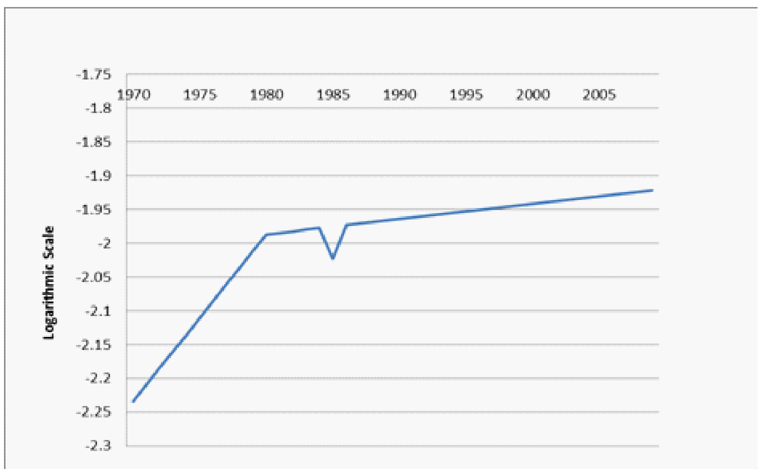
Again, an Irregular intervention (1974 & 1988) and slope intervention (1984) were required for this model to maintain normality of the residuals. The Yom Kippur War, which started in 1973, that led to the first oil price shock could have been the reason behind the irregular intervention of 1974. The crude oil price collapse that followed, which began in 1983 might have been captured by the slope intervention in 1984. On the irregular intervention in 1988, information obtained from World Development Indicators - World Bank indicates a temporary shock affected the MENA region in 1988 as the average annual growth rate was 0.28%, 1.57% and 0.95% for 1987, 1988 and 1999 respectively. Another possible reason might be the spike in oil price from $8 in 1986 to around $18 in 1987/88.

Africa The preferred model for Africa is the RAI with a deterministic trend.[35] The long-run income, price-max and price-rec elasticities are 0.57, -0.07 and -0.07 respectively, while the price-cut elasticity is zero. For this region, unlike

[35] Although, as Figure 2.5 shows, the interventions means that the estimated UEDT is far from a continuous straight line as given by a conventional deterministic trend

above, the data did not accept full asymmetric model based on statistical significance and a-priori expectations explained in the methodology section; however, the restricted model passes all the diagnostic tests. Unlike the previous regions, the estimated UEDT for Africa, shown in figure 2.5, is deterministic; nevertheless, given the interventions explained below it is kinked in places. The estimated UEDT therefore increases rapidly until the early 1980s, but the tare of increase declines thereafter.

Figure 2.5: UEDT for Africa



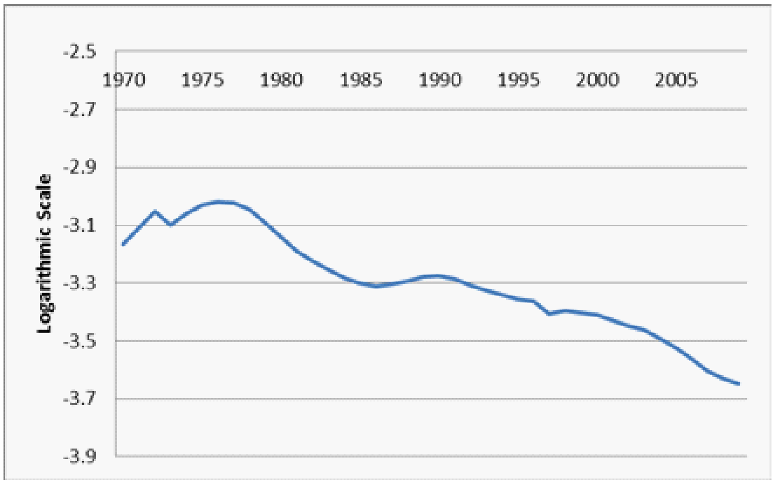
An irregular intervention in 1986 and a slope intervention in 1982 were required to maintain normality of the residuals. Since Africa's oil consumption is relatively small and the region is not considered a major oil exporter during the first and second oil price shocks, it is therefore not surprising that no intervention was required for the period. Sub-Saharan Africa experienced negative growth between 1982/84 before picking up quite slowly in 1985. This could have been the reason for the slope intervention in 1982. Structural Adjustment Programmes[36] in most African countries was launched around mid-1980s which led to most of the countries becoming more market oriented, and a shift from a managed to a more flexible exchange rate regime. This marked a major policy shift in most African countries and could most likely be the reason for the irregular intervention in 1986.

Asia Pacific Like Africa, the preferred model for this region is RAI but with a stochastic trend. The long-run income, price-max and price-cut elasticities are 0.90, -0.10 and -0.10 respectively, while the price-cut elasticity is zero given statistical insignificance. The LR test indicates that the stochastic specification of the trend is clearly accepted by the data since the distinct fluctuations would not be adequately captured by a simple linear trend. The estimated UEDT for Asia Pacific, shown in Figure 2.6, shows a gentle downward slope with regular fluctuations implying a slight exogenous decline in oil demand, with price and income being constant.

As found in the other models above, some interventions were required to maintain the normality of the residuals - Irregular (1998) and level (1974). The level intervention of 1974 might have captured the oil price shock of the early 1970s while the irregular intervention of 1998 might be the resultant effect of the Asian financial crisis that began 1997.

[36] Structural adjustment Programmes are policies created by the IMF and World Bank to be implemented by developing countries as conditions for getting new loans or for obtaining lower interest rates on existing loans

Figure 2.6: UEDT for Asia Pacific



Summary and Comparison of Results Generally, the results support the notion that for all the regions oil demand responds asymmetrically to changing oil prices and the relative exogenous 'oil using' or 'oil saving' behaviour can be captured by an estimated stochastic UEDT, except Africa where a deterministic trend is preferred, albeit kinked. The estimated UEDTs for North America, Europe/Eurasia and the Asia Pacific (see Figures 2.1, 2.3 and 2.6) are generally downward sloping, suggesting (exogenous) 'oil saving' behaviour whereby any technical improvement or energy efficiency improvements are outweighed by other exogenous behavioural factors.[37] For the other regions, however, the estimated UEDTs are generally increasing (see Figures 2.2, 2.4 and 2.5) suggesting (exogenous) 'oil using' behaviour.[38]

The results also show that oil demand responds more to income in North America than any other region; with Asia Pacific and Europe and Eurasia also

[37] See Hunt et al. (2003a, 2003b) and Dimititrpoulos et al. (2005) for further discussion.

[38] Although for the South and Central American region most of the 'oil using' behaviour appears to have taken place early in the period, before the late 1970s.

exhibiting a strong response to income. South and Central America, Middle East and Africa show a relatively much lower response, with the Middle East being the region with the least response. Furthermore, oil demand in the Middle East appears to respond more to prices than any other region, with the least response being in North America. While it might be expected that the reverse should be the case, results from recent oil demand studies points to a similar outcome as can be found in DG and Asali (2011).

The elasticity estimates obtained from this study therefore falls within the range of what has been obtained in previous literature, despite the different econometric technique applied. These elasticity estimates, along with the estimated UEDTs, are therefore used to produce future forecast scenarios for oil demand for the six regions up-to 2030, which is explained in the next section.

2.5 Forecasting Assumptions and Results

Three scenarios are implemented with different assumptions namely 'low', 'reference' and 'high' case and for each scenario different assumptions are made about the future path of key variables that drive oil consumption (discussed in detail below). For the 'reference' scenario, the assumptions are those seen as the 'most probable' outcome based on available information (like a 'business-as-usual forecast) whereas for the 'low' and 'high' case scenarios, the assumptions are chosen to produce sensible lower and upper bound values on the future path of key variables.[39]

[39] Although, for crude oil prices, which are available for 2011, these are used in all scenarios

2.5.1 Assumptions

Prices The crude oil price is very difficult to predict since its movements do not only depend on economic factors but also regional politics and speculative activities (at least in the short-term). Oil prices have increased in recent years, averaging about $80/bbl in 2010 and well above $100 in 2011. Even though the oil market has been prone to disruption, with major shocks to supply and prices, there has been continued increase in the average annual price of crude oil over the past eight years. According to OPEC, crude oil price of between $70 and $100 is required to make investment within the industry viable. OPEC holds 77% of global proved reserve and 40% share of current production, projected to rise to 46% by 2030.[40] In all probability, this will allow OPEC more significant influence in the oil market. As noted by Fattouh (2007), many international organisations project greater reliance on Middle Eastern oil in the next two decades which is seen to have the effect of automatically increasing OPEC's market power. OPEC's price assumption is between $85 and $95/bbl for this decade reaching $135 by 2030.[41] The same price assumption is adopted here in building the 'reference-case' scenario for the price variable. Actual data is used for 2011 and 2012 since information is available for the whole of 2011 and the first three-quarters of 2012. Assumptions made on the price variable is therefore based on an annual average rise of 3%, 3% and 1.5% for the remaining forecast period, for the 'low-case', 'reference-case' and 'high-case' scenarios respectively.

[40] See BP (2011)

[41] See OPEC World Oil Outlook 2011

Income The central driver of oil consumption in the mid-term is the economy, although other factors such as technology and international policies may have significant impact in the long-term. As noted by Finley (2012), the next 20 years is likely to see rapid growth in low and mid-income economies as the World's real income has risen by 87% over the past 20 years and is likely to rise by 100% over the next 20 years, mainly supported by the emerging economies.

The 'reference-case' assumption of the per-capita income variable is therefore based on the expectation that the global economy will experience a modest growth in line with historical data. It is expected that the developing regions will be the major players in supporting global economic growth, and this is assumed to continue to be the case over the forecast period. The 'low-case' scenario on the other hand is based on the assumption that the global economy will be marked by below average trend in growth due to the weak and fragile recovery from the global economic crisis especially in the industrialized regions of North America and Europe while the 'high-case' scenario is based on the assumption of a stronger than expected recovery from the current economic crisis. Other factors supporting the high-case scenario includes optimistic view on globalization as a result of rapid expansion in international trade over the next 20 years.

Table 2.3 shows the different scenario assumptions made about income growth rates for the various regions over the forecast period. For most of the regions analysed, reliable information on real income data for 2011 could not be obtained, therefore actual data was not used for 2011 as was the case for the price variable. The income assumptions therefore ran throughout the forecast period beginning from 2011. It can be observed from the table that the 'low-case' scenario assumption ranges between 1% and 2.2% for all the regions except Asia Pacific which is assumed to grow at more than 4% annually. Historical data was considered in the course of arriving at these figures - Asia Pacific enjoyed an average per capita growth rate of more than 5% over the past 10 years while other regions experienced less than 2.5%. The 'high-case' scenario assumes a growth rate of 5.5% for Asia Pacific and between 1.5% and 2.8% for the other regions.

Table 2.3

Assumptions about Per capita Income Growth Rates

Regions	Forecast Scenarios		
	'Low-Case'	'Reference'	'High-Case'
North America	1.4%	1.7%	2.0%
S. & Cen. Ame.	2.2%	2.5%	2.8%
Eur. & Eurasia	1.1%	1.3%	1.5%
Middle East	1.6%	1.8%	2.0%
Africa	1.8%	2.0%	2.2%
Asia Pacific	4.5%	5.0%	5.5%

Source: Authors assumptions based on information from OPEC (2011), IEA (2012), World Bank (2010) and BP (2012)

Population Given the forecast is constructed on a per-capita basis, assumptions about future population growth are required in order to convert the future figures into million barrels per day (mb/d) – the standard for reporting oil demand. According to BP (2012), world population has increased by 1.6 billion over the last 20 years, and it is projected to rise by 1.4 billion over the next 20 years. Historically, Population growth rates have been declining and this is set to continue - According to UN (2010), OECD population increased by an average of 1% per annum in the 1970s, but this had fallen to 0.6% per annum by 2010. In developing countries, average growth has been higher, at 2.5% per annum in the early 1970s, which has also declined to 1.4% per annum by 2010. OPEC's population growth rate assumptions for OECD and developing countries over the next 20 years are 0.4% and 1.05% per annum respectively.

Table 2.4

Assumptions about Future Population Growth Rates

(2011 - 2030)

Regions	Forecast Scenarios		
	Low-Case	Reference	High-Case
North America	0.55%	0.6%	0.65%
S. & Cen. Ame.	0.8%	0.9%	1.0%
Eur. & Eurasia	0.3%	0.35%	0.4%
Middle East	1.7%	1.8%	1.9%
Africa	1.4%	1.5%	1.7%
Asia Pacific	0.7%	0.8%	0.9%

Source: Authors assumptions based on information from UN (2010), OPEC (2011) and BP (2012)

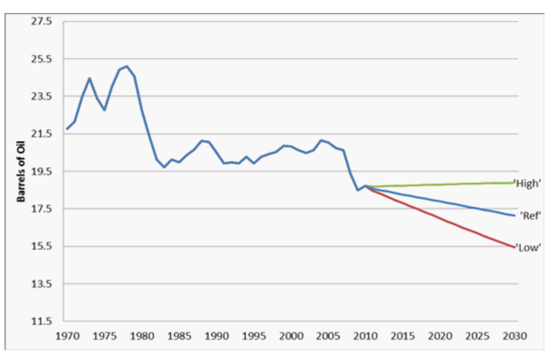
In this study, assumption made about population for the various regions considers both historical data and information obtained from BP (2012), OPEC (2011) and UN (2010). The various assumptions are reported in Table 2.4. The 'reference-case' scenario assumptions for the more developed regions of North America and Europe/Eurasia are between 0.35% and 0.6% while for the other regions, the assumptions made are between 0.8% and 1.5%. It can be observed from Table 2.4 that the assumptions made from 'reference to high' and from 'reference to low' for all the regions are symmetric except Africa which has a higher 'reference to high' margin. This is based on the argument that the population growth rate for the region has a greater chance of being higher than projected than lower than projected.

UEDTs It is also important to make assumption about the path of the future of each region's UEDT. Assumptions made for the 'reference-case' is based on an expectation that the oil demand trends will maintain similar patterns of movement while the 'low' and 'high' case scenarios are based on expected increase or decrease in technological advancement geared towards curtailing future oil demand.

2.5.2 Forecasting Results

Using the coefficients obtained from the parameter estimates reported in Table 2.1 and applying the various scenario assumptions, per capita oil demand projections for each of the regions are produced. Under the 'reference-case' scenario, per capita oil demand in North America is projected to decline from 18.72 barrels in 2010 down to 17.15 barrels in 2030 as shown in Figure 2.7.[42]

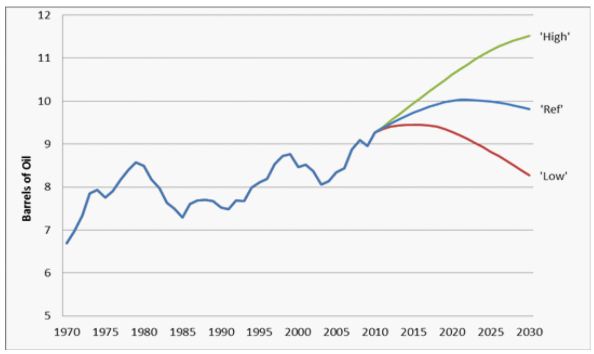
Figure 2.7: Per capita oil demand projections for North America



[42] Under the 'low-case' and 'high-case' scenario assumptions, per capita oil demand is projected to be 14.78 and 18.85 barrels respectively.

Under the ‘reference-case’ assumption, projections for South and Central America shows a slight rise in per capita oil consumption from 9.26 barrels in 2010 to 9.71 barrels in 2030. It is projected that per capita oil demand will peak in 2023 as shown in Figure 2.8. Under the ‘low-case’ and ‘high-case’ scenario assumptions, per capita oil demand in 2030 is projected to be 8.07 and 11.17 barrels respectively.

Figure 2.8: Per capita oil demand projections for South and Central America



The ‘reference-case’ scenario projection for Europe and Eurasia also reveals a slight increase in per capita oil demand from 8.52 barrels in 2010 to 8.73 barrels in 2030. The increase will most likely be driven by rise in oil consumption in the Former Soviet Union and other South-Eastern European countries. It is projected that per capita oil demand for the region will peak in 2026 as shown in Figure 2.9. Under the ‘low-case’ and ‘high-case’ scenario assumptions, per capita oil demand for the region is projected to be 7.81 barrels and 9.79 barrels respectively.[43]

[43] It can be observed from Figure 2.9 that per-capta oil demand in Europe and Eurasia experienced a steep decline between 1977 and 1994. The reason for the decline could be connected to significant reduction in the use of oil for electricity generation during the period. According to IEA (2012), in 1974, oil’s share of electricity generation in Europe was 24.7% which dropped to less than 10% by early 1990s. The increase in oil consumption in the region from mid 1990s is likely to be driven by the Russian Federation.

The 'reference-case' projection for the Middle East shows a rise in per capita oil demand from 13.47 barrels in 2010 to 20.90 barrels in 2030. It is expected that per capita oil demand for the region will continue to rise throughout the forecast period as shown in Figure 2.10. Under the 'low-case' and 'high-case' scenario assumptions, per capita oil demand is expected to rise to 19.16 and 22.09 barrels respectively.

The 'reference-case' scenario projection for Africa also shows a rise in per capita oil demand from 1.13 barrels in 2010 to 1.45 barrels in 2030. Per capita oil demand is also expected to continue to rise, although at a much slower pace than the Middle East. Figure 2.11 shows per capita oil demand projections for the region based on the different forecast scenario assumptions. Under the 'low-case' and 'high-case' assumptions, per capita oil demand is expected to rise to 1.38 and 1.56 barrels respectively.

Figure 2.9: Per capita oil demand projections for Europe and Eurasia

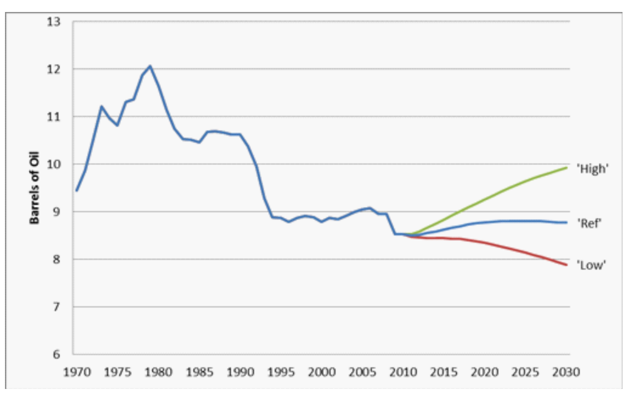
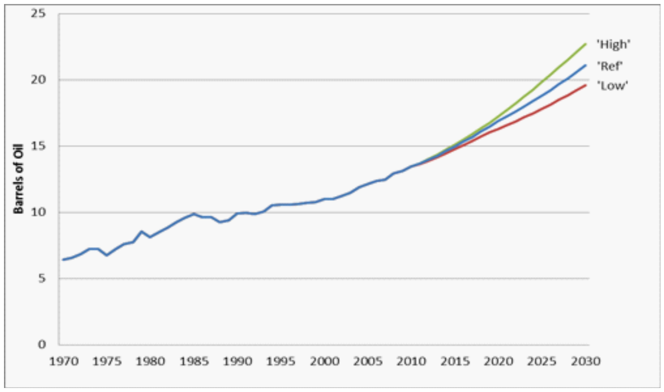
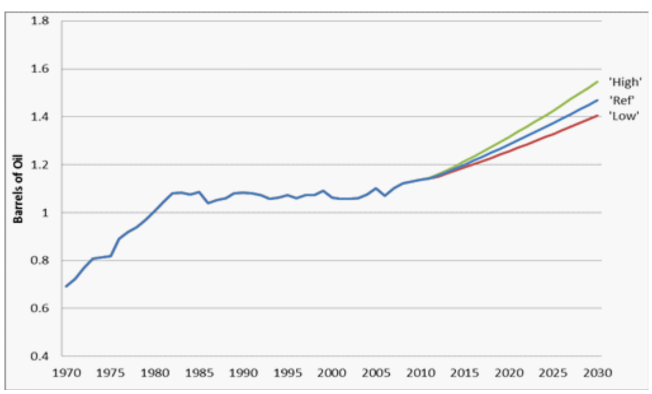


Figure 2.10: Per capita oil demand projections for Middle East



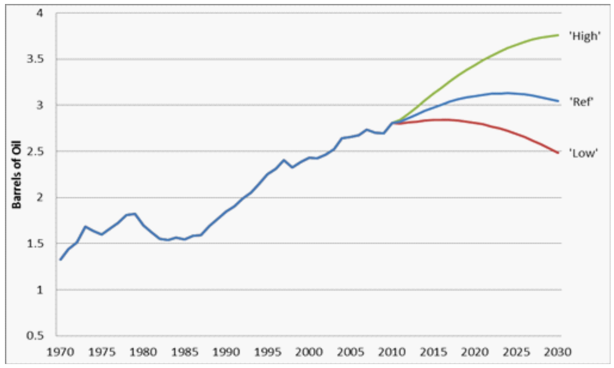
The 'reference-case' scenario projection for Asia Pacific shows a slight rise in per capita oil demand, from 2.80 to 2.98 barrels over the forecast period. It is expected that per capita oil demand for the region will peak in 2024 as shown in Figure 2.12.[44] Under the 'low-case' scenario assumption, per capita oil demand peaked in 2010 at 2.80 barrels and will fall to 2.40 barrels by 2030 while the 'high-case' scenario shows that it will rise to 4.32 barrels by 2030.

Figure 2.11: Per capita oil demand projections for Africa



[44]While the 'reference case' projection for Asia Pacific reveals a turning point in 2024, Middle East and Africa reveals no turning point throughout forecast period. This implies that the transition from oil using to oil saving is happening more in Asia Pacific that the other two regions.

Figure 2.12: Per capita oil demand projections for Asia Pacific



On a general note, Figure 2.7 shows that North American per capita oil consumption has already peaked, before the forecast period (according to all three scenarios). For South/Central America, Asia Pacific, Europe/Eurasia the 'reference-case' scenario suggest that for these regions, per capita oil consumption will peak in 2023, 2024 and 2026 respectively (shown in Figures 2.8, 2.9 and 2.12).[45] However, according to the 'reference-case' scenario per capita oil consumption in the Middle East and Africa is not expected to peak before the end of the projections in 2030 for any of the three scenarios (shown in Figures 2.10 and 2.11).[46] Furthermore, by 2030, Middle East will have the highest per capita oil consumption (20.90 barrels) followed by North America (17.15 barrels), then South/Central America (9.71 barrels), Europe/Eurasia (8.73 barrels), Asia Pacific (2.9 barrels) and finally Africa (1.45 barrels).

[45] As pointed out earlier, the UEDT charts for North America, Europe and Eurasia, South and Central America and Asia Pacific suggest 'oil saving' behaviour (see Figures 2.1, 2.2, 2.3, and 2.6). This is likely the reason why per capita oil demand in these regions (according to the 'referece-case' scenario) have peaked or is expected to peak before 2030.

[46] Note, however that the 'high-case' scenario suggests that per capita oil demand in all regions (other than North America) will continue to rise over the forecast period (see Figures 2.8 - 2.11). Whereas, according to the 'low-case' scenario, per capita oil demand is peaking about now or very soon for South and Central America and Asia Pacific (Figures 2.8 and 2.12) but has already peaked in Europe and Eurasia (Figure 2.9).

Table 2.5 presents the forecast scenarios for oil demand for all regions after applying the assumptions for future population growth for the three scenarios. This shows that for the 'reference' case scenario, global oil demand is projected to rise by about 26% to 110mb/d in 2030. However, the 'low' and 'high' case scenarios suggest a rise of about 10% (to 96mb/d) and about 50% (130mb/d) in 2030 respectively.

The forecast reveals that growth in oil consumption will mainly be supported by the developing regions; by 2030, oil consumption is projected to more than double in the Middle East (121%)[47] and more than two-thirds in Africa (72%), while South and Central America and Asia Pacific are projected to rise by 25.50% and 24.86% respectively.

Table 2.5

Oil Demand Projections (mb/d)

Regions	2010	2020 Projections			2030 Projections		
		Low	Ref.	High	Low	Ref.	High
N. America	23.418	23.02	23.77	25.60	21.56	24.18	27.18
S. & Cen Ame.	6.104	6.37	7.08	7.44	6.72	7.66	9.74
Eur. & Eurasia	19.51	19.68	20.63	22.02	19.17	21.43	24.58
Middle-East	7.821	11.20	11.5	12.07	15.94	17.33	19.21
Africa	3.291	4.17	4.24	4.5	5.36	5.66	6.26
Asia Pacific	27.237	28.51	31.86	36.47	27.71	34.01	43.60
World	**87.381**	**91.95**	**99.08**	**108.1**	**96.46**	**110.27**	**130.57**

[47] All analysis are based on the reference-case scenario unless otherwise stated

North America's oil consumption is projected to grow by 3.25%[48] over the forecast period while Europe/Eurasia is projected to grow by 9.84%. Asia Pacific will constitute 30.84% of global oil demand by the year 2030. This by far makes it the highest region, followed by North America with 21.92%. Europe & Eurasia, Middle East, South & Central America and Africa will constitute 19.43%, 15.71%,[49] 6.94% and 5.13% respectively.

2.6 Conclusions

Oil demand is arguably the most important factor that determines oil prices, thus modelling the demand for oil remains a significant element in projecting the future movement of the oil market. Over the years, oil consumption has declined in the most advanced regions of the world while on the other hand it has been rising in the non-OECD regions. As economies grow, they consume more energy and the unprecedented growth experienced in emerging economies (particularly China and India) over the past decade has significantly increased global oil demand.

One of the major factors that constrain oil consumption in the advanced regions is often linked to technological advancement and several studies in the literature have indicated the importance of capturing the impact of technological progress when modelling oil demand. The focus of this chapter therefore is to find robust estimates of price and income elasticities by applying the STSM methodology, which can capture exogenous efficiency effects and other factors

[48] According to the low-case scenario assumption, by 2030, oil demand in North America and Europe/Eurasia will fall by 7.90% and 1.74% respectively while South/Central America will grow by 2.06%.

[49] In 2010, Middle-East's share of global oil consumption was just around 9%.

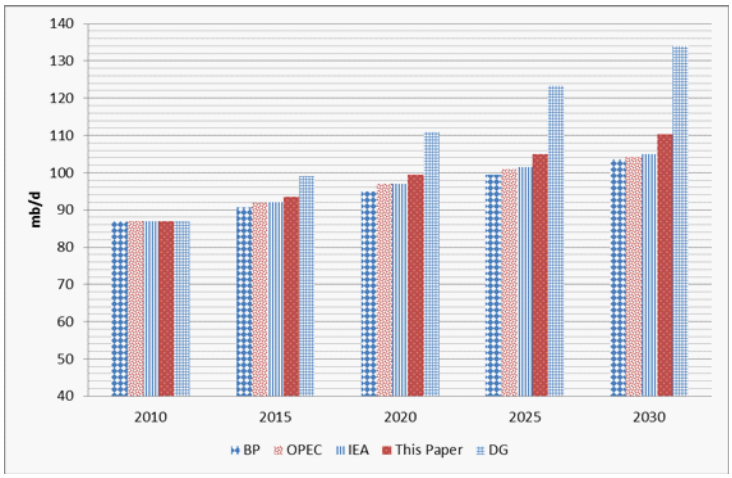
when estimating oil demand functions. It is argued that using the STSM and the UEDT concept provides a sounder basis for producing future demand forecast than other methodologies. Hence, using the estimates obtained from the STSM and the forecast that followed, global oil demand is projected to rise from 87 mb/d in 2010 to 110 mb/d in 2030.

It is of interest to compare the 'reference' scenario projections with other forecasts.[50] The world reference case oil demand projection of 110 mb/d for 2030 is somewhat less than the 134 mb/d projected by DG but slightly more than that projected by BP, IEA and OPEC, since their projections fall between 103 mb/d and 106 mb/d (see Figure 2.13 for a comparison). DG noted that some of the projections made by BP, IEA and OPEC for some groups of developing countries have per-capita demand growing by less than half its historical rate which they argue is unlikely given the trend in oil demand is expected to be upward in almost every part of the developing world. The assumptions made by these agencies, particularly the IEA, could be seen as being optimistic in relation to improvements in energy efficiency, as well as continued growth in the use of wind and solar technologies and global spread of unconventional gas production. This is despite all of these aspects still being very challenging especially in the developing regions of the world that account for most of the growth in oil demand. It is interesting therefore to note that the projections from the analysis in this chapter, although higher, are somewhat closer to those emanating from BP, the IEA, and OPEC than the DG projections. One possible explanation might be the models used; although DG employ a similar price decomposition to that used here, their models do

[50] The 'reference' scenario projection is only considered here in order to compare with the other forecasts.

not have any role for an exogenous UEDT.[51] Thus the projected 'energy saving' from the UEDT for North America, South and Central America, Europe and Eurasia, and Asia Pacific are likely to partly explain the difference between the projections here and those by DG – being more in line with the assumptions made by the IEA and OPEC for energy efficiency.

Figure 2.13: Oil Demand Projections



Note: 'DG', 'IEA', 'BP' and 'OPEC' relates to oil demand projections in Dagay and Gately (2010), IEA (2012), BP (2012) and OPEC (2012) respectively. 'This Paper' refers to the projections in this chapter.

The regional breakdown of the projections made in this study shows that growth in oil demand will mainly be supported by non-advanced regions as oil demand will more than double in the Middle East, a rise of more than two-thirds in Africa and a rise of more than one-quarter in Asia Pacific and South

[51] In an appendix, DG do explore the use of time dummies in their panel data models, which according to Adeyemi and Hunt (2007), can also be thought of as a UEDT. However, when the time dummies are included by DG, none of the coefficients for price are statistically significant any longer - whether it be the single un-decomposed price or the decomposed prices and hence are rejected by DG. They argue that the time dummy "coefficients tell us nothing about the determinants of demand changes, in either the past or the future" given they "are highly correlated with $p_{\max}$" (Dargay and Gately, 2010, p. 6277).

and Central America. In North America and Europe/Eurasia, oil demand is projected to grow by 3% and 9% respectively. In fact under the 'low case' scenario assumption, it is projected to fall in the two regions. While oil demand growth in Asia is mainly supported by high population and rapid economic growth, the Middle East may be linked to high oil prices over the years which brought a huge influx of cash and makes these countries tend to increase their oil consumption as they become wealthier. North American and European oil demand was curbed due to successful policies of promoting alternative energy for oil as well as energy conservation/efficiency techniques to constrain oil consumption.

Looking ahead, it is likely that growth in global oil demand will be maintained by the emerging regions, most importantly Asia Pacific, Middle East and Africa which, according to the reference scenario here, as a group will increase from 38 mb/d in 2010 to 57 mb/d in 2030. Thus, despite the expected fall/slight increase in oil demand in the other regions, total world oil consumption (according to the 'reference case' scenario) is expected to grow significantly (from 87 mb/d in 2010 to 110 mb/d in 2030). This suggest that oil producers will be required to make substantial investment to increase capacity and output. Already, BP (2012) has indicated that very large investment is needed merely to offset decline rates. Considering 77% of current global proved oil reserves is held by the OPEC countries, OPEC's investment decision is therefore critical towards meeting future world oil demand requirements.

CHAPTER 3[52]

3 Co-movements and Causality Relationship between Oil Prices and Economic Growth

3.1 Introduction

There is an extensive empirical literature on the oil price-GDP relationship, covering the last three decades. Derby (1982) and Hamilton (1983) were among the early studies and they conclude that many economic recessions were preceded by a sharp rise in the price of oil. This notion over the years weakened as later empirical studies that use data which extends beyond the 1980s shows oil prices having much lesser influence on economic output.[53]

Since the seminal work of Hamilton (1983), oil prices have been found to Granger-cause economic output on the US economy.[54] Similar results were also found for Japan, Germany, France, Canada, Norway and the United Kingdom by Jimenez-Rodriguez and Sanchez (2004). While all the afore-mentioned studies focused on short-term interactions, few studies have considered the long-term relationship between the two; Hooker (2002), however, in an analysis on the US economy estimated a long-run cointegrating relationship between oil prices, unemployment and interest rate while Lordic and Mignon (2006)

[52] Earlier preliminary work for this chapter was presented at the 30th USAEE/IAEE North American Conference, Washington DC, USA. October, 2011.

[53] See Hooker (1996) for a detailed explanation on the weakening role of oil prices on economic output

[54] See Jones et al. (2004)

showed evidence of cointegration between oil prices and GDP in the US and other European countries.

Another part of the oil price-GDP literature considered the role of asymmetric response to oil price changes arguing that the influence of oil prices on economic output depends on whether a symmetric or asymmetric model specification is applied. Symmetry in response to oil prices implies that the response of output to a fall in oil prices will be the exact mirror image of the response of a rise in oil prices of the same magnitude; whereas, asymmetry as the name suggests, implies that the response of output to a rise in oil prices differs to that of a fall in oil price of the same magnitude. Both specifications have been widely applied in investigating the direction of causality between oil prices and economic output in a time-series context. However due to numerous challenges,[55] no study has applied the asymmetric specification in a panel context to the oil price and GDP relationship.

A considerable body of economic literature has shown that the effect of oil prices on the economy of the US and other OECD countries, however there have been relatively fewer empirical studies on the non-OECD countries. And what has been undertaken in this area generally analysed the relationship in a time-series context - Lescaroux and Mignon (2008) is the only study that analysed the oil price-GDP relationship using a panel approach. Recently, panel data analysis has been enhanced since the technique can take heterogeneous country effect into account.

Against this background, this chapter aims to add to the literature by em-

[55] According to Arellano and Hahn (2007), non-linear panel models creates bias and inconsistent estimates.

ploying both time-series and panel based causality technique[56] to investigate the long term relationship between oil prices and economic growth across two panels of developing countries - grouped according to whether a country is a net-exporter or a net-importer of crude oil. According to Jimenez-Rodriguez and Sanchez (2004), the consequence of oil price fluctuations should be different in oil exporting and oil importing countries as an increase should be considered a good news in the former and a bad news in the latter. It is therefore a-priori expected that an increase in oil price will have a positive effect on the net oil exporting countries and a negative effect on the net oil importing countries.

The rest of the chapter is organised as follows: Section 3.2 reviews the causality literature on the oil price-GDP relationship and the role of asymmetry in the response of oil prices. Section 3.3 outlines the methodology of the two estimation techniques (time-series and panel), Section 3.4 describes the data while Section 3.5 reports the empirical results. Finally, Section 3.6 concludes.

3.2 Literature Survey

3.2.1 An Overview on the Concept of Causality

The concept of causality as proposed by Granger (1969) hereafter known as ‘Granger causality’ has gained wide acceptance and widely used by economists for over three decades. Granger causality implies causality in the prediction (forecast) sense rather than in a structural sense. According to Granger (1969),

[56] An overview on the concept of causality is provided in the next sub-section

if one considers two variables X and Y, X causes Y if the current value of Y can be better predicted by using past values of X. The concept has been widely used in time-series analysis and also recently in a panel data context. The causality concept is applied in this chapter to measure the influence/impact of oil prices on economic output of groups of non-OECD countries.

3.2.2 Causality Relationship between Oil Prices and Economic Output

The causality testing framework has been mainly based on the Granger-causality concept. Most of the earlier studies assumed a symmetric specification and generally found causality running from oil prices to GDP. The asymmetric specification which are mostly based on Mork's (1989) oil price increase and decrease and also Hamilton's (1996) net oil price increase specifications significantly improved model specification of the oil price-economic output relationship as elaborated in the studies that follow.

Hooker (1996) identified the changes in the causality relationship between oil prices and GDP while searching for a statistically stable specification. The works of Hooker (1996) and Hamilton (1996) has played a very important role in establishing a stable statistical relationship between oil price changes and GDP. Generally, the interaction of the oil price-GDP relationship with the models of transmission channels has improved the understanding on how oil prices might influence a macroeconomic aggregate such as GDP.

Hamilton (1983) was the first to report the weakening statistical relationship between oil prices and GDP. Hamilton's (1983) specification was the log change of the norminal oil price, which allowed for symmetric effect. Mork (1989) established the basis for both positive and negative GDP reponsive to oil price changes, being the first asymmetric specification of the oil price-GDP relationship using seperate variables for price increases and decreases. This specification strengthened the oil price-GDP relationship during the mid 1980s.

Hooker (1996a, 1996b) demonstrates that none of the two specifications (the symmetric and Mork's asymmetric specification) preserved a stable oil price GDP relationship beyond the early 1980s. Hamilton (1996a) responded with the Net Oil Price Increase (NOPI) specification of the oil price variable, defined as the difference betweeen the percent increase in the current period and the highest percent increase in the previous four quarters, if positive, and zero otherwise. Hamilton (1996b) extended his original NOPI from a one year peak to a three year peak. According to Hamilton (1996b), this specification captures the surprise element in the oil price change as it eliminates price increases that simply corrects recent decreases. Hooker (1996c) found that the NOPI specification Granger-caused GDP using data samples that extends to late-1990s.

According to Rotemberg and Woodford (1996), these specifications improved the statistical fit of regressions, but did not entirely settle the question of whether a stable, long-term relationship between oil prices and other macroeconomic variables existed. They further argued that the concept of 'how much effect' still attract interest to those responsible for policy formulation. Rotemberg and Woodford (1996) estimate that "a 10% increase in the price of oil is predicted to contract output by 2.5%, 5 or 6 quarters later".[57] Finn's (2000) specification of a similar aggregate model reveals that an oil price shock causes sharp, simultaneous decreases in energy use and capital utilisation.

Using bivariate and multivariate VAR specifications, Hooker (1999) examined the stability of the oil price GDP relationship over the period 1954-1995. He identified that oil prices directly affected output in the pre-1980 period, and appear to have operated through other indirect channels after 1980. Backus and Crucini (2000) in a study of US economy found that terms of trade volatility is significantly related to increased oil price volatility, as opposed to fluctuations in exchange rates.

Bercement et al. (2009) examine how oil prices affect the output growth of selected MENA countries that are considered either net-exporters or net-importers of oil using time-series technique. The result suggest that oil price increase have a statistically significant and positive impact on the output of Algeria, Iran, Iraq, Kuwait, Libya, Oman, Qatar, Syria and the UAE. However, oil prices do not appear to have a statistically significant impact on the output of Bahrain, Djibouti, Egypt, Israel, Jordan, Morocco and Tunisia.

Aliyu (2009) analysed the effect of oil prices on real macroeconomic activity in Nigeria employing both linear and non-linear specifications. The paper finds evidence of both linear and non-linear impacts of oil price shocks on real GDP. In particular, asymmetric oil price increases are found to have greater impact on real GDP growth than asymmetric oil price decreases adversely affects real GDP.

[57] See page 549

Most of the studies mentioned above used GDP as a measure of economic output. Cunado and Gracia (2003, 2005) in an analysis of 14 European countries and 6 Asian countries are among the few studies that used the industrial production index (IPI) as a measure of economic output. Tables 3.1 and 3.2 provide a summary of some major empirical studies of the OECD and non-OECD countries respectively, on the causal relationship between oil prices and economic output. The tabular approach helps to provide a snap-shot of the major studies obtained in the literature.

The studies summarised in Tables 3.1 and 3.2 reveal evidence of both uni-directional and bi-directional causality between oil prices and economic output. While most causality studies have been interested in investigating whether oil prices Granger-cause GDP (uni-directional causality), Jimenez-Rodriguez & Sanchez (2004) investigates the existence of bi-directional causality. The result shows evidence of a bi-directional relationship in five out of the eight OECD countries analysed. Furthermore, the result reveals different outcome for some countries depending on whether a symmetric or asymmetric specification is considered as is found for Italy in Jimenez-Rodriguez & Sanchez (2004); Germany, Ireland, Denmark and Greece in Cunado and Perez de Gracia (2003); Japan in Cunado and Perez de Gracia (2005); and China in Du and Wei (2010).

As far as is known, there is only one study, Lescaroux and Mignon (2008), that analysed the oil price – GDP relationship from a panel approach. Using annual data from 36 countries, they split the countries into oil exporting and

Table 3.1
Summary of Empirical Study on the Causal Relationship between Oil Prices and GDP for OECD Countries

Author	Year	Country	Period	Method	Result	Non-Linear Result	
						OP+	NOPI
Hamilton	1983	USA	1949-1972 (Q)	VAR	OP → GNP	-	-
Mory	1993	USA	1952-1990 (A)	OLS	OP →GDP	-	-
Hooker (a)	1996	USA	1947-1974 (Q)	VAR	OP →GDP	OP+ →GDP	-
Hooker (b)	1996	USA	1947-1994 (Q)	VAR	OP ∞ GDP	OP+ ∞ GDP	-
Rodriguez	2004	8 OECD Countries	1960-1999 (Q)	VAR			
and Sanchez		USA			OP →GDP	OP+ ⟷ GDP	NOPI → GDP
		Japan			OP↔ GDP	OP+ ⟷ GDP	NOPI ⟷ GDP
		Canada			OP↔ GDP	OP+ ⟷ GDP	NOPI ⟷ GDP
		France			OP↔ GDP	OP+ ⟷ GDP	NOPI → GDP
		Italy			OP →GDP	OP+ ⟷ GDP	NOPI ⟷ GDP
		Germany			OP↔ GDP	OP+ ⟷ GDP	NOPI ⟷ GDP
		UK			OP↔ GDP	OP+ ⟷ GDP	NOPI ⟷ GDP
		Norway			OP →GDP	OP+ → GDP	NOPI → GDP
Cunado and	2003	14 European Countries	1960-1999 (Q)	VAR			
Perez-de-Gracia		Germany			OP ∞ IPI	OP+ ∞ IPI	NOPI → IPI
		Belgium			OP →IPI	OP+ → IPI	NOPI → IPI
		Austria			OP →IPI	OP+ → IPI	NOPI → IPI
		Spain			OP ∞ IPI	OP+ ∞ IPI	NOPI ∞ IPI
		Finland			OP ∞ IPI	OP+ → IPI	NOPI ∞ IPI
		France			OP →IPI	OP+ →IPI	NOPI → IPI
		Ireland			OP ∞ IPI	OP+ → IPI	NOPI → IPI
		Italy			OP ∞ IPI	OP+ ∞ IPI	NOPI ∞ IPI
		Luxembourg			OP →IPI	OP+ → IPI	NOPI → IPI
		UK			OP →IPI	OP+ → IPI	NOPI → IPI
		Netherlands			OP →IPI	OP+ → IPI	NOPI → IPI
		Denmark			OP ∞ IPI	OP+ → IPI	NOPI → IPI
		Greece			OP ∞ IPI	OP+ → IPI	NOPI → IPI
		Sweden			OP →IPI	OP+ → IPI	NOPI → IPI
Hanabusa	2009	Japan	2000-2008 (M)	EGARCH	OP↔ GDP	-	-

Note: 1. OP → GDP - Oil Prices Granger-cause GDP (uni-directional causality), OP ∞ GDP - Oil prices do not Granger-cause GDP, OP↔GDP - Oil prices Granger-cause GDP and also GDP Granger-cause oil prices (bi-directional causality)
2. VAR - Vector Autoregression, OLS - Ordinary Least Square, EGARCH - Generalised Autoregressive Conditional Heteroscadasticity, Q - Quarterly data, A - Annual data, M - Monthly data
.

Table 3.2
Summary of Empirical Study on the Causal Relationship between Oil Prices and GDP for Non-OECD Countries

Author	Year	Country	Period	Method	Result	Non-Linear Result	
						OP+	NOPI
Cunado and	2005	6 Asian Countries	1975-2002 (Q)	VAR			
Perez-de-Gracia		Japan			OP ∞ IPI	OP+ ∞ IPI	NOPI $\rightarrow$ IPI
		Singapore			OP ∞ IPI	OP+ ∞ IPI	NOPI ∞ IPI
		South Korea			OP ∞ IPI	OP+ ∞ IPI	NOPI ∞ IPI
		Malaysia			OP ∞ IPI	OP+ ∞ IPI	NOPI ∞ IPI
		Thailand			OP ∞ IPI	OP+ ∞ IPI	NOPI ∞ IPI
		Phillipines			OP ∞ IPI	OP+ ∞ IPI	NOPI ∞ IPI
Lescaroux	2008	Three panels	1960-2005 (A)	VAR			
and Mignon		Group of oil importers			OP $\rightarrow$ GDP	-	-
		OPEC			OP $\rightarrow$ GDP	-	-
		Other oil exporters			OP ∞ GDP	-	-
Gou	2008	3 Countries	1999-2007 (Q)	VAR			
		Russia			OP $\rightarrow$ GDP	-	-
		Japan			OP $\rightarrow$ GDP	-	-
		China			OP $\rightarrow$ GDP	-	-
						-	-
Aliyu	2009	Nigeria	1980-2007 (M)	VAR	OP $\rightarrow$ GDP	OP+ $\rightarrow$ GDP	NOPI $\rightarrow$ GDP
Du and Wei	2010	China	1995-2008 (M)	VAR	OP $\rightarrow$ GDP	OP+ ∞ GDP	NOPI ∞ GDP

Note: 1. OP $\rightarrow$ GDP - Oil Prices Granger-cause GDP (uni-directional causality), OP ∞ GDP - Oil prices do not Granger-cause GDP, OP$\leftrightarrow$GDP - Oil prices Granger-cause GDP and also GDP Granger-cause oil prices (bi-directional causality)
2. VAR - Vector Autoregression, OLS - Ordinary Least Square, EGARCH - Generalised Autoregressive Conditional Heteroscadasticity, Q - Quarterly data, A - Annual data, M - Monthly data
3. Even though the table is mainly for non-OECD countries, a few OECD countries forms part of the group analyzed and are therefore indicated by (*).

oil importing countries.[58] The result shows that oil prices Granger-cause GDP for the group of oil importing countries and OPEC member countries while it fails to Granger-cause GDP for the group of other oil exporting countries.[59]

The above literature review mostly focuses on a single country as outlined earlier. While this study has come across only one panel study investigating the oil price – GDP relationship, quite a number of studies have applied panel approach to investigate other areas within the energy economics literature such as the causal link between energy consumption and economic growth and estimating energy demand functions. The panel causality approach normally requires prior testing on the properties of the data, using techniques that are often developed on the ideas of the time-series tests. The basic structure and literature behind both time-series and panel data testing are discussed in the next sub-sections.

3.2.3 Testing for Causality - Time-series Approach

The causality testing framework has been mainly based on the Granger-causality concept. Before undertaking causality testing, advances in econometrics suggests that the unit-root and cointegration test should be applied. For a long-time, econometricians did not realize that some basic assumptions made by the classical economic theory about the data generating process (DGP) of the variables are not satisfied by many macro time-series variables. In classical econometrics, it is assumed that all the variables have constant mean and constant variance which is not always the case. Variables of this type are known

[58] The list of oil exporting/importing countries considered includes both OECD and non-OECD countries.

[59] Represents other oil exporting countries that are not members of OPEC

as non-stationary variables.[60] Furthermore, it has been shown that regressions on non-stationary variables give spurious results (Phillips and Ouliaris, 1990). Moreover, the variables are expected to be integrated of the same order before cointegration test can be applied. As noted by Granger (1988), a series is said to be integrated of order one, denoted by I(1) if its changes are I(0). In order to be sure that the variables in the model are stationary, unit root tests to examine the stationarity properties of the variables will have to be employed. There are different types of unit root tests however the frequently used ones in the literature are Augmented Dickey Fuller (1981) test and Phillips Perron (1988) test, details of which are discussed in the methodology section.

The concept of cointegration in a time-series approach was originally introduced by Engle and Granger (1987) as a useful statistical tool to test for the long-run equilibrum relationship between non-stationary time-series. Cointegration as defined by Yoo (2006) is the systematic co-movement among two or more economic variables over the long-run. According to Engle and Granger (1987), X and Y are defined as being cointegrated if the linear combination of X and Y is stationary but each of the variable is not. Engle and Granger (1987) further outline that if a pair of I(1) series are cointegrated, there must be causation in at least one direction. The series is then generated by an error correction model to identify the direction of causation.[61]

One of the limitations of Engle and Granger method is that it cannot deal

[60] Patterson (2000) stated that if the series is non-stationary, then it can be differenced to achieve stationarity. It is said to be integrated of order d, I(d), with d unit-roots, where d is an integer indicating how many differences need to be taken before the series become stationary.

[61] The causality test based on an error correction model possesses two or even three avenues through which causal effect can emerge. The panel causality test in the next subsection is more detailed.

with a situation where more than one cointegrating relationship is possible. Johansen (1988) developed a system approach to cointegration that allows for up to 'r ' linearly cointegrated vectors. Johansen (1988, 1991) pointed out if cointegration exist, a Vector Error Correction Model (VECM) may be estimated. One important issue to note when performing cointegration test is the sensible lag structure to be determined. The most common creteria used in the literature are Schwartz Information Criteria (SIC) or Akaike Information Criteria (AIC).

Gregory et al. (2004) observe mixed signals, that is, a relatively high test statistic for one test and a relatively low test statistic for another, in time series cointegration test. According to them, this effect is particularly strong when comparing residual (such as Engle and Granger test) and system based tests (such as Johansen test). Decision on which of the test result to be relied upon lies with the researcher given that there is rarely a compelling theoretical reason to prefer one test over another in practice. Gregory et al. (2004) suggest that if interest is concentrated on a particular relationship or variable, the residual tests are more appropriate. However, for a multivariate settings, the system approach is likely to be adopted.

3.2.4 Testing for Causality - Panel Approach

Over the last two decades, time-series cointegration technique have been widely used in empirical analysis. However, Quah (1994) argued that the low power of the DF (Dickey Fuller) and ADF (Augmented Dickey Fuller) unit root test led researchers to develop unit root and cointegration tests for panel data. Following the extension of time-series unit root test to the panel data by Quah

(1994), Levin et. al (2002) and Im et al. (2003), the application of panel cointegration tests has attracted wide interest in empirical literature, part of the reason being that the technique can take into account heterogeneity across countries and the efficiency gains associated with more data. One of the major challenges faced by researchers in time-series estimation, particularly when dealing with non-OECD countries is the difficulty in finding long enough data span required for an efficient estimation process. Nicholas and Payne (2009) pointed that "estimation is usually difficult for many developing countries because of a short data span, different level of economic development/economic condition and the presence of structural breaks which lowers the power of unit roots and cointegration tests in time-series data analysis. To circumvent the reduction in power and size properties, panel unit-root and panel cointegration tests should be utilized" (p.5).

As pointed out by Jun (2004), there are mainly two different approaches to panel cointegration tests - residual and system-based. The residual-based panel cointegration test statistics were introduced by Pedroni (1997, 1999, 2002) and Kao (1999) while the system-based panel cointegration statistics were introduced by Larsson and Lyhagen (1999) and Maddala and Wu (1999). Researchers often find conflicting result when applying different panel cointegration tests; Hanck (2006) studied the extent to which different widely used panel cointegration tests yield the same decision for a given sample and found that "the consensus in test decisions among panel data cointegration tests generally does not seem to be higher than among time series cointegration tests. Thus, it seems all but unlikely that a researcher will find conflicting evidence when applying some pairs of panel cointegration test to a given data set" (p.8).

A possible explanation to this could be that the complexities inherent to panel data such as treatment of cross-sectional heterogeneity.[62]

Most of the previous literature that estimated causality in a panel context adopted the panel based error correction model to account for the long-run relationship using the two step procedure from Engle & Granger (1987). The error correction based causality method allows for the inclusion of the lagged error correction term derived from the cointegration equation. According to Narayan and Smith (2008), by including the lagged error correction term, the long-run information that is lost through differencing is re-introduced in a statistically acceptable way. Acarachi and Ozturk (2010) pointed out by using error correction based causality models, Granger causality can be examined in three ways; short-run causality, long-run causality and strong Granger causality (jointly testing the significance of both long-run and short-run causality). The various stages involved in time-series and panel causality testing and all the technical details within each stage are outlined in the next section.

3.3 Methodology

3.3.1 Time-series Approach

The following tests are employed to estimate causality relationship in a time-series context; firstly, unit-root tests are undertaken based on Augmented Dickey Fuller test (ADF) and Phillips Perron test (PP) - the two most commonly used unit-root test in the literature. Secondly, if the series are found to

[62] The technical aspect of the panel unit root and panel cointegration tests will be explained in the next section

integrated of order I(1), cointegration tests developed by Engle and Granger (1987) and Johansen (1988) are applied before finally testing for causality relationship using the error-correction model based causality tests. The technical details of the various tests are specified below:

Unit Root Test

The Augmented Dickey Fuller (ADF) test is an augmented version of the Dickey Fuller (DF) test. The DF tests assume the error term is not autocorrelated or serially correlated with the explanatory variable. Consider a simple AR(1) model, thus:

$$y_t = \rho y_{t-1} + u_t \tag{3.1}$$

where y_t is the variable of interest (in the case of this research log of oil prices and log of GDP), ρ is a coefficient and u_t is the error term. A unit root is present if $\rho = 1$, in which case the model would be non-stationary.

The regression model to test for a unit root with intercept and time trend can be written as:

$$\Delta y_t = \alpha + \lambda t + \rho y_{t-1} + u_t \tag{3.2}$$

where Δ is the first lag operator, α is a constant, and λ is the coefficient of time trend.[63] The model is estimated and testing for a unit root is done by testing $\rho = 0$.

[63] Since unit-root test will be undertaken on all the variables, y represents LRGDP in one test and LROP in another. Similar approach will be taken when presenting panel unit-root test.

The testing procedure for the ADF is the same with the DF only that the ADF adds lag of the dependent variable in the model.

$$\Delta y_t = \alpha + \lambda t + \rho y_{t-1} + \delta_1 \Delta y_{t-1} + \delta_p \Delta y_{t-p} + u_t$$

where Δ is the first lag operator, α is a constant, and λ is the coefficient of time trend and p is the lag order of the autoregressive process. The unit root test is undertaken under the null hypothesis $\rho = 0$ against the alternative hypothesis $\rho < 0$.

The Phillips Perron test builds on the Dickey-Fuller test of the null hypothesis $\delta = 0$ in

$$\Delta y_t = \delta y_{t-1} + u_t \tag{3.3}$$

where Δ is the first lag operator. Like the ADF test, the Phillips and Perron (1988) addresses the issue of autocorrelation that is associated with the DF test. Whilst the ADF test addresses this issue by introducing lags of Δy_t, the Phillips-Perron (PP) test makes a non-parametric correction to the t-test statistics. One of the major advantages of the PP test over the ADF is that it is more robust in dealing with serial-correlation and heteroskedasticity in the error term.

Cointegration Test

Following the Engle and Granger (1987) cointegration procedure, a long-run relationship between oil prices and GDP is estimated at the first stage using the following simple specification:

$$LRGDP = \alpha_0 + \alpha_1 LROP + \alpha_2 T + u_t \tag{3.4}$$

where LRGDP and LROP are natural log of real GDP and real oil prices, repectively and T is the time trend. The trend is included to capture other exogenous factors that affect the model.

To determine if the real GDP and real oil prices are cointegrated, the residual of the first stage regression should be stationary, which is tested using the ADF test. The null hypothesis is that the variables are cointegrated, that is the residuals are I(0).

Johansen (1988) cointegration technique takes its starting point in the vector autoregression (VAR) of order p given by

$$y_t = \mu + A_1 y_{t-1} + ... + A_p y_{t-p} + \varepsilon_t \tag{3.5}$$

where y_t is an nx1 vector of variables[64] that are integrated of order one. Equation 3.5 can be re-written as

$$\Delta y_t = \mu + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t$$

where

$$\Pi = \sum_{i=1}^{p} A_i - I \text{ and } \Gamma_i = -\sum_{j=i+1}^{p} A_j.$$

Johansen proposes two different likelihood ration test - the trace test and maximum likelihood test, shown in the following equations respectively.

[64]Since Johansen test can be used to test multivariate cointegration test, y_t here represents all the variables in the equation.

$$J_{trace} = -T \sum_{i=r+1}^{n} In(1 - \widehat{\lambda}_i)$$

$$J_{\max} = -T \text{ In}(1 - \widehat{\lambda}_{r+1})$$

As explained in Johansen (1988), the trace test tests the null hypothesis of r cointegrating vectors against the alternative hypothesis of n cointegrating vectors while the maximum eigenvalue tests the null hypothesis of r cointegrating vectors against the alternative hypothesis of r+1 cointegrating vectors. The asymptotic critical values is reported in Johansen (1990).[65]

Causality Test

The initial formulation of Granger model used variables at levels (as shown in the previous section) but with later advances in econometrics that requires pre-testing on time-series macro-economic variable, the models are replaced by:

$$\Delta LRGDP_t = \alpha_{1j} + \sum_{k=1}^{m} \alpha_{11k} \Delta LRGDP_{t-k} + \sum_{k=1}^{m} \alpha_{12k} \Delta LROP_{t-k} + u_{1t} \quad (3.6)$$

$$\Delta LROP_t = \alpha_{2j} + \sum_{k=1}^{m} \alpha_{21k} \Delta LROP_{t-k} + \sum_{k=1}^{m} \alpha_{22k} \Delta LRGDP_{t-k} + u_{2t} \quad (3.7)$$

where Δ is the first lag operator, m is the lag length. In the output equation

[65] The critical values are given by most econometric packages. The package used for this study is EViews 7

(3.6), short-run causality from real oil price to real GDP is tested based on $H_0 : \alpha_{12ik} = 0$. In the real oil price equation (3.7), short-run causality from real GDP to real oil price is tested based on $H_0 : \alpha_{21ik} = 0$.

If, however, it is found that the two integrated variables cointegrate, then the equation can be augmented as follows:

$$\begin{aligned} \Delta LRGDP_t &= \alpha_{1j} + \sum_{k=1}^{m} \alpha_{11k} \Delta LRGDP_{t-k} + \sum_{k=1}^{m} \alpha_{12k} \Delta LROP_{t-k} \\ &\quad + \lambda_{1k} ECTG_{t-k} + u_{1t} \end{aligned} \tag{3.8}$$

$$\begin{aligned} \Delta LROP_t &= \alpha_{2j} + \sum_{k=1}^{m} \alpha_{21k} \Delta LROP_{t-k} + \sum_{k=1}^{m} \alpha_{22k} \Delta LRGDP_{t-k} \\ &\quad + \lambda_{2k} ECTP_{t-k} + u_{2t} \end{aligned} \tag{3.9}$$

where ECTG is the error correction term from the estimate of the long-run relationship with LRGDP being the dependent variable (equation 3.4) while ECTP is the error correction term from the long-run relationship with LROP being the dependent variable. The null hypothesis of no long-run causality is tested by examining the significance for the coefficient of the error correction terms λ_{1k} and λ_{2k} respectively. The optimum lag length is selected automatically based on Schwartz Information Criteria (SIC).

Figure 3.1: Time-series Causality Testing Framework

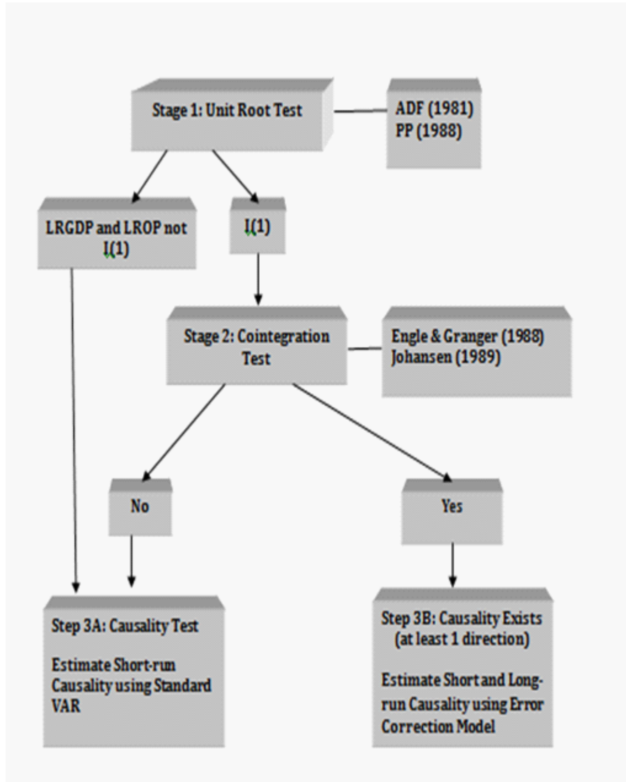


Figure 3.1 provides a summary of the time-series methodology adopted in this chapter.[66] The methodology involves the following stages:

Stage 1: Unit-root test on the variables (LRGDP and LROP) for each country is tested using Augmented Dickey Fuller (ADF) test and Phillips-Perron (PP) test. The number of lags is determined by using Schwarz Information Criteria (SIC). If both variables are found to be I(1), then proceed to stage 2. If on the other-hand the variables are found to be I(0), then proceed to stage 3A.

Stage 2: At this stage, cointegration between LRGDP and LROP is tested using Engle & Granger (1988) and Johansen (1989) cointegration techniques.

[66] Presentation of the causality testing framework is similar to what was done in Chontanawat et al. (2008)

The specification for both tests allows for linear trend and constant. If cointegration is not found, proceed to stage 3A, but if cointegration is found, proceed to stage 3B.

Stage 3A: If cointegration is not found, short-run causality is tested using the conventional Granger (1969) methodology.[67]

Stage 3B: Existence of a long-run relationship signifies causality at least in one direction. Direction of causality is determined using the error correction model based causality test. However, if the estimated coefficient of the error correction term is positive then causality is re-estimated using the conventional approach (stage 3A).

3.3.2 Asymmetric Specification

As discussed in the litegrature review, there is the perception that the impact of oil price changes on macro-economic variables is asymmetric. According to Mork (1989), Hamilton (1996) and Hooker (1999), there is evidence that oil prices have asymmetric and non-linear effects on economic activity. The baseline VAR specification in the previous section assumes the impact of oil price changes is linear and direct. In order to test for asymmetries, two leading non-linear transformations of oil prices are considered. The first type of transformation was developed by Mork (1989). Based on this method, asymmetric response of oil price changes can be captured by specifying oil price increase and decrease as seperate variables. This can be defined thus:

[67] Chontanawat et al. (2008) and Gries et al. (2009) have used the basic Hsiao-Granger causality to test for short-run causality where cointegration does not exist. Even though the long-run causality relationship is what is of key interest, short-run relationship can have some useful economic interpretation as shown by Cunado and Perez de Gracia (2003).

$$O_t^+ = \{ \begin{matrix} O_t \ if \ O_t > 0 \\ 0 \ otherwise \end{matrix}$$

$$O_t^- = \{ \begin{matrix} O_t \ if \ O_t < 0 \\ 0 \ otherwise \end{matrix}$$

where O_t the rate of change in the price of oil while O_t^+ and O_t^- are positive and negative rates of changes in oil prices respectively. The second transformation is the one suggested by Hamilton (1996) which considers the net increase in oil prices over a period of three years. The net oil price increase (NOPI) specification is defined as follows:

$$NOPI_t = \max\{0, O_t - \max(O_{t-1,}O_{t-2}, O_{t-3})\}$$

if the value of the current year exceeds the previous three years maximum, the percentage change over the period is calculated. If the price of oil at time t is lower than it had been during the previous three years, the series is defined to be zero for time t.[68]

Asymmetric relationship is tested based on the two specification outlined above using time series data. Unit root tests are conducted in order to confirm the order of integration of the decomposed oil price variables before testing for the short-run asymmetric effects of oil price changes on economic output in line with the works of Kilian and Park (2009), Du et al. (2010) and Chuku et al. (2010). Thus, the following short-run equations will be used to test whether oil price increase, oil price decrease or net oil price increase Granger-

[68] Studies of the oil-price GDP relationship that applied the asymmetric specification used the zero threshold following Mork (1989) and Hamilton (1996). This study, therefore also applies the zero threshold.

cause GDP.

$$\Delta LRGDP_t = \alpha_j + \sum_{k=1}^{m} \alpha_{ik} \Delta LRGDP_{t-k} + \sum_{k=1}^{m} \lambda_j^{+} \Delta LROP_{t-k}^{+} + \sum_{k=1}^{m} \lambda_j^{-} \Delta LROP_{t-k}^{-} + u_t \quad (3.10)$$

$$\Delta LRGDP_t = \alpha_j + \sum_{k=1}^{m} \alpha_{ik} \Delta LRGDP_{t-k} + \sum_{k=1}^{m} \lambda_j^{+} \Delta NOPI_{t-k} + u_t \quad (3.11)$$

where Δ is the first lag operator, m is the lag length and u is the serially uncorrelated error term. $\Delta LROP^{+}$ represent oil price increases, $\Delta LROP^{-}$ represent oil price decreases and the NOPI is the net oil price increase. Asymmetric relationship is tested based on the coefficients of the decomposed oil price variables, λ_j^{+} and λ_j^{-}. Thus, the specifications are used to test whether oil price increases, oil price decreases or net oil price increases Granger-causes GDP.

3.3.3 Panel Approach

Panel causality tests also involves different stages; firstly, panel unit root tests is undertaken for the series and if the series is found to be integrated of order one I(1), panel cointegration tests is employed being the second stage of the estimation process. If cointegration is accepted, the long-run cointegrating vector is estimated using Fully Modified OLS (FMOLS) developed by Pedroni (2000). A long-run relationship implies the existence of causality at least in one direction. Finally, a panel error correction model is established by generating an error correction term from the long-run estimator to examine the direction of causality. However if cointegration is not found, panel causality will still be tested in a standard VAR model to estimate short-run causality relationship.

Panel Unit Root Test

Three different panel unit-root tests are applied to check the order of integration; Levin et al. (2002)[69], Im et al. (2003) and The Fisher ADF test – Choi (2001). Following the methodology used in similar literature, this work test for both trend and mean stationarity for the two variables - log of real GDP (LRGDP) and log of real oil price (LROP). Consequently, the panel unit roots test will be undertaken based on two different models; model with constant and no time trend (model 1) and model with constant and time trend (model 2).The number of lagged first differences is based on automatic selection of Schwartz Information Criterion.

The technical details of the three panel unit root tests are therefore presented below:

Levin et al. (2002) (LLC thereafter) Using pooled t-statistic of the estimator, LLC developed a procedure to evaluate the hypothesis that each time series contains a unit root against the alternative hypothesis that each time series is stationary. Hence, LLC assume homogeneous autoregressive coefficient between individual, that is, $\rho_i = \rho$ for all i and test the null hypothesis $H_0 : \rho_i = \rho = 0$ against the alternative $H_a : \rho_i = \rho < 0$ for all i.

[69] Levin and Lin (1992) first proposed the test in 1992. In 1993 they generalized the analysis allowing for Heteroscedastity and autocorrelation. Their paper in 2002 Levin, Lin and Chu (2002) collect major result from their researches

The structure of the LLC may be specified as follows:

$$\Delta y_{it} = \rho_i y_{it-1} + \alpha_{0i} + \alpha_{1i} t + u_{it} \tag{3.12}$$

where $i = 1....,N$ for each country in the panel, $t = 1....,T$ for the time period. A time trend ($\alpha_{1i}t$) as well as individual effects (α_i) are incorporated.

According to Westerlund (2006), there should be some caution on the use of the LLC test. Firstly, the test depends on the independent assumption across individuals, and therefore not applicable if cross sectional correlation exist. Secondly, the autoregressive parameters are considered being identical across the panel. These limitations have been overcome by Im Pesaran & Shin (2003) and Choi (2001) test which proposed a panel unit root test without the assumption of identical first order correlation.

Im et al. (2003) (IPS thereafter) IPS panel unit root test takes the average of ADF unit root test applied on each of the cross-sections while allowing for different orders of serial correlation. The IPS unit root test renders the following expression:

$$y_{it} = \rho_i y_{it-1} + \sum_{j=1}^{pi} \varphi_{ij} e_{it-1} + \delta_i x_{it} + u_{it} \tag{3.13}$$

Where $i = 1...,N$ for each country in the panel; $t = 1....,T$ refers to the time period; x_{it} represents the exogenous variables including fixed effects or individual time trend; ρ_i are the autoregressive coefficients, pi represents the number of lags in the ADF regression; and e_{it} are the stationary error terms. If $\rho_i < 1$, y_{it} is considered weakly trend stationary where as if $\rho_i = 1$, then y_{it} contains unit root. As was the case in LLC, the null hypothesis is that each series in the panel contains a unit root while the alternative hypothesis is that at least one of the individual series in the panel is stationary. IPS specifies a t-bar statistic which is normally distributed under the null hypothesis with the critical values provided by IPS (2003).

The Fisher's ADF Test Choi (2001) suggest the use of non parametric test which uses a combination of the p-values of the test statistics for a unit root in each cross-sectional unit. One advantage of the Fisher test over LLC is that it relaxes the restrictive assumption that ρ_i is the same under the alternative.

Barbieri (2006) noted, previous tests (LLC and IPS) suffer from some common inflexibilities which can restrict their use in applications; (i) they all require an infinite number of groups (ii) all the groups are assumed to have the same type of non-stochastic component (iii) T is assumed to be the same for all the cross-section units and to consider the case of unbalanced panel further simulations is required (iv) finally, the critical value are sensitive to the choice of lag lengths in the ADF regressions.

Choi (2001) has overcome these limitations by proposing a test based on the combination of p-values from a unit root test applied to each cross-section of the panel data. Accordingly, Choi (2001) considers the model:

$$y_{it} = d_{it} + x_{it} \tag{3.14}$$

where

$$d_{it} = \alpha_{i0} + \alpha_{i1}t + ... + \alpha_{im}t^m$$

$$x_{it} = \rho_i x_{i(t-1)} + u_{it}$$

Note that y_{it} in equation 3.14 is composed of non-stochastic process d_{it} and a stochastic process x_{it} . Each y_{it} can have different sample size and different specification of non-stochastic and stochastic component depending on i. According to Choi (2001), the null hypothesis is given as:

$H_0 : \rho_i = 1$ for all i which implies that all the time series non-stationary while the alternative hypothesis is given as:

$H_a : \rho_i < 1$ for at least one i for finite N (that is some time series are non-stationary while the others are not) or $H_a : \rho_i < 1$ for some i's for infinite N (that all the time series are stationary, as it is considered in LLC).

Barbieri (2006) identified some important advantages of the Fisher test being that it does not require a balanced panel, it can be carried out for any unit root test derived and that it is possible to use different lag lengths in the individual ADF regression.

Despite the limitations of the LLC and IPS tests, they remain the most widely applied unit root tests in panel data analysis. All three tests are applied to re-confirm the order of integration and after defining the order of integration prompted by the existence of unit-roots in the series, the long-run cointegrating relationship is estimated using three different panel cointegration test.

Panel Cointegration Tests

If the series (LRGDP and LROP) are found to be integrated of the same order, a long-run cointegrating relationship between them is estimated at the second step of the estimation process. Three different panel cointegration tests developed by Pedroni (1999, 2004), Kao (1999) and Maddala and Wu (1999) are applied. Details of the tests provided below

Pedroni (1999, 2004) heterogeneous panel cointegration test, which allows for cross section interdependence with different individual effects, is specified as follows:

$$LRGDP_{it} = \alpha_{it} + \delta_i t + \beta_{1i} LROP_{it} + e_{it} \tag{3.15}$$

where $i = 1....,N$ for each country in the panel and $t = 1....,T$ refers to the time period. LRGDP is the natural logarithm of real gross domestic product while LROP is the natural logarithm of real oil price. The parameters α_{it} and δ_i allows for the possibility of country specific fixed effects and deterministic trend, respectively. e_{it} is the estimated residuals representing deviations from the long run relationship. To test the null hypothesis of no cointegration, $\rho_i = 1$, the following unit root test is conducted on the residuals as follows:

$$e_{it} = \rho_i e_{it-1} + w_{it} \tag{3.16}$$

Pedroni (1999, 2004) proposes seven residual-based tests under the null of no cointegration. Out of the seven tests proposed, four are based on pooling the residuals for the within group estimation (which includes panel v-statistic, panel ρ-statistic, panel PP-statistic, and panel ADF-statistic) while the other three are based on pooling the residuals for the between group estimation (which includes group ρ-statistic, group PP-statistics, and group ADF-statistics). According to Pedroni (2001), one of the key advantages of the between group estimators is that the point estimate has a more useful interpretation in the event that the true cointegrating vectors are heterogenous. Following Pedroni (1999, 2004), the heterogeneous panel and heterogeneous group mean panel cointegration statistics are calculated as follows:

Panel v-statistic:

$$Z_v = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \widehat{L}_{11i}^{-2} \widehat{e}_{it-1}^{2} \right)^{-1}$$

Panel ρ-statistic:

$$Z_\rho = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \widehat{L}_{11i}^{-2} \widehat{e}_{it-1}^{2} \right)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \widehat{L}_{11i}^{-2} (\widehat{e}_{it-1} \Delta \widehat{e}_{it} - \widehat{\lambda}_i)$$

Panel PP-statistic:

$$Z_\rho = \left(\widehat{\sigma}^2 \sum_{i=1}^{N} \sum_{t=1}^{T} \widehat{L}_{11i}^{-2} \widehat{e}_{it-1}^{2} \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \widehat{L}_{11i}^{-2} (\widehat{e}_{it-1} \Delta \widehat{e}_{it} - \widehat{\lambda}_i)$$

Panel ADF-statistic:

$$Z_t^* = \left(\widehat{S}^{*2} \sum_{i=1}^{N} \sum_{t=1}^{T} \widehat{L}_{11i}^{-2} \widehat{e}_{it-1}^{*2} \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \widehat{L}_{11i}^{-2} \widehat{e}_{it-1}^{*} \Delta \widehat{e}_{it}^{*}$$

Group ρ-statistic:

$$\widetilde{Z}_\rho = \sum_{i=1}^{N} \left(\sum_{i=1}^{T} \widehat{e}_{it-1}^{2} \right)^{-1} \sum_{t=1}^{T} (\widehat{e}_{it-1} \Delta \widehat{e}_{it} - \widehat{\lambda}_i)$$

Group PP-statistic:

$$\widetilde{Z}_t = \sum_{i=1}^{N} \left(\widehat{\sigma}^2 \sum_{i=1}^{T} \widehat{e}_{it-1}^{2} \right)^{-1/2} \sum_{t=1}^{T} (\widehat{e}_{it-1} \Delta \widehat{e}_{it} - \widehat{\lambda}_i)$$

Group ADF-statistic:

$$\widetilde{Z}_t^* = \sum_{i=1}^{N} \left(\sum_{i=1}^{T} \widehat{S}_i^2 \widehat{e}_{it-1}^{*2} \right)^{-1/2} \sum_{t=1}^{T} (\widehat{e}_{it-1}^* - \widehat{e}_{it}^*)$$

Here, $\widehat{e}_{it}$ is the estimated residual from equation (3.4) and $\widehat{L}_{11i}$ is the estimated long-run covariance matrix for $\Delta\widehat{e}_{it}$. Of the seven tests proposed by Pedroni (1999, 2004), the panel v-statistic reject the null hypothesis of no cointegration with large positive values where as the remaining test statistics reject the null hypothesis of no cointegration with large negative values. The critical values are provided in Pedroni (1999) and also given by some econometric software packages.

Kao (1999), which is another residual based panel cointegration test follows the same basic approach as the Pedroni test but specifies cross-section specific intercepts and homogeneous coefficients on the first-stage regressors. The bivariate case described in Kao (1999) is provided below:

$$LRGDP_{it} = \alpha_i + \beta LROP_{it} + e_{it} \tag{3.17}$$

for

$$LRGDP_{it} = LRGDP_{it-1} + u_{i,\, t}$$

$$LROP_{it} = LROP_{it-1} + \varepsilon_{i,\, t}$$

Kao then runs an augmented pooled auxiliary regression,

$$e_{it} = \widetilde{\rho} e_{it-1} + \sum_{j-1}^{p} \Psi_j \Delta e_{it-j} + v_{it} \tag{3.18}$$

Under the null of no cointegration, Kao derives the following statistics,

$$ADF = \frac{t_{\widetilde{\rho}} + \sqrt{6N\widehat{\sigma}_v/(2\widehat{\sigma}_{0v})}}{\sqrt{\widehat{\sigma}_{0v}/(2\widehat{\sigma}_v^2 + 3\widehat{\sigma}_v^2/(10\widehat{\sigma}_v^2))}}$$

Where, $\widetilde{\rho}$ is the estimate of the residuals from the fixed effects panel regression and $t_{\widetilde{\rho}}$ is the associated t-statistic. The test is standard normal under the null hypothesis and reject for large negative values.

Maddala and Wu (1999) developed the Johansen-type panel cointegration test. Maddala and Wu (1999) used Fisher's result to propose an alternative test for cointegration based on a method for combining test from individual cross-sections to obtain a test statistic for the full panel. The Johansen type Fisher tests from trace and maximum eigen-value are developed.

Assuming ρ_i denotes the p-value from an individual cointegration test of cross-section i of the Johansen statistic, then under the null hypothesis of the panel we have the result:

$$-2\sum_{i=1}^{N} \log(\rho_i) \rightarrow X_{2N}^2$$

The test is quite easy to compute and does not assume homogeneity of coefficients in different countries. In other words, it takes into account the heterogeneous country effect that might arise from the data. Evidence of cointegration is obtained if the null hypothesis of none ($r = 0$) cointegrating variables is rejected and the null of at most 1 ($r \leq 1$) cointegrating variable is accepted. In other word, it would confirm the existence of unique cointegrating vector for the estimated model.

The first two panel cointegration test discussed above (Pedroni 1999 and Kao 1999) are residual based test while the Maddala and Wu (1999) test is a system based test. All three panel cointegration methods were adopted to test whether the existence or absences of long-run relationship between the variables. If cointegration is fond on either the residual or system based test, the long-run cointegrating vector will be estimated to form the error correction term which will be used to estimate the dynamic error correction model. On the other hand if cointegration is not found, a standard causality equation will be estimated to obtain the short-run relationship between the variables.

Estimating Long-run Cointegrating Relationship

If a long-run cointegrating relationship is found to exist between LRGDP and LROP, the long-run cointegrating vector is estimated using a fully modified OLS (FMOLS) for heterogeneous cointegrated panels developed by Pedroni (2000). This method is based on the between dimension estimator which takes into account heterogeneity across countries. This is chosen because the mode in which the data is pooled allows for greater flexibility in the presence of heterogeneity of cointegrating vectors. According to Pedroni (2000), the point estimate for the between dimension estimator can be interpreted as the mean value of the cointegrating vector. Thus, consider the regression:

$$LRGDP_{it} = \alpha_i + \beta_i LROP_{it} + u_{it} \tag{3.19}$$

where $LRGDP_{it}$ and $LROP_{it}$ are cointegrated with slopes β_i which may or may not be homogeneous across i. As outlined in Pedroni (2001), the expression for the between-dimension, group-mean panel FMOLS estimator is given as:

$$\widehat{\beta}^{*}_{GFM} = N^{-1}\sum_{i=1}^{N}\widehat{\beta}^{*}_{FM,i}$$

where $\widehat{\beta}^{*}_{FM,i}$, is the time-series FMOLS estimator, which is applied to each country member of the panel. The associated t-statistic for the between dimension-estimator is given as:

$$t\widehat{\beta}^{*}_{GFM} = N^{-1/2}\sum_{i=1}^{N}t\widehat{\beta}^{*}_{FM,i}$$

where $t\widehat{\beta}^{*}_{FM,i}$ is the associated t-value from the individual FMOLS estimates.

Panel Causality Tests

Having estimated the long-run cointegrating vector, the causality relationship is obtained by incorporating residuals from equation (3.17) as an error correction term (ECT) in a dynamic error correction model. The equation being:

$$\begin{aligned}\Delta LRGDP_{it} &= \alpha_{1j} + \sum_{k=1}^{m}\alpha_{11ik}\Delta LRGDP_{it-k} + \sum_{k=1}^{m}\alpha_{12ik}\Delta LROP_{it-k} \\ &\quad +\lambda_{1i}ECT_{it-1} + u_{1it} \qquad (3.20)\end{aligned}$$

This allows for the testing of whether LROP Granger-causes LRGDP which is the main focus of this work; however, the following equation is also considered in order to test whether LRGDP Granger causes LROP.

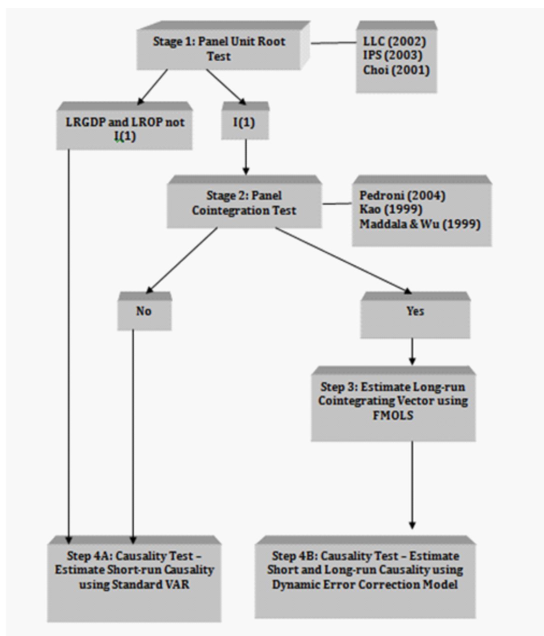
$$\Delta LROP_{it} = \alpha_{2j} + \sum_{k=1}^{m} \alpha_{21ik} \Delta LRGDP_{it-k} + \sum_{k=1}^{m} \alpha_{22ik} \Delta LROP_{it-k} + \lambda_{2i} ECT_{it-1} + u_{2it} \quad (3.21)$$

where Δ is the first lag operator, m is the lag length; ECT is the lagged error correction term derived from the long-run cointegrating relationship; λ_i is an adjustment coefficient and u_{it} is a disturbance term. In the real GDP equation (3.20), short-run causality from real oil price to real GDP is tested based on $H_0 : \alpha_{12ik} = 0$. In the real oil price equation (3.21), short-run causality from real GDP to real oil price is tested based on $H_0 : \alpha_{21ik} = 0$. The null hypothesis of no long-run causality in each of equation (3.20) and (3.21), is tested by examining the significance of the t-statistic for the coefficient on the respective error correction term (ECT) represented by λ_{1i} and λ_{2i} accordingly. The coefficient of ECT's represents how fast deviations from the long-run equilibrium are eliminated following changes in each variable. The significance of the parameter indicates a long-run relationship of cointegrating process and thus movement along the path can be considered permanent.

It is also appropriate to check whether the two sources of causation are jointly significant. This can be done by testing the joint hypothesis H_0:$\alpha_{12ik} = 0$ and $\lambda_{1i} = 0$ in equation (3.20) or H_0:$\alpha_{21ik} = 0$ and $\lambda_{2i} = 0$ in equation (3.21). This is referred to as a strong Granger causality test. As noted by Asafu-Adjaye (2000) the joint test indicates which variable(s) bear the burden of short-run adjustment to re-establish long-run equilibrium following a shock to the system. If there is no causality, then the neutrality hypothesis holds. As indicated earlier, if cointegration is not found, λ_{1i} and λ_{2i} are set to zero in Equations (3.20) and (3.21) giving the standard Granger causality equations used to test only the short-run impact between LRGDP and LROP; again by testing H_0:$\alpha_{12ik} = 0$ and H_0:$\alpha_{21ik} = 0$.

The methodology adopted for the panel causality test can be summarised using the figure below:

Figure 3.2: Panel Causality Testing Framework



Stage 1 : Panel unit root test will be undertaken to check the order of integration of the variables based on three different test; Levin et al. (2002), Im et al. (2003) and Fisher ADF, Choi (2001). The tests conducted on the variables both at level and first difference will be based on three different model specifications; model 1 includes only a constant term, model 2 includes constant and time trend while model 3 includes neither constant nor time trend. If it is found that the variables are integrated of the same order, then proceed to stage 2.

Stage 2: This stage involves investigating the long-run relationship between the variables using three different panel cointegration techniques developed by Pedroni (1999, 2004), Kao (1999) and Maddala & Wu (1999). If evidence of cointegration is found based on any of the cointegration technique, then proceed to stage 3. However, if cointegration is not found, proceed to stage 4a.

Stage 3: If cointegration exists, the long-run cointegrating vector will be estimated using FMOLS developed by Pedroni (2000) before proceeding to stage 4b.

Stage 4a: If cointegration is not found, short-run causality on the variables will estimated using the standard Granger procedure.

Stage 4b: Panel causality test will be conducted using dynamic error correction model to jointly test for both short-run and long-run causality on the variables.

The methodology outlined above explains the technical details of the various tests involved in the estimation process. The empirical result section will report the results of all the analysis undertaken as described above. Before then, the data is discussed in the next section.

3.4 Data

The analysis is undertaken on 20 non-OECD contries using annual data over the period 1971 - 2007. The countries are divided into two categories, detailed as follows:

- **Category A** (net oil exporting countries) consist of non-OECD countries with substantial export of crude oil. The group consist of OPEC member countries: Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, UAE and Venezuela. The OPEC member countries accounts for two-thirds of world's oil reserves and almost 40% of the world's oil production. Also, most of the OPEC countries export more than a million barrels of oil per day. Thus, making it a suitable group to analyse net oil exporting countries.

- **Category B** (net oil importing countries) is a group of non-OECD countries whose economy has not reached First World status but have attained some level of industrialization. One important indicator of this group of countries is their rapid industrial development as result of a switch from agricultural to industrial economies, especially in the manufacturing sector which makes them among the big consumers of crude oil. This group are net oil importers and include the countries: Brazil, China, India, Malaysia, Philippines, Thailand, Turkey and South Africa.[70]

[70] The World Bank refer to these countries as the Newly Industrialized Countries (NIC). The World Bank's list of NIC 2010 also includes Mexico which is omitted in this work because the country is a net oil exporter. Brazil and Malaysia are major oil producers but remain net oil importers over the period covered by this research based on the information obtained from CIA World Fact Book 2010.

The variables considered are LRGDP (real GDP), being the measure of economic output and LROP (real price of internationally traded UK Brent crude) all expressed in natural logs. The real GDP data for all the countries is obtained from the energy information administration data bank while the real oil price data is obtained from BP (2011).

3.5 Empirical Results

3.5.1 Time-series Estimation Results

Unit Root Result

The first-step in the estimation process is to ascertain the order of integration of the variables. Tables 3.3 and 3.4 presents the results derived from Augmented Dickey Fuller (ADF) and Phillips-Perron unit root tests respectively. The choice of the lag length required for the test is based of Scwarz Information Criterion (SIC). Based on the ADF test, the null hypothesis of unit-roots for most of the countries cannot be rejected at levels but strongly rejected at first difference for most of the countries except Brazil and Nigeria, where surprisingly, the GDP series is still not rejected at first difference. This is rather unusual as most GDP series are known to be integrated of order one [I(1)].[71]

The Phillips-Perron test however strongly rejects the null hypothesis of unit-roots (for both series) at first difference for all the countries. It is therefore

[71] See Ozturk and Huseyn (2007)

concluded that real GDP and real oil prices are I(1).[72]

Table 3.3

ADF Unit Root Test Results

Country	$LRGDP$	$LROP$	$\Delta LRGDP$	$\Delta LROP$
Algeria	-1.811	-2.305	-7.550***	-5.599***
Angola	-0.174	-2.305	-3.747**	-5.599***
Ecuador	-2.523	-2.305	-4.490***	-5.599***
Iran	-0.653	-2.305	-6.275***	-5.599***
Iraq	-1.917	-2.305	-5.133***	-5.599***
Kuwait	-1.790	-2.305	-6.098***	-5.599***
Libya	-1.646	-2.305	-4.177**	-5.599***
Nigeria	-2.747	-2.305	-2.694	-5.599***
Qatar	-0.210	-2.305	-6.768***	-5.599***
Saudi Arabia	-2.133	-2.305	-3.133***	-5.599***
UAE	-2.316	-2.305	-4.323***	-5.599***
Venezuela	-2.873	-2.305	-4.634***	-5.599***
Brazil	-0.974	-2.305	-2.797	-5.599***
China	-2.846	-2.305	-3.791**	-5.599***
India	-1.264	-2.305	-7.229***	-5.599***
Malaysia	-1.862	-2.305	-5.012***	-5.599***
Phillipines	-2.512	-2.305	-3.607**	-5.599***
Thailand	-1.718	-2.305	-3.481**	-5.599***
Turkey	-2.726	-2.305	-6.069***	-5.599***
South Africa	-0.436	-2.305	-3.828**	-5.599***

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively

[72] As outlined earlier, Phillips Perron test is considered better than ADF because it is more robust in dealing with serial-correlation and heteroskedasticity.

Table 3.4

Phillips-Perron Unit Root Test Results

Country	$LRGDP$	$LROP$	$\Delta LRGDP$	$\Delta LROP$
Algeria	-4.220**	-2.330	-6.854***	-5.599***
Angola	0.553	-2.330	-3685**	-5.599***
Ecuador	-2.249	-2.330	-4.523***	-5.599***
Iran	-1.140	-2.330	-4.228**	-5.599***
Iraq	-2.027	-2.330	-5.137***	-5.599***
Kuwait	-1.519	-2.330	-9.467***	-5.599***
Libya	-1.883	-2.330	-5.497***	-5.599***
Nigeria	-1.104	-2.330	-5.706***	-5.599***
Qatar	0.117	-2.330	-7.071***	-5.599***
Saudi Arabia	-4.092	-2.330	-3.229**	-5.599***
UAE	-2.638*	-2.330	-4.310***	-5.599***
Venezuela	-1.876	-2.330	-4.549***	-5.599***
Brazil	-3.011*	-2.330	-4.034***	-5.599***
China	-3.001	-2.330	-4.251***	-5.599***
India	-1.264	-2.330	-7.422***	-5.599***
Malaysia	-2.101	-2.330	-5.015***	-5.599***
Phillipines	-0.463	-2.330	-2.900**	-5.599***
Thailand	-1.165	-2.330	-3.499**	-5.599***
Turkey	-2.825	-2.330	-6.068***	-5.599***
South Africa	-0.854	-2.330	-3.709**	-5.599***

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively

Cointegration Result

Tables 3.5 to 3.8 present results of Engle & Granger and Johansen cointegration tests, being the second stage in the estimation process. Both tests include trend in the model and the optimal lag length selection is based on Schwartz Information Criterion (SIC). The non-OECD countries are grouped according to the two categories outlined earlier.

Table 3.5 reports the result of the ADF test conducted on the residuals of the long-run relationship (shown in equation 3.4) as required in testing for cointegration based on the Engle & Granger procedure. If the residuals are staionary at levels, then a long-run relationship (cointegration) is said to exist between GDP and oil prices. It can be observed from the table that the null hypothesis of no cointegration is strongly rejected at 1% significance level for almost all the oil exporting countries except Kuwait where it is rejected at 10% significance level. Angola and Qatar fails to reject the null hypothesis even at 10% significance level. Thus, cointegration appears to exist between oil prices and GDP for all the oil exporting countries except Angola and Qatar.

Table 3.5

Engle & Granger Cointegration Test Result

Country[a]	*ADF*	Country[b]	*ADF*
Algeria	-3.100***	Brazil	-3.050***
Angola	-1.208	China	-1.831*
Ecuador	-3.408***	India	-1.158
Iran	-2.910***	Malaysia	-2.205**
Iraq	-2.644***	Philippines	-3.455***
Kuwait	-1.874*	South Africa	-2.311**
Libya	-3.788***	Thailand	-2.248**
Nigeria	-3.027***	Turkey	-2.829***
Qatar	-0.935		
Saudi Arabia	-3.673***		
UAE	-4.332***		
Venezuela	-3.006***		

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively.
[a] OPEC member coutries and
[b] newly industrialised countries.

For the net oil importing countries, the null hypothesis of no cointegration is rejected, at least at 10% significance level for all the countries except India where it fails to reject the null hypothesis. In summary, the Engle and Granger cointegration test fails to show evidence of long-run equilibrum relationship in 3 out of the 20 countries considered in this chapter. Hence, the error correction model test is not undertaken for these countries - rather, the conventional or standard Granger test is applied as explained in the methodology section.

Table 3.6

Johansen Cointegration Test Result (Net Oil Exporting Countries)

Country	Lags	Hypothesis	Trace Stat.	Max-Eigen Stat.	Summary
Algeria	1	$r = 0$	22.030**	16.866**	Evidence of Cointegration
		$r \leq 1$	5.164	5.164	
Angola	2	$r = 0$	25.870**	23.140**	Evidence of Cointegration
		$r \leq 1$	2.730	2.730	
Ecuador	1	$r = 0$	21.726**	16.796**	Evidence of Cointegration
		$r \leq 1$	4.930	4.930	
Iran	3	$r = 0$	28.278**	20.442**	Evidence of Cointegration
		$r \leq 1$	7.836	7.836	
Iraq	1	$r = 0$	12.221	10.443	No Cointegration
		$r \leq 1$	1.777	1.777	
Kuwait	1	$r = 0$	32.234***	27.134***	Evidence of Cointegration
		$r \leq 1$	5.099	5.099	
Libya	1	$r = 0$	42.183***	39.823***	Evidence of Cointegration
		$r \leq 1$	2.360	2.360	
Nigeria	2	$r = 0$	15.193	11.731	No Cointegration
		$r \leq 1$	3.462	3.462	
Qatar	1	$r = 0$	39.309***	27.383***	Evidence of Cointegration
		$r \leq 1$	11.925	11.925	
Saudi Arabia	2	$r = 0$	15.444	13.578	No Cointegration
		$r \leq 1$	1.866	1.866	
UAE	1	$r = 0$	22.888**	19.351**	Evidence of Cointegration
		$r \leq 1$	3.536	3.536	
Venezuela	1	$r = 0$	11.009	7.770	No Cointegration
		$r \leq 1$	3.239	3.239	

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively

Tables 3.6 and 3.7 reports the result of Johansen cointegration test for the net oil exporting and oil importing countries respectively. The Johansen cointegration test for the oil exporting countries (Table 3.6) reveals that in 8 of the 12 countries, the null hypothesis of no cointegrating variables ($r = 0$) is rejected at least at 10% significance level for both the trace and maximum-eigen value statistics. The four countries that fail to show evidence of cointegration are Iraq, Nigeria, Saudi Arabia and Venezuela.

Table 3.7, which reports the result for the net oil importing countries reveals that the null hypothesis of no cointegrating relationship could not be rejected for Brazil, Mexico, Thailand and Turkey as shown in Table 3.8 while it was rejected, at least at 5% significance level for China, India, Malaysia, Philippines and South Africa.

Table 3.7

Johansen Cointegration Test Result (Net Oil Importing Countries)

Country	Lags	Hypothesis	Trace Stat.	Max-Eigen Stat.	Summary
Brazil	1	$r = 0$	20.970	16.652	No Cointegration
		$r \leq 1$	4.317	4.317	
China	2	$r = 0$	24.471**	21.432***	Evidence of Cointegration
		$r \leq 1$	3.039	3.039	
India	1	$r = 0$	33.223***	24.753***	Evidence of Cointegration
		$r \leq 1$	8.470	8.470	
Malaysia	3	$r = 0$	21.648**	13.238	Evidence of Cointegration
		$r \leq 1$	8.410	8.410	
Philippines	1	$r = 0$	25.688***	20.623***	Evidence of Cointegration
		$r \leq 1$	5.064	5.064	
Thailand	1	$r = 0$	17.272	10.264	No Cointegration
		$r \leq 1$	7.008	7.008	
Turkey	2	$r = 0$	19.455	12.345	No Cointegration
		$r \leq 1$	7.110	7.110	
South Africa	1	$r = 0$	21.297**	14.940*	Evidence of Cointegration
		$r \leq 1$	6.356	60356	

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively

In general, out of a total of 20 countries, the Johansen cointegration test fails to reject the null hypothesis of no cointegrating relationship in 8 countries while it was rejected in the remaining 12 countries, thus concluding that a long-run relationship exist in the later countries. Usually, for countries where cointegration exist, vector error correction model based causality test is employed to identify the direction of both short-run and long-run causality while the standard Granger causality test is applied for countries where cointegration is not found to test for the short-run relationship as discussed earlier.

Causality Result

Tables 3.8 and 3.9 report the causality test result for the two categories. The error correction model based test which tests for both short-run and long-run causality is applied for the countries where cointegration is found. As indicated in the methodology, strong Granger causality is also tested by jointly testing the significance of short and long-run causality. There can be four possible outcomes from the causality tests;

- Oil prices Granger-causes GDP
- GDP Granger-causes Oil prices
- Oil prices Granger-caused GDP and GDP Granger-causes Oil prices
- No Granger causality exist.

The first two are cases of uni-directional (one way) causality while the third is a case of bi-directional (both ways) causality. Causality test has often been mis-interpreted as impact/effect test even though it has clearly been stated by Granger (1969) that the test is not a cause or effect test but rather used for prediction purposes as outlined in the literature review section. The fully modified ordinary least squares (FMOLS) is emplyed to estimate the long-run effect as the technique has proved to be efficient in estimating long-run relationships. The technique applies a semi-parametric correction to eliminate the problems caused by long-run correlation between regressors, thus making it asymptotically un-biased and effecient. The FMOLS results for the individual countries and the Group-FMOLS results are reported in the next sub-section.

Table 3.8 reports the F-test results of the individual causality tests for the group of oil exporting countries. As shown from the table, the F-stat value of oil prices and ECT are statistically significant in the real GDP equation for Angola, Iran, UAE and Venezuela which indicates the existence of both short and long-run causality running from oil prices to GDP. Hence, oil prices strongly Granger-causes GDP for these countries. In the real oil price equation, only the F-stat value of the ECT is significant for Angola and Iran which implies GDP also Granger-cause oil prices in the long-run for the two countries. Thus a bi-directional long-run causality exist for Angola and Iran while a uni-directional long-run causality running from oil prices to GDP exist for UAE and Venezuela.

The results for Ecuador, Iraq, Nigeria and Saudi Arabia shows no evidence of short-run causality as only the F-stat value of the ECT is significant indicating the existence of a long-run causality. Apart from Ecuador that shows a uni-directional long-run causality (which runs from oil prices to GDP), all the other three countries reveals a case of bi-directional long-run causality.

Table 3.8

Causality Tests Result (Net Oil Exporting Countries)

Country	Depend. Var.	Source of Causation (Independent)			
		Short-run		Long-run	Joint
		ΔLRGDP	ΔLROP	ECT	SR/LR
Algeria	ΔLRGDP	-	0.732	-	-
	ΔLROP	0.950	-	-	-
Angola	ΔLRGDP	-	3.746**	4.253***	3.992**
	ΔLROP	0.569	-	2.689*	1.553
Ecuador	ΔLRGDP	-	0.020	4.724***	1.443
	ΔLROP	1.673	-	1.151	1.322
Iran	ΔLRGDP	-	5.097***	5.737***	5.233***
	ΔLROP	1.121	-	3.234**	1.944
Iraq	ΔLRGDP	-	0.167	3.368**	1.431
	ΔLROP	1.097	-	3.279**	1.722
Kuwait	ΔLRGDP	-	2.167*	2.440*	2.233*
	ΔLROP	0.237	-	1.125	0.242
Libya	ΔLRGDP	-	0.017	5.318***	1.765
	ΔLROP	2.819*	-	3.299**	3.142**
Nigeria	ΔLRGDP	-	1.006	3.180**	1.582
	ΔLROP	0.892	-	3.442**	1.023
Qatar	ΔLRGDP	-	1.267	-	-
	ΔLROP	2.529**	-	-	-
Saudi Arabia	ΔLRGDP	-	1.002	2.215*	1.521
	ΔLROP	0.306	-	2.568*	1.078
UAE	ΔLRGDP	-	2.137*	5.740***	3.855**
	ΔLROP	0.265	-	1.182	0.842
Venezuela	ΔLRGDP	-	2.042*	4.428***	3.545**
	ΔLROP	0.592	-	1.136	0.877

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively

As for Libya, the F-stat value of ECT and GDP are significant in the real oil price equation which indicates the existence of both long-run and short-run causality running from GDP to oil prices. The ECT F-stat value is also significant in the real GDP equation, thus, revealing a bi-directional long-run causality. Since cointegration does not exist for Algeria and Qatar, only the short-run causality is estimated with causality running from GDP to oil prices for Qatar while no Granger causality exist for Algeria.

Table 3.9 reports the F-test result for the group of net oil importing countries. The result shows evidence of strong Granger causality running from oil prices to GDP for China and Thailand as both the F-stat value of LROP and ECT are significant, at least at 10% level. As for Brazil, Philippines, Turkey and South Africa, only the F-stat value of ECT is significant in the GDP equation, suggesting a uni-directional long-run causality relationship running from oil prices to GDP while Malaysia reveals evidence of long-run bi-directional causality as the ECT in both equations are significant.

Table 3.9

Causality Tests Result (Net Oil Importing Countries)

Country	Depend. Var.	Source of Causation (Independent)			
		Short-run		Long-run	Joint
		ΔLRGDP	ΔLROP	ECT	SR/LR
Brazil	ΔLRGDP	-	1.018	3.270**	1.752
	ΔLROP	1.021	-	1.104	1.054
China	ΔLRGDP	-	2.132*	3.371**	2.545*
	ΔLROP	1.763	-	1.129	1.341
India	ΔLRGDP	-	1.028	-	-
	ΔLROP	1.947	-	-	-
Malaysia	ΔLRGDP	-	1.031	2.251*	1.533
	ΔLROP	1.378	-	2.406*	1.635
Philippines	ΔLRGDP	-	1.017	3.435**	1.547
	ΔLROP	2.422*	-	1.306	1.322
Thailand	ΔLRGDP	-	2.132*	3.138**	2.714*
	ΔLROP	1.735	-	1.383	1.492
Turkey	ΔLRGDP	-	1.096	3.425**	1.332
	ΔLROP	0.449	-	0.128	0.311
South Africa	ΔLRGDP	-	1.014	2.270*	1.768
	ΔLROP	2.145*	-	0.342	1.288

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively

Table 3.10

Summary of Causality Result

	Short-run causality			Long-run causality			Strong causality		
	OP⟹GDP	GDP⟹OP	OP⟺GDP	OP⟹GDP	GDP⟹OP	OP⟺GDP	OP⟹GDP	GDP⟹OP	OP⟺GDP
Algeria									
Angola	✓					✓	✓		
Ecuador				✓					
Iran	✓					✓	✓		
Iraq						✓			
Kuwait	✓			✓			✓		
Libya		✓				✓		✓	
Nigeria						✓			
Qatar		✓							
Saudi Arabia						✓			
UAE	✓			✓			✓		
Venezuela	✓			✓			✓		
Brazil				✓					
China	✓			✓			✓		
India									
Malaysia						✓			
Phillippines		✓		✓					
Thailand			✓	✓			✓		
Turkey				✓					
South Africa		✓		✓					

In summary, the result shows evidence of stong Granger-causality in 8 out of the 20 countries analysed (as shown in Table 3.10) with the direction of causality running from oil prices to GDP in 7 of the countries; Angola, Iran, Kuwait, UAE, Venezuela, China and Thailand. The result implies that oil prices have a stong influence, both in the short and long-run, on the economic output of these countries.[73] As poited out earlier, Acarachi and Ozturk (2010) noted that one of the advantages of using the ECM based causality test is that Granger causality can be tested in three ways; short-run, long-run and strong (jointly testing the significance of both short-run and long-run) Granger causality.

3.5.2 Results from Asymmetric Specification

As outlined in the previous section, two methods of non-linear transformation of oil prices; Mork (1989) and Hamilton (1996) are utilized. As a preliminary procedure, unit root tests on the transformed series are under taken and the results are reported in Table 3.11.

Table 3.11

Unit root Test for Asymmetric Specification

Variable	ADF		PP		Conclusion
	Level	1st Diff.	Level	1st Diff.	
OP+	-5.569***	-	-5.557***	-	I(0)
OP-	-6.544***	-	-6.526***	-	I(0)
NOPI	-6.624***	-	-7.638***	-	I(0)

[73] It can be observed from Table 3.10 that for countries where the short-run coefficients are not significant, no strong Granger causality exist. See, for instance, Ecuador, Nigeria and India among others.

The result reveals that the decomposed oil prices are I(0),[74] hence, the model is estimated at levels. Tables 3.12 and 3.13 presents the result of the asymmetric specification which shows whether oil price increase, oil price decrease or net oil price increase Granger-causes GDP.

Table 3.12

Asymmetric Effects (Net Oil Exporting Countries)

	ΔGDP		
	OP+	OP-	NOPI
Algeria	1.046	1.029	2.190*
Angola	3.429**	0.714	2.028*
Ecuador	1.069	4.734***	1.021
Iran	3.479**	0.186	1.123
Iraq	1.211	1.254	0.220
Kuwait	1.339	0.736	1.072
Libya	3.128**	1.301	3.119**
Nigeria	2.080*	2.182*	1.056
Qatar	0.621	1.001	2.035*
Saudi Arabia	1.161	2.244**	1.140
UAE	1.036	0.735	1.039
Venezuela	2.272*	1.095	3.306**

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively

The results for the group of oil exporting countries which is reported in Table 3.12 shows the F-stat value of oil price increase is significant (at least at 10% level) for Angola, Iran Libya, Nigeria and venezuela, indicating oil price increase Granger-cause GDP in those counries. The result implies that positive changes in current GDP is better explained by past oil price increases than oil price decreases. As for Nigeria, the value of oil price decrease is also significant indicating both rise and fall in oil prices exerts strong influence

[74] Cunado and Perez de Gracia (2003) also conducted unit-root test on the decomposed oil price variables and found the series to be I(0)

on current GDP. The results for Ecuador and Saudi Arabia reveals that only oil price decrease variable is significant indicating changes in GDP is more influenced by a fall in oil prices.

It is often argued that the net oil price increase (NOPI) is the most reliable asymmetric specification based on the argument that output responds only to increases larger than its maximum recent history. As shown in Table 3.12, NOPI Granger-causes GDP for Algeria, Angola, Libya and Qatar and Venezuela - indicating a strong influence of past oil price increases on current GDP.

Results for the group of net oil importing countries, reported in Table 3.13 reveals that both oil price increase and oil price decrease Granger-causes GDP for China, India, Malaysia and Thailand while for Brazil, only the oil price increase Granger cause GDP. The NOPI specification also Granger-causes GDP for Brazil, Philippines, South Africa, Thailand and Turkey.

Table 3.13

Asymmetric Effects (Net Oil Importing Countries)

	ΔGDP		
	OP+	OP-	NOPI
Brazil	3.221**	1.207	3.012**
China	2.883*	3.874**	0.752
India	3.828**	2.260*	0.982
Malaysia	5.310***	2.134*	1.347
Philippines	3.262**	0.076	2.227*
South Africa	0.003	-0.059	2.162*
Thailand	3.680**	3.393**	5.743***
Turkey	1.003	1.059	2.162*

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively

In summary, the asymmetric specification reveals oil price increase having more influence on changes in GDP than oil price decrease in both the groups of net oil exporting and net oil importing countries. The next sub-section reports result from the panel technique.

3.5.3 Panel Estimation Result

Panel Unit Root Result

As indicated in the methodology, the panel unit root tests are applied based on two different models. Model 1 which includes only constant and no time trend provides mixed/inconsistent results in both series at level terms especially for the real oil price variable. The various tests shows the series are stationary at levels at least at 10% significance level. Model 2 (which includes both constant and time trend) on the other hand, shows the series are non-stationary at levels but achieved stationarity after taking the first difference at 1% significance level. Table 3.14 presents the results derived from the panel unit root tests conducted.

Since all the panel unit root test assume the null hypothesis of each individual series is non-stationary, results obtained reveals that the null hypothesis cannot be rejected for both series at levels but is strongly rejected (at 1% significance level) at their first difference. It is therefore concluded that both series are I(1) and as such can proceed to test for cointegration.

Table 3.14

Panel Unit Root Test Result

Variables	Panel A			Panel B		
	LLC	IPS	Choi	LLC	IPS	Choi
Model 1						
LRGDP	-2.38**	2.22	2.09	0.71	3.77	3.42
LROP	-2.35**	-3.94***	-4.14***	'-1.58*	-2.64**	-2.78**
ΔLRGDP	-14.14***	-14.87***	-13.13***	-9.30***	-9.06***	-8.32***
ΔLROP	-24.17***	-20.93***	-17.69***	-16.21***	-14.04***	-11.87***
Model 2						
LRGDP	0.81	-1.16	-0.79	-0.38	-0.41	-0.41
LROP	-0.57	-0.73	-0.89	-0.38	-0.49	-0.60
ΔLRGDP	-13.31***	-14.26***	-12.19***	-8.94***	-8.05***	-7.03***
ΔLROP	-22.23***	-18.87***	-15.37***	-14.91***	-12.54***	-10.31***

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively

Panel Cointegration Result

Table 3.15 shows the results of the Pedroni panel cointegration tests, as outlined in the methodology section, for both panels. Under the null hypothesis of no cointegration, the test statistic of Panel ρ, Panel PP, Panel ADF, Group ρ, Group PP and Group ADF cannot be rejected even at 10% significance level for both panels. The only test statistic that is significant is Panel v – statistic which is significant at 5% for panel A and at 1% for panel B. Thus, the Pedroni test statistics suggest that there is no cointegration between the variables.

Table 3.15

Pedroni Panel Cointegration Test Result

Statistics	Panel A	Panel B
Panel v-statistic	1.685**	46.768***
Panel ρ-statistic	0.608	0.667
Panel PP-statistic	-0.168	0.083
Panel ADF-statistic	-0.222	0.164
Group ρ-statistic	1.632	1.324
Group PP-statistic	0.198	0.515
Group ADF-statistic	0.049	0.799

Note: ** and *** indicate significance level at 5% and 1%, respectively

Table 3.16 reports the results of the Kao cointegration test, which is also a residual-based cointegration technique. Based on the results, the null hypothesis of no cointegration could not be rejected for Panel A but was rejected at 5% significance level for Panel B. Therefore, the Kao cointegration test could only support evidence of long-run equilibrium relationship in Panel B which is the group of net oil importing countries.

Table 3.16

Kao Cointegration Test Result

	ADF Statistics
Panel A	0.411
Panel B	1.657**

Note: ** indicate significance level at 5%

The results of the Johansen Fisher panel cointegration test developed by Maddala and Wu (1999), reported in Table 3.17, are fairly conclusive. Results from both Fisher's trace and max-eigen test statistics support the presence of cointegrated relation between the two variables for both panels.

Table 3.17

Johansen Fisher Cointegration Test Result

Hypothesized No. of CE(s)	Fisher Statistics	
	Trace Test	Max-Eigen Test
Panel A		
None	60.1*	69.99***
At most 1	14.05	14.05
Panel B		
None	28.02*	33.22**
At most 1	8.76	8.76

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively

In summary, the Pedroni (1999, 2004) tests suggest that there is no cointegration between LRGDP and LROP for both Panel A and Panel B. The Kao (1999) test suggests that there is no cointegration for Panel A but does find cointegration between LRGDP and LROP for Panel B. Whereas, the Johansen Fisher panel cointegration test suggest that a long-run equilibrium relationship between LRGDP and LROP does exist for both Panel A and Panel B. The results are therefore split, so it is assumed that there is potentially a long run relationship between the two variables, thus allowing for the testing of short and long run causality between the natural log of real oil prices and real GDP.

Estimating Long-run Cointegrating Relationship – FMOLS Results

Tables 3.18 - 3.19 report the estimated long-run coefficients of the individual and panel FMOLS. The panel estimators are shown at the bottom of each table. The coefficients of oil prices in both panels are statistically significant at 1% level, and the effect is positive. This implies oil prices have a long-term positive effect on GDP for both the group of net oil exporting and net oil importing countries. While the results for Panels A is in line with a-priori expected results (positive effect for oil exporting countries), the result for Panel B is not. It was expected that positive shocks should have a negative effect on the group of oil importing countries. Perhaps the influence of countries like Brazil and Malaysia that have recently become net oil exporters despite their high consumption level might be the reason for the positive effect. According to CIA World Fact Book 2010, Brazil and Malaysia became net oil exporters in 2009. Another possible explanation could be linked to what is often argued in the literature that oil prices do not have any serious effect on economic output especially when the data runs beyond the 1980s.[75] The positive effect for Panel B may be seen as a justification to this argument.

On a per country basis, it can be observed from Table 3.18 that oil prices have a positive impact on GDP of all the OPEC member countries, though the coefficient is not significant for Angola, Iran, Nigeria and Venezuela. The FMOLS estimates of the coefficient of oil prices with respect to GDP ranges from 0.101 (Ecuador) to 0.604 (Iraq). In essence, the coefficient of oil prices is positive and statistically significant in eight out of the twelve OPEC member

[75] See Hooker (1996)

countries; indicating an increase in oil prices tends to promote GDP. The panel estimate for the group reveals that oil prices have a strong positive effect on output.

Table 3.18

FMOLS Estimates (Net Oil Exporting Countries)

Country	Coefficient of LROP	t-statistics
Algeria	0.131	4.248***
Angola	0.138	1.472
Ecuador	0.101	4.553***
Iran	0.075	1.226
Iraq	0.604	3.604***
Kuwait	0.046	0.462
Libya	0.202	4.871***
Nigeria	0.053	1.226
Qatar	0.159	1.488
Saudi Arabia	0.209	4.498***
UAE	0.372	7.696***
Venezuela	0.036	1.027
Panel	0.177	10.51***

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively

Similarly, in the group of net oil importing countries (Table 3.19), the oil price coefficient is significant in four of the eight countries. While the coefficients for Brazil, Philippines and South Africa are positive and statistically significant, that of China is negative (-0.082) indicating on the average, 1 percent increase in oil prices reduces the GDP of the Chinese economy by 0.082 percent. The panel estimate however shows a weak positive effect for the whole group.

Table 3.19

FMOLS Estimates (Net Oil Importing Countries)

Country	Coefficient of LROP	t-statistics
Brazil	0.081	2.748***
China	-0.082	-3.653***
India	0.005	0.225
Malaysia	-0.081	-0.527
Philippines	0.128	7.396***
South Africa	0.082	5.464***
Thailand	-0.089	-1.510
Turkey	-0.009	-0.380
Panel	0.012	3.452***

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively

Significant coefficients obtained from the Group-FMOLS estimates are a confirmation that real oil prices and real GDP are cointegrated and the long-run relationship is positive. This means on average an increase in oil prices has a long-term positive effect on economic output of both the groups of oil exporting and the net oil importing countries. A long-run relationship between the variables is an indication there is causality at least in one direction. The panel causality results (reported in the next sub-section) will show whether the direction of causality is from oil prices to GDP or otherwise.

Panel Causality Result

As indicated in the methodology section, a panel based error correction model is employed to account for the long and short-run causality relationship. Table 3.20 shows the F-test results of the panel causality tests.

Table 3.20

Panel Causality Result

	Depend. Var.	Source of Causation (Independent)			
		Short-run		Long-run	Joint
		ΔLRGDP	ΔLROP	ECT	SR/LR
Panel A	ΔLRGDP	-	3.660**	2.482*	3.200**
	ΔLROP	1.197	-	0.332	1.021
Panel B	ΔLRGDP	-	0.516	0.889	0.628
	ΔLROP	1.614	-	2.394*	1.660

Note: *, ** and *** indicate significance level at 10%, 5% and 1%, respectively

As is apparent from the table, the F-stat value of oil prices and ECT are significant in the GDP equation of Panel A, however the GDP and ECT values in the oil price equation are not significant. This indicates that there is uni-directional Granger causality running from oil prices to GDP in both the short-run and long-run. Therefore, oil prices strongly Granger-causes GDP for the group of oil exporting countries. This implies that oil prices have a strong influence on economic output and whenever a shock occurs in the system, output (GDP) would make short-run adjustment to restore long-run equilibrium. It also implies that it is possible to use oil price as an economic tool to control output.

As for Panel B, only the ECT in the oil price equation is significant indicating a uni-directional long-run causality running from GDP to oil prices. As indicated earlier, most similar studies are more interested in whether oil prices Granger-causes GDP which is obtained from the GDP equation and neither the oil prices nor ECT value are significant. This implies oil prices have a neutral effect on GDP for the net oil importing countries.

Table 3.21

Summary of Panel Causality Result

	Short-run	Long-run	Joint
Panel A	OP$\rightarrow$GDP	OP$\rightarrow$GDP	OP$\rightarrow$GDP
Panel B	OP$\nleftrightarrow$GDP	OP$\longleftarrow$GDP	OP$\nleftrightarrow$GDP

Note: OP$\rightarrow$GDP = oil prices Granger-caused GDP; OP$\longleftarrow$GDP = GDP Granger-causes oil prices; OP$\nleftrightarrow$GDP = no causality in either direction.

In essence, oil prices Granger-causes GDP for the group of oil exporting countries (Panel A) but fail to Granger-cause GDP for the group net oil importing countries (Panel B) as shown in Table 3.21. In comparison with previous study, Lescaroux and Mignon (2008) found that oil prices Granger-causes GDP in both the group of oil exporting and oil importing countries. The result from this study therefore is consistent with what they found for the oil exporting countries but contradict their findings for the oil importing countries.[76]

3.6 Summary and Conclusion

This chapter employs time-series and panel causality technique to investigate the oil price-GDP relationship for 20 non-OECD countries from 1971 to 2007. Empirical studies using time-series data on US and other advanced countries have shown that oil prices fail to Granger-cause GDP when the data is extended beyond the 1980s, and there were also indication that the effect of oil prices on oil exporting countries is different from that of oil importing countries. While it is believed that oil price increase have a positive effect on

[76] It is however important to note that Lescaroux and Mignon (2008) considered both OECD and non-OECD countries in their analysis.

output for oil exporting countries, the reverse was expected for oil importing countries. In line with the above argument, this chapter seeks to add to the literature by investigating the effect of oil prices on economic growth of non-OECD countries and also investigate the causal link between them from a time-series and panel context. The non-OECD countries are categorized into two sub-groups; group of net oil exporting countries, which comprise of OPEC member countries, and the group of net oil importing countries, which is a group of emerging economies.

The main results may be summarised as follows: oil prices Granger-causes GDP for the group of net oil exporting countries while it fails to Granger-cause GDP for the net oil importing countries. For the net oil exporting countries, it implies that changes in crude oil prices have a significant influence on their economic activity, thus oil prices remains an important factor in determining future performance of those countries. As for the net oil importing countries, oil prices have little or no influence in predicting their economic output despite their high consumption level.

The group FMOLS results provides evidence that there are fairly strong positive long-run relationships between the variables as the coefficient of oil prices are significant and positive in both panels, indicating an increase in oil prices has a positive effect on the GDP of both the oil exporting and oil importing countries. The panel estimate result shows that on average, a 1% rise in oil prices increases GDP by 0.174% for the group of oil exporting countries and 0.012% for the group of oil importing countries.

On a per country basis (based on individual country time-series FMOLS estimate), the coefficient of oil prices is significant in 6 out of the 12 oil exporting countries. The relationship is positive as expected indicating a rise in oil prices leads to an increase GDP. The result suggests that on average, a 1% rise in oil prices leads to an increase of 0.609%, 0.209%, 0.372%, 0.131%, 0.101% and 0.202% for Iraq, Saudi Arabia, UAE, Algeria, Ecuador and Libya respectively.

In the group of net oil importing countries, the coefficient of oil prices is significant for Brazil, China, Philippines and South Africa - with the coefficient being positive for all the countries except China. The result suggests that on average, a 1% rise in oil prices reduces GDP by 0.082% in China,[77] and increases GDP by 0.081%, 0.128% and 0.082% in Brazil, Philippines and South Africa respectively.

The result for China is in line with the a-priori expectation - according to EIA (2010), China is the largest consumer of oil behind the US and also the second largest importer in 2009. Even though Brazil is among the major oil producers in the world, the country's high consumption level makes it a net importer until recently. One could argue that since Brazil has the capacity to meet its domestic demand, the positive relationship can therefore be justified. The case for South Africa and Philippines clearly contradicts our a-priori expectation. According to EIA, South Africa and Philippines imports 64.53% and 91.52% of their total crude oil consumption respectively.

The results from this work are quite essential for governments of both the oil exporting/importing countries. Reliable estimates on the impact of oil prices on the economy are important information for governments when formulating

[77] While the result for China suggest a negative effect of oil prices on GDP, the panel estimate for the overall group of net oil importing countries suggest a positive effect on GDP as explained a little earlier.

medium and long-term policies. Due to the fact that oil is an exhaustible resource, the results further re-confirm the need for oil exporting countries to diversify their economy and reduce the over-dependence on oil revenue.

On a final note, it is important to mention that the rise in GDP as a result of favourable oil prices in most oil exporting countries have not been reflected in tangible economic development. The question of why oil abundant countries experience poor growth performance still remains an important issue in the literature. In the next chapter, this thesis investigates the issue by applying a heterogenous panel technique to analyse the effect of oil abundance on economic output, as seen in the level of income per capita.

3.7 Appendix to Chapter 3

3.7.1 Appendix 3.1: Descriptive Statistics

Table A3.1 reports the descriptive statistics of the data used in the analysis of Chapter 3. The statistics used are mean, median, maximum, minimum, std deviation, skewness and kurtosis and are reported for the groups of net oil exporting and net oil importing countries. The descriptive statistics shows that both the real GDP and real oil price data are satisfactory and fairly evenly distributed around the mean.

Table A3.1

Descriptive Statistics (Group of all Countries)

	Net Exporters		Net Importers	
	RGDP	ROP	RGDP	ROP
Mean	97.70	43.11	830.80	43.11
Median	56.51	35.38	439.18	35.38
Maximum	554.02	97.46	9911.78	97.46
Minimum	7.79	12.04	28.69	12.04
Std. deviation	93.89	22.31	1248.19	22.31
Skewness	1.79	0.83	4.01	0.83
Kurtosis	6.52	2.87	22.41	2.87

3.7.2 Appendix 3.2: Diagnostic Tests

Tables A3.2 and A3.3 reports the diagnostic test conducted on the time-series causality results. The results have passed most diagostic test and hence may be considered robust.

Table A3.2

Diagnostic Test (Group of Oil Exporting Countries)

Country	Equation	Serial Correlation		Heteroscadasticity		Normality	
		F-Stat	Probability	F-Stat	Probability	Jaq. bera	Probability
Algeria	LRGDP	1.04	0.26	0.41	0.84	0.69	0.71
	LROP	3.15	0.04	0.62	0.68	1.30	0.52
Angola	LRGDP	1.23	0.29	1.21	0.31	1.29	0.52
	LROP	1.76	0.21	0.57	0.68	1.33	0.50
Ecuador	LRGDP	0.67	0.55	0.71	0.55	0.57	0.68
	LROP	0.86	0.49	1.22	0.30	1.93	0.41
Iran	LRGDP	0.97	0.42	0.57	0.72	1.29	0.52
	LROP	0.63	0.60	1.33	0.28	2.71	0.39
Iraq	LRGDP	0.57	0.61	1.05	0.38	2.50	0.41
	LROP	0.44	0.69	0.94	0.47	1.64	0.46
Kuwait	LRGDP	1.03	0.30	1.03	0.35	3.44	0.28
	LROP	4.01	0.04	0.74	0.59	1.45	0.47
Libya	LRGDP	1.55	0.31	0.95	0.44	2.05	0.42
	LROP	0.86	0.49	1.08	0.39	1.93	0.57
Nigeria	LRGDP	4.46	0.01	0.99	0.44	0.49	0.78
	LROP	0.65	0.52	0.03	0.99	1.30	0.53
Qatar	LRGDP	4.73	0.03	0.42	0.65	1.33	0.49
	LROP	1.36	0.34	0.46	0.68	0.59	0.75
Saudi Arabia	LRGDP	0.63	0.67	1.05	0.41	1.44	0.48
	LROP	0.98	0.51	0.93	0.57	1.06	0.54
UAE	LRGDP	1.77	0.31	0.49	0.68	2.01	0.43
	LROP	4.17	0.03	0.77	0.61	1.60	0.49
Venezuela	LRGDP	1.43	0.42	0.28	0.91	1.83	0.39
	LROP	2.31	0.52	0.24	0.94	4.71	0.13

Table A3.3

Diagnostic Test (Group of Oil Importing Countries)

Country	Equation	Serial Correlation		Heteroscadasticity		Normality	
		F-Stat	Probability	F-Stat	Probability	Jaq. bera	Probability
Brazil	LRGDP	0.31	0.73	0.87	0.51	3.92	0.14
	LROP	4.01	0.03	1.55	0.20	0.38	0.83
China	LRGDP	0.69	0.50	1.66	0.17	2.81	0.24
	LROP	8.07	0.01	1.47	0.22	3.05	0.21
India	LRGDP	0.47	0.67	0.81	0.57	1.57	0.48
	LROP	0.86	0.49	1.52	0.26	1.90	0.46
Malaysia	LRGDP	1.97	0.41	0.47	0.82	0.79	0.67
	LROP	0.93	0.62	1.33	0.28	1.71	0.47
Mexico	LRGDP	0.47	0.69	0.95	0.45	2.45	0.21
	LROP	3.35	0.50	0.24	0.94	0.40	0.81
Phillipines	LRGDP	4.03	0.04	1.13	0.32	2.35	0.49
	LROP	0.81	0.48	0.55	0.53	1.26	0.57
South Africa	LRGDP	1.59	0.32	1.95	0.17	1.05	0.56
	LROP	0.96	0.41	0.85	0.42	0.93	0.78
Thailand	LRGDP	5.41	0.01	0.99	0.44	1.42	0.49
	LROP	0.68	0.51	1.03	0.39	1.03	0.57
Turkey	LRGDP	1.73	0.23	0.49	0.60	2.13	0.35
	LROP	1.36	0.34	1.36	0.28	1.51	0.55

Chapter 4[78]

4 Oil Abundance and Economic Growth

4.1 Introduction

Before the late 1980s, the general belief was that natural resource abundance is a major advantage for a country attempting to achieve rapid economic development. Prominent development enonomists[79] argued that natural resource endowments would enable countries to make the transition from underdevelopment to industrial 'take-off', as it had done for some of the advanced countries such as the United States, Australia and the United Kingdom. Similarly, Krueger (1980) argued that natural resources would facilitate a country's industrial development by providing investable funds and domestic market.

However, over the past three decades, the apparent notion that natural resource abundance leads to lower growth performance has attracted much attention. Several studies[80] from the fields of economics and political science have pointed to the particularly strong negative economic and political impacts of natural resource abundance, especially oil. Most of the empirical literature on the resource curse paradox followed the influential work of Sachs and Warner (1995). According to this paradox, abundance of natural resources increases the likelihood that countries will experience negative economic, social and political outcomes including poor economic performance, low levels

[78] Earlier preliminary work for this chapter was presented at the 9th BIEE Academic Conference, Oxford, UK. September, 2012.

[79] See, for instance, Rostow (1961)

[80] See for instance, Collier and Hoeffler (2005), Hodler (2006) and Ross (2001)

of democracy, and civil war - hence, resource abundance is a curse and not a blessing.[81]

According to Cavalcanti et al. (2011), there are a number of grounds on which the econometric evidence of the resource curse paradox (which is mostly based on Sachs and Warner (1995) cross-sectional specification) may be questioned. Firstly, the resource curse hypothesis literature primarily relies on the cross-sectional approach which does not take into account the time-dimension of the data and is also subject to an endogeneity problem. Secondly, most of these studies measure resource dependence rather than abundance - for instance, Sachs and Warner (1995) use the ratio of primary export to GDP in the initial period as a measure of resource abundance which they argue measures resource dependence rather than abundance.[82] Thirdly, most of the studies focus on the effects of resource abundance on the rate of economic growth, even though most traditional growth models like Solow and Ramsey suggest that the effects on growth is temporary and could be permanent for the level of per capita income. Finally, most studies that apply panel data techniques use homogeneous approaches, such as the traditional fixed and random effects estimators, and the generalized methods of movements (GMM) estimators, which impose a high degree of homogeneity across the countries and according to Koedijk el al. (2011), homogeneous estimates exhibit potentially large biases which can lead to mis-leading inferences - they highlight the importance of allowing for heterogeneous estimation techniques.

[81] In some studies, the resource curse paradox is tagged as Dutch disease syndrome. As Davis (1995) points out, the first symptom associated with the resource curse was an overvalued currency in the Netherlands following the discovery of natural gas deposits in the late 1950s and early 1960s - hence the term Dutch disease syndrome.

[82] Earlier, Brunnschweiler and Bulte (2008) made similar argument on the variable being more of a measure of resource dependence rather than resource abundance,

In addition to these critiques, Cavalcanti et al. (2011) developed a theoretical model that requires the use of natural resources as an input in the production process. The Cavalcanti et al. (2011) theoretical model suggests a long-run relationship between per capita income, the investment rate and the real value of oil production per capita, an approach used in this chapter as the basis for empirical investigation. To further enhance the empirical model used here, an institutional quality variable is included in response to a recommendation made by van der Ploeg (2011) that future empirical work on the resource curse hypothesis should apply panel data technique and take into account the changing role of institutions. Apart from using the real value of oil production per-capita as a proxy of natural resource, this study also uses the real value of oil reserve per-capita to investigate the resource curse hypothesis. Alexeev and Conrad (2009) suggested the use of hydocarbon deposit per capita and/or oil production per capita as the most appropriate measures of oil resource abundance and also stressed that it should not be expressed as a share of GDP. According to Alexeev and Conrad (2009), if the share of oil output in GDP is used as an indicator of resource dependence, then, given some output of oil, a country that for whatever reason has a low growth rate or low GDP would have a higher oil:GDP ratio and this would bias the results, artificially creating a negative effect of oil on GDP.

In testing the resource curse hypothesis, this study recognizes that within the resource abundant countries, there may be a substantial degree of heterogeneity in their growth experience - hence, a heterogeneous panel data approach is employed. As indicated in the previous chapter, this econometric approach provides additional power in combining cross-sectional and time series data while allowing for heterogeneity across countries. Nevertheless, in order to build upon and compare with previous work in this area, initially the work follows Sachs and Warner (1995) by employing a standard cross-sectional estimation technique to investigate the growth effect of resource abundance. Since most studies in the literature applied the cross-sectional approach using different measure of resource abundance, it would be interesting to compare results from this study and what is obtained in the literature despite the shortcomings of the cross-sectional approach.[83]

The rest of the chapter is organized as follows: Section 4.2 explains the growth experience of the oil rich non-OECD countries considered in this chapter, Section 4.3 reviews the empirical literature on the resource curse paradox while Section 4.4 explains the methodology behind both the cross-sectional and panel estimation technique. Section 4.5 reports the empirical results and finally Section 4.6 concludes.

4.2 Growth Experience of Oil Abundant Economies: Some Stylized Facts

Many oil rich counties have experienced large windfall gains as a result of a rise in international oil prices. These accumulated gains are often associated with potential macroeconomic volatility that reliance on oil can introduce into the economy. Furthermore, many oil exporting countries are relatively poor in terms of social development indicators and economic welfare. In a study of five

[83] The cross-sectional estimation result in this study is compared with those obtained from Sachs and Warner (1995), Mehlum et al. (2006) and Cavalcanti et al. (2001). Section 4.6.1 provides detailed comparison of the regression results from these studies and also measures of resource abundance adopted.

oil exporting countries (Algeria, Iran, Indonesia, Nigeria and Venezuela) in the midst of two oil booms in the 1970s, Karl (1997) argued that oil rich countries created awkward centralized bureaucracies, geared towards generating more oil profits which allowed established interest groups, such as investors and state officials to acquire additional influence and fight to retain it, creating enormous barriers to change. He further argued that during this period, policy makers put aside any plans for nurturing long-term sustainable growth, and when oil prices began their drastic plunge, the results were economic failure, double digit inflation and decline in the efficiency of their public enterprises. Furthermore, Auty (2004) and Manzano and Rigobon (2001) shows that oil abundant economies present lower growth rates and experience higher volatility due to fluctuating commodity prices combined with un-diversified revenue and export bases. According to Deacon (2012), the resource curse problem affects most of the oil exporting countries, however, Sub-Saharan African countries seem to be more vulnerable than others.

This section therefore provides background analyses of the average growth performance and growth volatility of oil abundant countries over the past four decades beginning from 1970.[84] The first period 1970 - 1979 captures the first and the beginning of the second oil price shocks. The economic situation in the early 1970s was characterized by different factors; according to World Bank (2010), the world economy grew at around 5% on average from the end of the 1960s to the beginning of the 1970s - the growth rate rose from 3.7% in the late 1960s to 6.9% in 1972. Worldwide growth suffered a severe setback during

[84]Even though the background analysis on the growth performance of these developing countries begins from 1970, the data used for the empirical analysis of this chapter begins from 1984 as explained in Section 4.4.

the first oil shock. While the world economy still grew at 6.9% in 1973, the growth rate fell to 2.1% in 1974 and to 1.4% in 1975 (WTO, 2005). It was only in 1976 that growth picked up to its normal rate.

As indicated by Farzanegan and Markwardt (2009), the overall economic situation in the mid-seventies was determined by the after-shocks of the first oil price shock as economies were just recovering from the slump while the political environment was still characterized by tension in the Middle-East, particularly the revolution in Iran which led to the second oil price shock in the late 1970s. According to World Bank (2010), worldwide economic growth slightly decreased from 4.7% in 1978 to 4% in 1979, reaching its lowest point in 1982 at 0.8%.

Oil rich countries experienced increased revenue due to high oil prices over the period which was reflected in their growth performance. As depicted in Table 4.1, GDP per capita grew at an annual average rate of 7.2%, 9.28%, 7.44% and 5.8%[85] for the oil producing countries in South-East Asia (SE Asia), Middle-East and North Africa (MENA), sub-Saharan Africa (SSA) and Latin America respectively. The impressive growth rate of the oil producing countries over the period was associated with a very high growth volatility, particularly in SSA, 11.31% and MENA, 8.21% while SE Asia and Latin America performed relatively well with a growth volatility of 2.28% and 3.06% respectively.

[85] Note that the data used to compute the growth rate and growth volatility figures (reported in Table 4.1) are obtained from World Bank (2010)

Table 4.1

Growth Performance and Volatility of Oil Abundant Developing Countries

	1970 - 1979		1980 - 1989		1990 - 1999		2000 - 2009	
Countries/ Regions	Growth (%)	Volatility (%)	Growth (%)	Volatility (%)	Growth (%)	Volatility (%)	Growth (%)	Volatility (%)
Indonesia	7.81	1.24	6.37	2.54	4.83	6.77	5.09	0.80
Malaysia	7.72	3.20	5.87	3.42	7.24	5.27	4.79	3.10
Philippines	5.79	1.78	2.01	5.11	2.78	2.37	4.56	1.92
Thailand	7.50	2.91	7.29	3.17	5.27	6.55	4.06	2.68
Vietnam	-	-	4.53	1.79	7.41	1.82	7.26	1.01
SE Asia	**7.20**	**2.28**	**5.21**	**3.20**	**5.50**	**4.55**	**5.15**	**1.90**
Algeria	7.16	9.31	2.79	2.73	1.57	2.46	3.62	1.71
Iran	6.16	8.97	-0.30	8.81	4.64	5.06	5.09	2.08
Kuwait	2.31	7.77	-0.80	14.89	7.46	12.13	7.01	5.35
Libya	13.01	3.4	1.4	6.8	7.8	4.1	4.32	4.98
Oman	6.84	11.59	9.83	6.96	4.08	2.78	5.36	3.55
Qatar	12.4	2.4	0.6	19.3	21.6	0.4	13.54	9.36
Saudi	14.23	9.51	-0.61	6.57	3.10	3.41	3.36	2.59
Syria	8.82	11.58	2.83	7.44	5.65	4.42	4.23	1.26
UAE	12.62	9.46	1.22	12.62	5.57	5.12	5.82	3.90
MENA	**9.28**	**8.21**	**1.88**	**9.56**	**6.81**	**4.43**	**5.81**	**3.86**

Table 4.1 Cont'd

Growth Performance and Volatility of Oil Abundant Developing Countries

	1970 - 1979		1980 - 1989		1990 - 1999		2000 - 2009	
Countries/ Regions	Growth (%)	Volatility (%)	Growth (%)	Volatility (%)	Growth (%)	Volatility (%)	Growth (%)	Volatility (%)
Angola	-	-	4.17	3.26	0.99	10.61	10.85	7.78
Congo	5.47	5.60	6.81	9.74	0.83	3.21	4.58	3.09
Gabon	9.86	19.36	1.87	8.38	2.47	4.76	1.49	2.14
Nigeria	6.99	8.98	0.93	7.32	3.06	2.26	6.05	2.76
SSA	**7.44**	**11.31**	**3.44**	**7.17**	**1.83**	**5.21**	**5.74**	**3.94**
Argentina	2.92	4.39	-0.72	5.57	4.52	5.41	3.56	7.05
Brazil	8.47	3.48	2.98	4.75	1.69	2.94	3.28	2.18
Colombia	5.81	1.80	3.40	1.54	2.86	3.08	3.96	2.03
Ecuador	7.34	3.62	2.27	3.35	1.84	3.23	4.54	2.21
Mexico	6.43	2.20	2.29	4.52	3.38	3.59	1.91	3.60
Venezuela	3.96	2.87	-0.16	4.74	2.46	4.83	3.85	8.51
Latin America	**5.82**	**3.06**	**1.67**	**4.07**	**2.79**	**3.85**	**3.51**	**4.26**

Source: World Bank (2010)

The second period between 1980 - 1989 was a period of oil price collapse and the beginning of structural reforms to address perceived negative consequences of resource dependence which negatively affected the growth performance of these countries. According to World Bank (2010), during the period GDP per capita grew at an average of less than 2% per anum in MENA and Latin America while SSA and SE Asia recorded a growth rate of 3.4% and 5.21% per anum respectively. Apart from the low economic performance experienced by oil rich countries during the period, growth volatility was also high, particularly within MENA and SSA. This episode marked a period of poor performance both interms of GDP growth and volatility.

The third period between 1990 - 1999 witnessed the Asian financial crisis when the region's growth volatility increased to its highest level. Another major event that affected the global oil market was the Iraqi invasion of Kuwait in August 1990. According to Foad (2009), The Gulf War led the market to react with panic, leading to a 100% inccrease in the price of oil within two months. As reported in Table 4.1, the high oil prices is again reflected in the growth performance of the MENA countries as the annual average growth rate rose from of 1.88% in the 1980s to 6.81% in the 1990s. Oil producing countries in SSA recorded a very low growth performance over the period with an average annual growth rate for the region at 1.83%.[86] This outcome[87] is in line with the empirical findings in the previous chapter which reveals oil prices having a short-term impact on economic output of selected MENA and SSA countries (see Table 3.8) and a long-term positive effect on most MENA

[86] Latin America recorded a modest average growth rate of 2.79%

[87] Although is based on past information over short to medium term, it would be intresting to see how it connects with the findings in Chapter 3.

countries while the long-term coefficients for SSA countries are not significant. Hence, the long-term effect of oil prices on SSA countries is insignificant (see Table 3.18).

The fourth period witnessed an improvement in both growth performance and volatility across most of the regions. According to World Bank (2010), SSA witnessed its lowest growth volatility rate and a considerable rise in average per capita growth rate from the previous decade. The other regions also performed quite well with an average growth rate of more than 5% except Latin America which grew at 3.51% with an associated growth volatility of more than 4%.

The growth experiences over the whole period showed that oil producing countries of MENA and SSA have witnessed more volatile growth compared to those of SE Asia and Latin America and their growth performance is strongly influenced by activities in the oil market. While oil prices may seem to have a positive relationship with economic output of oil producing countries in the short-term, empirical studies of the long-term effect of natural resource abundance on economic performance of oil producing countries have pointed to a negative relationship, hence the resource curse paradox, hence, the key literature associated with this is discussed in the next section.

4.3 Literature Review

Several studies in the literature have explained the resource curse paradox from a different context - according to van Wijnberger (1984), resource curse occurs where an increase in revenue from natural resources makes a nations's currency stronger, thus making the manufacturing sector less competitive. Gylfason

(2001) explained the resourse curse paradox from the context of how the price of raw materials fluctuates in world markets. According to Gylfason (2001), the resulting fluctuations in export earnings trigger exchange rate volatility which creates uncertainty that can be harmful to exports and other trade, including foreign investment. Economic growth is then adversely affected by the resulting re-allocation of resources from the manufacturing and service sectors to the natural resource sector. Torvik (2002) explained the resource curse paradox from a rent-seeking theory and argued that natural resource abundance generates an incentive for economic agents to engage in non-productive activities which lead to lower welfare. According to Torvik (2002), a greater amount of natural resources increases the number of entrepreneurs engaged in rent seeking and reduces the number of entrepreneurs running productive firms; as a result, the drop in income from productive firms is higher than the increase in income from natural resource.

Evidence from political theories have linked natural resources to political instability armed conflict and violence. According to Rosser (2006), oil, gas and other valuable resources are strongly associated with the onset of civil wars as well as their duration - Rosser (2006) identifies three channels through which this link operates; (i) natural resource makes the state a more valuable target for take-over, (ii) regional concentration of resource wealth increase the possibility of conflicts, and (iii) resource abundance can weaken the state, rendering it less able to resolve conflict and manage its economy, and thereby foster conditions in which conflict is likely to erupt. Mehlum et al. (2006) have attempted to show that the extent to which growth winners and growth losers differ systematically depends on the level of their institutional arrangements.

According to Mehlum et al. (2006), natural resources drive aggregate income down when institutions are 'grabber friendly', while more resources increase income, when institutions are 'producer friendly'. While it is not the goal of this research to discuss these political theories in detail, it is important to note that they provide interesting channels through which natural resourse affect economic growth. A more detailed survey of the resource curse theories can be found in Gylfason et al. (1999), Casseli and Cunningham (2009) and van der Ploeg and Venables (2011).

As explained in Section 4.1, most empirical evidence of the resource curse paradox tend to follow Sachs and Warner (1995) cross-sectional study which shows that resourse rich countries indeed grew on average about one percentage point less during the 1970 - 1989 period even after controlling for initial income, investment, rule of law and openess. The study is the cornerstone of many discussion of the resource curse but can be criticized on econometric ground as highlighted earlier in this chapter. Following the Sachs and Warner (1995) cross-sectional technique, Leite and Weidmann (1999) and Glyfason et al. (1999) found natural resource abundance to be negatively correlated with economic growth.[88] Aghion et al. (2009), also using cross-sectional specification, suggest that market volatility can have a negative effect on long-term productivity growth, particularly in countries with low level of financial delopment.

Several studies from the field of political economy have applied cross-country regression analysis to show that the natural resource curse is stronger in a particular system of governance while others show resource windfall in-

[88] All emprical studies reviewed in this section uses ratio of primary exports to GDP or GNP as a measure of resource abundance/dependence unless otherwise stated.

crease corruption, especially in non-democratic regimes. Anderson and Aslaksen (2008) using a cross-country sample of ninety countries suggests that the resource curse occurs more in presidential democracies stressing that the presidential systems are less accountable and less representative when compared with the parliamentary system, thus making the presidential system offer more scope for resource rent extraction. Ades and Tella (1999), also using cross-country regression, suggest that natural resource rent encorage corruption, crowds out social capital, erodes the legal system and also induce armed conflicts and civil wars.

Some of the critique of the cross-country approach have pointed to the fact that it does not consider the time dimension of the data and faces the problem of omitted variable bias. As noted by Parente and Prescott (1994), cross-sectional regressions suffer from the problem of omitted variable bias arising, mainly from correlation between initial income and the initial level of productivity, hence, it is important to adopt the panel data estimation as against the cross-country regression.[89] Manzano and Rigabon (2001) in a panel study reveals that the impact of natural resource on growth found in cross-country regression disappears once one allows for fixed effects. Ross (2001) in another panel study that investigates the link between natural resources, institutional development and growth in resource rich countries found that point-source type natural resource retard democratic and institutional development which stunts growth. Ross (2001) used oil export as a ratio of GDP to measure natural resource abundance. Furthermore, Bhattacharyya and Holder (2010) in

[89] Parente and Prescott (1994)'s study attempts to explain a wide disparity in per capita income across countries based on a theory of economic development in which technology adoption and barriers to such adoptions are the focus.

a panel of ninety-nine countries covering 1980 - 2004 suggest that natural resource encorages corruption in countries that practice non-democratic regime for more than half of the years since 1956.

van der Ploeg (2011) in an extensive survey of empirical works within the resource curse literature recommended that "future empirical works should move from cross-sections to panel data regressions to over come the problem of ommitted variable bias and should also allow for changing quality of institutions" (pp 408). While there are a few studies that apply the panel data technique, most of them use homogeneous approaches, such as traditional fixed and random estimation or the generalized method movements (GMM) estimators which impose high degree of homogeneity across countries. Cavalcanti et al. (2011) applied a heterogeneous technique but did not account for the role of institutions in building their empirical model. As indicated earlier, this chapter investigates the resource curse hypothesis by applying a heterogeneous panel analysis using a model that captures the role of institution as recommended by van der Ploeg (2011). The technical details of this technique is explained in the next section.

4.4 Methodology

4.4.1 Cross-sectional Estimation

As stated above, before estimating the panel model, this work begins by applying the commonly used estimation technique in the literature which is the standard cross-sectional technique to investigate the growth effects of resource abundance. Even though this technique has a lot of limitations as indicated in section 4.1, applying it will provide a good basis for comparison with previous results since most of these studies applied this technique, although using different measures of resource abundance. Three studies that applied the cross-sectional technique (Sachs and Warner (1995), Mehlum et al. (2006) and Cavalcanti et al. (2011)) are selected and the results from these studies are compared with what is obtained here. As mentioned several times, Sachs and Warner (1995) is the pioneer study in the empirical literature of the resource curse paradox, and hence its inclusion among the selected studies. Mehlum et al. (2006) captured the role of institution in their model but used a different measure of resource abundance from what is used in this study while Cavalcanti et al. (2011) used the same measure of resource abundance but did not account for the role of institutions in their model. Section 4.6.1 provide details of the variables used and results obtained from these studies. The cross-sectional specification adopted here is therefore outlined as follows:

$$\overline{y}_i = \alpha_i + \beta_1 y_{84,i} + \beta_2 \overline{I/Y_i} + \beta_3 \overline{iq}_i + \beta_4 \overline{oprd}_i + e_i \tag{4.1}$$

where $\overline{y}_i$ is the average of the logarithm of GDP per-capita between 1984[90] and 2009 for country $i = 1....N$, and $y_{84,i}$ is the logarithm of the initial GDP per-capita (in 1984). $\overline{I/Y}_i$ is the average of the logarithm of investment share of GDP, $\overline{oprd}_i$ is the average of the logarithm of the real value of oil production and $\overline{iq}_i$ is the average of the index of institutional quality. Oil reserve is another important variable that can be used to measure oil abundance as indicated by Alexeev and Conrad (2009). Therefore, the above equation is also estimated by replacing $\overline{oprd}_i$ with the average value of oil reserve per-capita, $\overline{orsv}_i$. Most

[90]Institutional quality data (obtained from ICRG) used in this study is only available from 1984, hence the reason for the start date of 1984.

growth related studies that used cross-sectional estimation technique have always included initial income variable in the regression model. According to Cannon and Duck (2000), it is important to be able to distinguish between initial conditions when estimating growth models in cross-country regressions as they imply the existence of convergence. Also, van der Ploeg (2011) noted that the coefficient of initial income in cross-country regression is used to draw inferences about the speed of convergence - however, he cautioned that one should be careful about drawing such inferences when intermediate variables such as war and institutional quality are included in the model. The cross-sectional specification presented above therefore includes the initial income variable in line with what is obtained in the literature.

4.4.2 Panel Estimation

Panel estimates provide higher degrees of freedom, are more informative and biases are substantially smaller than cross-sectional estimates. One of the biggest challenges faced in panel data estimation as indicated in the previous chapter is how to face heterogeneity characteristics in the data set applications. Barbieri (2006) noted that the development of heterogenous panel unit root and panel cointegration tests have greatly enhanced empirical analysis using panel data. The research reported in this chapter therefore investigates the resource curse paradox by applying some of the recent panel estimation techniques.

The panel estimation tests applied in this chapter are similar to those carried out in Chapter 3 only that the panel error correction model in this chapter is also heterogenous based on a recent technique by Canning and

Pedroni (2008). As was the case in Chapter 3, the estimation approach involves four different stages: Firstly, panel unit-root test is estimated based on Im et al. (2003)[91] and Fisher ADF test, Choi (2001) to ensure the variables are integrated of the same order. Secondly, panel cointegration technique based on Pedroni (1999)[92] and Maddala and Wu (1999) are applied to check whether there is a long-run cointegrating relationship between the variables. Specifically, the research is interested in the group-statistics which takes into account heterogeneity. If cointegration is found, the long-run cointegrating relationship is estimated using the group fully modified OLS (GFMOLS) based on Pedroni (2000). Finally a heterogenous panel error correction model based on Canning and Pedroni (2008) is estimated to determine the short-run effect and how fast the system reverts to a long-run equilibrum following a shock. Each of these tests are explained in the sub-sections that follow.

4.4.3 Panel Unit-Root Test

The technical details of the two panel unit root techniques applied to test the stationarity of each of the five variables in this chapter are outlined in Section 3.3.3. If the variables are found to be integrated of the same order, the long-run cointegrating relationship is estimated using the between dimension approach (group-mean panel statistics) of Pedroni panel cointegration test (1999, 2004).

[91] Im, Pesaran and Shin (2003) has been found to have superior test power by researchers in analysing panel data. The test is based on the ADF statistics averaged accross groups, thus making it a heterogeneous test.

[92] As indicated in the previous chapter, Pedroni (1999) proposes two sets of statistics, the first is based on pooling the residuals along the within dimension of the panel while the second set is based on between dimension of the panel. The second set allows for heterogeneity across members.

4.4.4 Panel Cointegration Test

The cointegrating relationship estimated is as follows:

$$y_{it} = \alpha_{it} + \delta_i t + \beta_1 (I/Y)_{it} + \beta_2 iq_{it} + \beta_3 oprd_{it} + e_{it} \tag{4.2}$$

where $i = 1....,N$ for each country in the panel and $t = 1....,T$ refers to the time period. y_{it} is the natural logarithm of GDP per capita, $(I/Y)_{it}$ is the logarithm of investment share of GDP, iq_{it} is the logarithm of institutional quality while $oprd_{it}$ is the logarithm of real value of oil production. The cointegrating relationship is also estimated by replacing $oprd_{it}$ with $orsv_{it}$ as was done in the cross-sectional test. The parameters α_{it} and δ_i allows for the possibility of country specific fixed effects and deterministic trend, respectively. e_{it} is the estimated residuals representing deviations from the long run relationship. To test the null hypothesis of no cointegration, $\rho_i = 1$, the following unit root test is conducted on the residuals as follows:

$$e_{it} = \rho_i e_{it-1} + w_{it} \tag{4.3}$$

As indicated in the previous chapter, Pedroni (1999, 2004) proposes two sets of tests for cointegration; these are the panel and group tests for cointegration. Expressions for the various test statistics can be found in Section 3.3.3.

The cointegration equation above is also tested using the Johansen Fisher panel cointegration test which is based on Maddala and Wu (1999). Again, details of the test can be found in Section 3.3.3.

4.4.5 Estimating the Long-run Relationship

If a long-run relationship is established between real GDP per capita, share of investment in real GDP, real value of oil production per capita (as well as real value of oil reserve per capita), the long-run cointegrating relationship using group fully modified OLS (GFMOLS) based on Pedroni (2000) is estimated. The expression of the between dimention group-mean panel FMOLS estimation and the associated t-statistic can also be found in Section 3.3.3. While the FMOLS allows for estimation of the long-term effect of oil abundance on levels of per capita output, it is important to estimate the short-term effect, and how fast it reverts to a long-run equilibrum following a shock in the system which can be achieved using the panel error correction model.

4.4.6 Panel Error Correction Model

The residual from the estimated long-run cointegrating relationship is incorporated as an error correction term in a dynamic error correction model as follows:

$$\begin{aligned}\Delta y_{it} \quad &= \quad \alpha_j + \sum_{k=1}^{m} \alpha_{1ik} \Delta y_{it-k} + \sum_{k=1}^{m} \alpha_{2ik} \Delta (I/Y)_{it-k} + \sum_{k=1}^{m} \alpha_{3ik} \Delta iq_{it-k} \\ &\quad + \sum_{k=1}^{m} \alpha_{4ik} \Delta oprd_{it-k} + \lambda_i e_{it-1} + u_{it} \qquad (4.4)\end{aligned}$$

The variable e_{it} (error correction term) represents how far the variables are from the equilibrum relationship and the error correction mechanism estimates how this disequilibrum causes the variable to adjust towards equilibrum in order to keep the long-run relationship intact. The above equation is estimated for each of the individual country in the panel. Following Canning and Pedroni (2008), the lamba-Person test to compute the significance of the panel test is applied. The lamba-Person test, as explained in Canning and Pedroni (2008) uses the p-values associated with each of the individual country test to compute the accumulated marginal significance. Specifically, the lambda-Person test for the coefficient of long-run effect take the form

$$P_\lambda = -2\sum_{i=1}^{N} InP_\lambda \tag{4.5}$$

where InP_λ is the log of p-value associated with individual country i's F test for the null hypothesis $\lambda = 0$. The P_λ is distributed as X^2 with 2N degrees of freedom under the null hypothesis no long-run effect for the panel.

The short-run effect of the variables on GDP per capita is computed following the same approach using the probability values associated with the individual country i's F-test values for the null hypothesis of $\alpha_{2ik} = 0$, $\alpha_{3ik} = 0$, and $\alpha_{4ik} = 0$ for investment, institutional quality and oil production respectively.

4.5 Data

The analysis is undertaken on 25 non-OECD countries using annual data over the period 1984 to 2009.[93] The criteria for country selection is based on all oil producing non-OECD countries that are among the top 50 as contained in the World Fact Book 2010 of the US Central Intellegence Agency. Due to incomplete information, the following countries were not included; Azerbidjan,

[93] The reason for the start date of 1984 is due to availability of data - the ICRG database which provides detailed information on institutional quality data is only available from 1984.

Kazakhtan, Sudan, Vietnam, Iraq and Angola. The list of countries used for this chapter is shown in Appendix 4.1.

In the course of the analysis, the countries are divided into different sub-groups/panels so as to investigate whether the impact of oil abundance on net oil exporting countries is different from that of net oil importing countries. The various panels are therefore detailed as follows: **Panel A** represents a group of OPEC member countries; **Panel B** represents a group of other net oil exporting countries, **Panel C** represents group of net oil importing countries, and **Panel D** represents a group consisting of all countries.

As indicated earlier, the variables used for the study are GDP per capita, investment as a share of GDP, institutional quality, oil production per capita and oil reserve per capita.[94] GDP data for all countries is obtained from WDI database provided by the World Bank (accessed via ESDS database at www.esds.ac.uk) while the investment data for all countries is obtained from IFS database provided by International Monetary Fund (IMF). Data for oil production and oil reserve are obtained from Energy Information Administration (2010) while the institutional quality data is obtained from International Country Risk Guide (ICRG) database (2010). Descriptive statistics on the data for the various sub-groups are shown in Appendix 4.2.

The institutional quality data, obtained from the ICRG database is based on a number of political risk component factors which includes; government stability, socio-economic conditions, investment profile, internal conflict, external conflict, corruption, military in politics, religion in politics, law and order,

[94] Oil production and oil reserve data are measured in barrels of oil while the investment data is based on gross fixed capital formation as a share of GDP.

ethnic tensions, democratic accountability and bureaucracy quality. Each component is assigned a maximum numerical value (risk points), with the highest number points indicating the lowest potential risk for that component and the lowest number indicating the highest potential risk.

4.6 Empirical Results

4.6.1 Cross-sectional Estimation Result

The cross-sectional estimation results are reported in Table 4.2.[95] The coefficients of institutional quality in both specifications are significantly positive implying institutions play a key role in determining economic performance of the oil rich countries considered in this study. However, the coefficients of investment share of GDP are not significant and negative.

Table 4.2a

Cross-sectional Estimation Result

	(a)	(b)
In y_{84} (Initial income)	0.521***	0.467***
In $\overline{I/Y}_i$ (Investment)	-0.281	-0.227
In $\overline{iq}_i$ (Institutional quality)	1.509**	1.595**
In $\overline{oprd}_i$ (Oil production)	-0.111*	-
In $\overline{orsv}_i$ (Oil reserve)	-	-0.045
No. of countries	25	25
	0.97	0.97

Note: *, ** and *** indicates 10%, 5% and 1% significance values respectively
(a) = Model using oil production as a measure of resource abundance
(b) = Model using oil reserve as a measure of resource abundance

[95] The cross-sectional estimation is only undertaken on the entire sample (as against the panel estimation which is also undertaken on various sub-groups) because of the limited number of countries involved.

The estimated value of the measure of resource abundance using oil production variable is statistically significant and negative, thus suggesting that the resource curse is present for the countries in the sample. The coefficient of the other measure of resource abundance (oil reserve) is also negative but not significant even at 10% significance level.

Table 4.2b

Cross-sectional Regressions from Previous Studies

Annual Growth in real GDP	Sachs & Warner (1995)	Mehlum et al. (2006)	Cavalcanti et al. (2011)
Initial Income	-1.76**	-1.26**	-0.07
Resource dep./abun.	-10.57**	-14.34**	-0.18**
Rule of law	0.36*	-	-
Institutional quality	-	-1.3	-
Investments	1.02*	0.16***	0.23***
No. of countries	71	87	53
Adj R^2	0.72	0.71	0.34

Note: *, ** and *** indicates 10%, 5% and 1% significance values respectively

The cross-sectional estimation results from Sachs and Warner (1995), Mehlum et al. (2006) and Cavalcanti et al. (2011) all reveal evidence of resource curse as shown in Table 4.2b. While Sachs and Warner (1995) and Mehlum et al. (2006) uses share of resources in GDP (resource dependence) as a measure of resource curse, Cavalcanti et al. (2011) uses real value of oil production (resource abundance) - all three studies however point to the same outcome which is also in line with the cross-sectional estimation result obtained in this study.

As outlined earlier, these cross-sectional estimates are arguably subject to a number of problems which the panel estimate attempt to address. The next sub-section therefore reports result from the panel estimates.

4.6.2 Panel Estimation Results

Panel Unit Result

As outlined earlier, the first stage in the panel esimation process is to consider the unit root properties of the variables in the model. Table 4.3 reports the unit root result derived from the two tests conducted.

The results indicate that all the series are non-stationary at levels but achieved stationatity after taking the first difference, all at 1% significance level. It is therefore concluded that all the series are integrated of order one and as such can proceed to test for cointegration.

Table 4.3

Panel Unit Root Test Result

	Panel A		Panel B		Panel C		Panel D	
Variables	IPS	Choi	IPS	Choi	IPS	Choi	IPS	Choi
In y_{it}	3.054	3.054	3.687	3.729	-0.518	-0.616	2.792	3.084
In $(I/Y)_{it}$	0.580	1.309	1.143	1.346	0.569	0.639	-0.277	-0.137
In iq_{it}	-0.118	-0.095	-0.859	-0.865	-0.936	-0.652	0.604	0.919
In $oprd_{it}$	-1.127	0.099	0.629	0.794	-0.403	-0.475	-0.523	-0.498
In $orsv_{it}$	-0.661	-0.387	0.093	0.146	-0.751	-0.713	-1.034	-0.805
Δ In y_{it}	-7.334***	-6.808***	-8.218***	-7.543***	-4.588***	-3.978***	-9.806***	-8.650***
Δ In $(I/Y)_{it}$	-2.908***	-2.627***	-7.088***	-6.518***	-7.684***	-6.745***	-10.786***	-9.951***
Δ In iq_{it}	-10.187***	-8.826***	-6.692***	-6.354***	-6.686***	-5.805***	-12.551***	-11.108***
Δ In $oprd_{it}$	-12.271***	-5.827***	7.523***	-6.507***	-8.854***	-7.106***	-16.608***	-13.462***
Δ In $orsv_{it}$	-31.783***	-12.863***	9.969***	-8.850***	-10.424***	-8.615***	-31.185***	-17.666***

Note: *, ** and *** indicates 10%, 5% and 1% significance values respectively

Table 4.4

Pedroni Panel Cointegration Result

	Pedroni test on residuals of MG estimators		
	Group ρ-stat.	*Group PP-stat.*	*Group ADF-stat.*
Panel A			
(a)	1.056	-3.770***	-3.698***
(b)	1.079	-4.331***	-3.179***
Panel B			
(a)	2.627	-2.247**	-0.962
(b)	2.295	-2.349***	-1.833**
Panel C			
(a)	2.235	-2.011**	-0.083
(b)	2.607	0.016	-1.945**
Panel D			
(a)	3.339	-3.698***	-3.163***
(b)	3.337	-4.141***	-4.064***

Note: *, ** and *** indicates 10%, 5% and 1% significance values respectively
(a) = Model using oil production as a measure of resource abundance
(b) = Model using oil reserve as a measure of resource abundance

Panel Cointegration Test Results

The three panel cointegration test statistics based on the group-mean approach of Pedroni (1999, 2004) are reported in Table 4.4. Under the null hypothesis of no cointegration, the test statistics of Group PP and/or Group ADF are rejected at least at the 5% significance level using either the oil production or the oil reserve specification for all panels while the Group ρ statistic cannot be rejected even at 10% significance level for all panels.

The results of the Johansen Fisher panel cointegration test[96] reported in Table 4.5 clearly supports the presence of cointegrating relationship among the variables in all panels using both specifications.

[96] The test is based on Maddala and Wu (1999)

Table 4.5

Johansen Fisher Panel Cointegration Test

	Trace Statistic				Max-Eigen Statistic			
	At most 1	At most 2	At most 3	At most 4	At most 1	At most 2	At most 3	At most 4
Panel A								
(a)	280.8***	132.1***	308.6***	287.7***	497.4***	108.1***	54.40***	287.7***
(b)	337.0***	165.1***	322.9***	297.8***	250.6***	126.9***	60.54***	297.8***
Panel B								
(a)	103.9***	54.98***	28.30*	17.91	61.22***	38.56***	23.18	17.91
(b)	309.4***	165.1***	82.73***	35.30***	393.1***	99.89***	66.62***	35.30***
Panel C								
(a)	206.8***	94.03***	50.96***	26.74***	249.1***	53.35***	37.17***	26.74***
(b)	247.9***	154.3***	78.39***	30.99***	125.2***	90.42***	60.64***	30.99***
Panel D								
(a)	322.2***	164.8***	82.10***	48.08	199.2***	117.3***	70.63**	48.08
(b)	894.3***	484.4***	484.0***	364.1***	768.8***	317.3***	187.8***	364.1***

Note: *, ** and *** indicates 10%, 5% and 1% significance values respectively

Since the results from Pedroni's Group PP and Group ADF test statistics as well as results from Fisher's trace and max-eigen test supports the presence of cointegration, it can be concluded that there is a long-run cointegrating relationship among the variables, thus allowing for the estimation of the long-run relationship

Estimated Long-run Relationship - GFMOLS Results

The FMOLS group mean estimates and the corresponding t-values are reported in Table 4.6. The significant estimate of the coeffcient of investment and institutional quality indicates that they are both important variables in explaining the long-term effect of resource abundance on the levels of per capita output. The estimated coefficient of the measure of resource abundance using oil production variable is statistically significant and negative for the group of OPEC countries (Panel A) and the group of other oil exporting countries (Panel B) while the coefficient is significatly positive for the group of net oil exporting countries (Panel C). The results therefore suggest evidence of resource curse for the net oil exporting countries using oil production as proxy resource abundance while no evidence of resource curse is found for the net oil importing countries.

The second specification estimated using oil reserve as a measure of resource abundance only shows evidence of resource curse in Panel B where the coefficient is significatly negative while that of Panel A is significantly positive. The coefficient of oil reserve in Panel C is not significant.

Table 4.6

FMOLS Estimation Result

		In $(I/Y)_{it}$	In iq_{it}	In $oprd_{it}$	In $orsv_{it}$
Panel A					
	(a)	0.63 (5.74)***	0.34 (1.92)*	-0.02 (2.56)**	-
	(b)	0.41 (3.53)***	-0.17 (1.23)	-	0.22 (1.62)*
Panel B					
	(a)	0.53 (1.04)	3.13 (15.08)***	-0.07 (-8.93)***	-
	(b)	0.35 (1.86)*	1.56 (9.40)***	-	-0.62 (-7.49)***
Panel C					
	(a)	1.53 (12.05)***	0.94 (1.88)*	1.52 (9.39)***	-
	(b)	1.63 (13.77)***	0.07 (1.55)	-	-0.59 (-1.58)
Panel D					
	(a)	0.89 (10.14)***	1.47 (11.17)***	0.48 (2.16)*	-
	(b)	0.80 (10.93)***	0.49 (7.12)***	-	-0.33 (-4.32)***

Note: *, ** and *** indicates 10%, 5% and 1% significance values respectively
(a) = Model using oil production as a measure of resource abundance
(b) = Model using oil reserve as a measure of resource abundance
(c) = t-values in parenthesis

For the overall sample (Panel D), the result suggest evidence of resource curse using the oil reserve specification while it is not found using the oil production specification as the coefficient oil production variable is significantly positive (although only at 10% significance level). The results therefore suggest that the long-term effect of resource abundance depends on the measure of natural resource and also whether or not the country/group of countries is a net oil exporter or net oil importer. While both oil production and oil reserve are important measures of resource abundance as explained earlier in this chapter, it is the view of this research that oil reserve better represent abundance of natural resource since it reports the total amount of technically and economically recoverable oil. The group of major oil exporting countries (Panel A) shows a positive long-term effect of oil reserve on per-capita output.

Having estimated the long-term effect, the next sub-section reports result from panel error correction model which estimate the short-run effect and whether or not the model reverts to a long-run relationship following a shock.

Panel Error Correction Model Results

Table 4.7 reports the panel error correction model results. It can be observed from the table that each result has two entries; the top entry reports the group mean F-stat values while the bottom entry reports the panel lambda-Person result obtained from the probability values of the individual F-test results. In all specifications and accross all panels, the F-stat value of the error correction term (reported in column 5 of the table) are statistically significant indicating that the model reverts to long-run equilibrum following a shock in the system. On the short-term effect of oil abundance on per capita output, the result reveals that real value of oil production have a short-term growth enhancing effect on per capita output for the group of other oil exporting countries (Panel B) and the group of net oil importing countries (Panel C) whereas it does not have a short-term effect on per capita output for the group of OPEC countries. This can be viewed as a further evidence of resource curse on the OPEC countries using the oil production measure of resource abundance.

Furthermore, results obtained using the oil reserve specification shows that real value of oil reserve have a short-term growth enhancing effect on per capita output for the group of OPEC countries whereas it does not show evidence of short-term effect for the other two sub-groups. Panel D, which covers the

Table 4.7
Panel Error Correction Model

		Δ In $(I/Y)_{it-j}$	Δ In iq_{it-j}	Δ In $oprd_{it-j}$	Δ In $orsv_{it-j}$	ect_{it-1}
Panel A						
	(a)	2.076	1.416	0.793	-	3.771
		33.17 (0.05)**	24.57 (0.20)	14.61 (0.50)	-	46.14 (0.001)***
	(b)	2.322	1.528	-	2.233	5.083
		37.59 (0.01)**	28.24 (0.20)	-	35.53 (0.02)**	59.52 (0.001)***
Panel B						
	(a)	1.947	1.905	2.871	-	2.477
		28.62 (0.05)**	26.42 (0.10)*	33.85 (0.02)**	-	31.33 (0.025)**
	(b)	1.267	2.655	-	1.269	4.202
		18.37 (0.50)	34.48 (0.01)**	-	16.42 (0.50)	45.71 (0.001)***
Panel C						
	(a)	1.572	1.906	2.916	-	4.298
		16.00 (0.20)	20.01 (0.10)*	23.96 (0.025)**	-	30.15 (0.002)***
	(b)	1.176	1.883	-	1.590	3.720
		12.16 (0.50)	19.58 (0.10)*	-	16.26 (0.20)	28.82 (0.005)***
Panel D						
	(a)	1.865	1.742	2.193	-	3.515
		77.78 (0.010)***	71.01 (0.025)**	72.42 (0.020)**	-	107.63 (0.001)***
	(b)	1.588	2.022	-	1.697	4.335
		68.12 (0.050)**	82.30 (0.005)***	-	68.21 (0.020)**	134.04 (0.001)***

Note: 1: *, ** and *** indicates 10%, 5% and 1% significance values respectively

2: p-values corresponding to the lambda-Person test in parenthesis whole sample shows evidence of both long and short-run impact on GDP based on both specifications.

In conclusion, the results obtained from the long-run estimates using group FMOLS and short-run estimates using panel ECM seem to suggest the presence of resource curse for the oil exporting countries using oil production as a proxy of natural resource while no evidence of resource curse is found using oil reserve. As for the net oil importing countries, no evidence of resource curse is found (both in the short and long-run) using oil production and the coefficient of oil reserve is not significant in both estimates.

4.7 Summary and Conclusion

Economic failure among resource rich countries has been attributed to abundance of natural resources, and is often tagged in the literature as the 'Dutch disease' or 'resource curse' - implying natural resource is more of a curse than a blessing. The empirical literature of the resource curse paradox is mostly built on Sachs and Warner's (1995) cross-sectional approach which recent studies have criticized due to problems of omitted variable bias and the fact that it does not take into account the time dimension of the data - thus, suggesting the use of panel estimation technique which allows for the role of institutional quality in the model.[97] Also, most of these studies uses the share of resources in GDP which actually measures resource dependence not abundance.

In line with the above, this chapter investigates the resource curse paradox by using the real value of oil production and the real value of oil reserve as

[97] See van der Ploeg (2011)

measures of resource abundance. The analysis begins by applying the commonly used cross-sectional estimatation technique in order to provide a basis for comparison with previous empirical literature - it particularly seeks to investigate whether a cross-sectional model that uses the resource abundance variable and accounts for the role of institutions would lead to a different outcome from what is mostly obtained in the literature. Since the cross-sectional estimation technique has a lot of shortcomings, the study also applies a heterogenous panel model to empirically investigate the relationship using both measures of resource abundance.

The cross-sectional estimation result suggest evidence of resource curse for the entire sample using the real value of oil production as a measure of resource abundance. Even though different measure of resource dependence/abundance is used, the cross-sectional estimation result is in line with what was obtained in Sachs and Warner (1995), Mehlum et al. (2006) and Cavalcanti et al. (2011) among others.

The results from the panel estimate on the other hand show a slightly different outcome; the panel estimate results for the entire sample suggest that the effect of oil abundance is significantly positive using the real value of oil production but significantly negative using the real value of the oil reserve. This implies that from the panel estimate of the entire sample, evidence of resource curse could only be found using oil reserve as a measure for resource abundance and not oil production. When the various sub-groups are considered, it is found that oil production has a negative long-run effect on per capita output of OPEC countries while oil reserve has a positive effect for the same group of countries. As for the net oil importing countries, the result reveals a positive relationship between oil production and per capita output. The panel estimates generally suggests evidence of resource curse on the major oil exporting countries using oil production as a proxy of natural resource while no evidence of resource curse is found using oil reserve. The group of net oil importing countries also reveals no evidence of resource curse.

To determine the short-run growth enhancing effects of oil abundance, a panel error correction model is estimated. The results for the whole sample from both specifications indicates that oil abundance have a short-run growth enhancing effect on per capita output. Again when the various sub-groups are considered, it shows different results depending on the measure of oil abundance. The result reveals that oil production does not have a short-run growth enhancing effect on per capita GDP of OPEC countries while it has for the net oil importing countries and oil reserve have a growth enhancing effect for the OPEC group while it does not have for the net oil importing countries.

Since the resource curse paradox is mostly linked to resource rich exporting countries, a close look at the results obtained from the oil exporting countries is essential. The results from the group of OPEC countries (Panel A) shows evidence of resource curse using oil production while no evidence of resource curse is found using oil reserve. This implies that stock of natural resource, in this case oil reserve, does not hinder economic performance in the oil rich exporting countries - however, the flow process of production does, as indicated by the oil production variable. It is therefore concluded that oil abundance is not a curse on these countries and the negative effect of oil production might have been caused by poor macro economic policies and other factors assotiated with oil production process such as negative consequence of oil price volatility or perhaps poor fiscal regime framework which in most cases has an adverse effect on exploration activities in the petroleum industry. Furthermore, most oil rich exporting countries are characterized by weak democratic structures, and in some cases non-democratic regimes. This can have adverse effect on macro-economic performance as the governments tend to be unaccountable to the people and usually lack the capacity to effectively manage huge oil rents accruing to it.

While the study concludes that oil abundance is not always a curse as against most studies in the literature, it is important to state that oil rich countries could benefit more from their natural wealth by adopting growth and welfare enhancing policies and the presence of strong and vibrant institutions. Natural resource rents should be channelled into reproducible asset such as good infrastructure to facilitate growth of the real sector. More importantly, natural resource revenue should be managed in such a way that promotes sustainable growth, alleviates poverty and avoids conflicts.

4.8 Appendix to Chapter 4

4.8.1 Appendix 4.1: List of Countries

Appendix 4.1 shows the list of all countries included in the analysis of Chapter 4. The selection is based on all oil producing developing countries that are among the top 50 as contained in World Factbook 2010. As reported in Table A4.1, each country is listed under one of three broad categories; OPEC, other oil exporters and net oil importers. These categories make-up the various sub-groups applied in the panel data analysis section.

Table A4.1

List of Countries

OPEC Countries	Other Oil Exporters	Net Oil Importers
Algeria	Argentina	Brazil
Ecuador	Colombia	China
Iran	Egypt	India
Kuwait	Indonesia	Peru
Libya	Malaysia	Romania
Nigeria	Mexico	Thailand
Qatar	Oman	
Saudi Arabia	Syria	
UAE	Trinidad	
Venezuela		

4.8.2 Appendix 4.2: Descriptive Statistics

Appendix 4.2 reports the descriptive statistics of the data used in the analysis of Chapter 4. The statistics are reported for each of the categories applied in the panel data analysis section - hence, Tables A4.2 - A4.5 reports the statistics for the group of OPEC countries, group of other oil exporters, group of net oil importers and group of all countries respectively. The descriptive statistics reveals that the data is generally satisfactory and evenly distributed except for the institutional quality variable which is slightly skewed.

Table A4.2

Descriptive Statistics (OPEC Countries)

	y_{it}	$(I/Y)_{it}$	iq_{it}	$oprd_{it}$	$orsv_{it}$
Mean	9953.98	20.36	50.37	138.72	12643.24
Median	5394.74	20.23	59.72	53.52	4960.02
Maximum	86435.82	39.34	79.33	489.65	65048.23
Minimum	203.21	5.30	28.50	4.86	126.11
Std. deviation	12845.63	6.81	11.07	146.96	16729.54
Skewness	2.78	0.07	-0.30	0.84	1.39
Kurtosis	12.66	2.93	2.45	2.22	3.68

Table A4.3

Descriptive Statistics (Other Oil Exporting Countries)

	y_{it}	$(I/Y)_{it}$	iq_{it}	$oprd_{it}$	$orsv_{it}$
Mean	4005.96	21.50	62.89	25.19	433.07
Median	3012.04	20.76	64.16	10.09	141.60
Maximum	21648.57	43.58	79.41	147.12	2671.80
Minimum	450.66	11.93	31.66	1.57	16.48
Std. deviation	3537.81	5.58	9.79	38.70	704.01
Skewness	1.83	1.19	-0.60	2.18	2.18
Kurtosis	7.61	5.54	2.75	6.43	6.33

Table A4.4

Descriptive Statistics (Net Oil Importing Countries)

	y_{it}	$(I/Y)_{it}$	iq_{it}	$oprd_{it}$	$orsv_{it}$
Mean	2063.64	24.96	61.48	1.46	24.13
Median	1650.64	22.74	63.68	1.42	16.05
Maximum	9299.73	45.61	76.16	3.82	66.76
Minimum	248.29	14.38	34.75	0.17	1.12
Std. deviation	1764.54	7.27	8.81	0.97	19.24
Skewness	1.74	0.86	-1.11	0.60	0.68
Kurtosis	6.54	2.80	3.64	2.54	2.24

Table A4.5

Descriptive Statistics (Group of all Countries)

	y_{it}	$(I/Y)_{it}$	iq_{it}	$oprd_{it}$	$orsv_{it}$
Mean	5919.01	21.87	60.74	64.91	5218.99
Median	2793.87	20.92	62.58	11.50	204.59
Maximum	86435.82	45.61	79.41	489.65	65048.23
Minimum	203.21	5.31	28.50	0.17	1.12
Std. deviation	9083.13	6.75	10.29	113.75	12194.15
Skewness	4.20	0.60	-0.58	2.07	2.85
Kurtosis	26.76	3.90	2.75	6.20	10.43

4.8.3 Appendix 4.3: Individual FMOLS Results

The Group Fully Modified OLS requirs one to estimate the individual FMOLS before computing the group estimate. The individual FMOLS results are therefore reported in Appendix 4.3 in Tables A4.6, A4.7 and A4.8 for the various sub-groups. The group estimate is indicated at the bottom of the table.

Table A4.6

Individual FMOLS Results (OPEC Group)

		In $(I/Y)_{it}$	In iq_{it}	In $oprd_{it}$	In $orsv_{it}$
Algeria	(a)	0.427 (1.185)	0.897 (2.610)**	2.464 (3.889)***	-
	(b)	-0.406 (-1.053)	1.920 (5.911)***	-	-0.409 (-0.341)
Ecuador	(a)	2.151 (3.957)***	1.175 (0.810)	2.291(7.702)***	-
	(b)	0.942 (0.916)	-2.597 (-0.985)	-	0.688 (3.077)***
Iran	(a)	0.977 (0.897)	-0.720 (-0.677)	-0.734 (-0.338)	-
	(b)	1.655 (2.064)**	-1.273 (-3.311)***	-	1.826 (2.604)**
Kuwait	(a)	1.021 (1.958)*	1.832 (2.619)**	0.146 (0.355)	-
	(b)	0.522 (1.669)*	1.288(3.264)***	-	-1.862 (-2.762)**
Libya	(a)	0.902 (8.665)***	-0.061 (-0.362)	1.567 (3.910)***	-
	(b)	0.924 (5.833)***	0.394 (1.622)	-	-0.525 (-1.322)
Nigeria	(a)	-0.337 (-0.617)	0.023 (0.013)	-3.941 (-2.432)**	-
	(b)	-0.026 (-0.062)	-0.288 (-0.242)	-	3.072 (4.191)***
Qatar	(a)	1.472 (3.021)***	-0.236 (-0.163)	0.576 (0.542)	-
	(b)	1.240 (3.594)***	-0.150 (-0.179)	-	0.440 (3.227)***
Saudi	(a)	-0.016 (-0.026)	2.470 (3.791)***	-1.263 (-2.396)**	-
	(b)	0.040 (0.089)	0.702 (1.708)*	-	-1.560 (-4.647)***
UAE	(a)	-1.429 (-3.404)***	0.316 (0.878)	-0.762 (-2.240)**	-
	(b)	-1.515 (-4.157)***	0.181 (0.535)	-	-0.570 (-2.583)**
Venezuela	(a)	1.114 (2.427)**	-2.320 (-3.333)***	-0.549 (-0.880)	-
	(b)	0.683 (2.290)**	-1.904 (-4.429)***	-	1.123 (3.759)***
Panel	**(a)**	**0.632 (5.739)*** **	**0.337 (1.962)***	**-0.021 (2.563)** **	**-**
	(b)	**0.404 (3.533)*** **	**-0.170 (1.230)**	**-**	**0.222 (1.622)***

Table A4.7

Individual FMOLS Results (Other Oil Exporting Countries)

		In $(I/Y)_{it}$	In iq_{it}	In $oprd_{it}$	In $orsv_{it}$
Argentina	(a)	0.262 (0.903)	3.935 (7.175)***	-0.580 (-1.367)	-
	(b)	0.634 (2.862)***	3.102 (10.509)***	-	0.195 (0.713)
Colombia	(a)	2.676 (3.511)***	-1.115 (-0.642)	0.596 (1.172)	-
	(b)	2.642 (4.348)***	-2.385 (-2.036)**	-	-0.531 (-2.271)**
Egypt	(a)	0.573 (1.167)	1.051 (1.641)	-1.059 (-4.163)***	-
	(b)	0.353 (0.587)	0.192 (0.197)	-	-1.724 (-2.520)**
Indonesia	(a)	0.178 (0.959)	1.467 (9.361)***	-1.334 (-14.789)***	-
	(b)	0.045 (0.096)	0.796 (1.706)*	-	-0.930 (-4.887)***
Malaysia	(a)	-1.006 (-2.647)**	5.085 (6.841)***	1.063 (0.937)	-
	(b)	-1.021 (-3.643)***	4.825 (6.402)***	-	0.842 (1.092)
Mexico	(a)	3.071 (2.817)**	7.266 (4.821)***	-0.722 (-0.661)	-
	(b)	-0.390 (-0.971)	4.930 (9.636)***	-	-0.475 (-10.140)***
Oman	(a)	0.133 (0.572)	1.734 (4.238)***	-1.840 (-4.341)***	-
	(b)	0.340 (1.097)	0.376 (0.837)	-	-3.193 (-2.674)**
Syria	(a)	-0.649 (-2.891)***	1.438 (5.619)***	-1.344 (-9.274)***	-
	(b)	0.297 (0.524)	-0.158 (-0.326)	-	-1.721 (-3.398)***
Trinidad	(a)	-0.500 (-1.277)	7.264 (6.013)***	4.593 (5.642)***	-
	(b)	0.455 (0.691)	2.373 (1.289)	-	0.669 (0.772)
Panel		**0.526 (1.036)**	**3.125 (15.007)*** **	**-0.069 (-8.939)*** **	**-**
		0.350 (1.861)*	**1.561 (9.395)*** **	**-**	**-0.620 (-7.494)*** **

Table A4.8

Individual FMOLS Results (Net Oil Importing Countries)

		ln $(I/Y)_{it}$	ln iq_{it}	ln $oprd_{it}$	ln $orsv_{it}$
Brazil	(a)	0.396 (0.416)	4.720 (1.361)	0.924(4.647)**	-
	(b)	1.243 (1.573)	1.705 (0.638)	-	0.916 (4.165)***
China	(a)	2.584 (2.488)**	-0.810 (-0.510)	9.289 (6.733)***	-
	(b)	3.643 (3.473)***	-1.502 (-0.860)	-	-4.006 (-4.140)***
India	(a)	2.545 (12.366)***	0.275 (1.649)	-0.176 (-0.477)	-
	(b)	2.442 (22.592)***	0.114 (1.212)	-	-0.829 (-5.513)***
Peru	(a)	0.080 (0.180)	1.756 (2.500)**	-0.019 (-0.037)	-
	(b)	-0.016 (-0.039)	1.993 (5.617)***	-	0.506 (0.913)
Romania	(a)	2.498 (6.092)***	-0.392 (-0.672)	-1.662 (-3.417)***	-
	(b)	1.593 (3.308)***	-0.531 (-1.112)	-	-1.078 (-4.778)***
Thailand	(a)	1.048 (7.979)***	0.077 (0.282)	0.790 (15.466)***	-
	(b)	0.904 (2.837)***	-1.335 (-1.699)*	-	0.956 (5.479)***
Panel	(a)	1.525 (12.054)***	0.937 (1.881)*	1.524 (9.395)***	-
	(b)	1.634 (13.767)***	0.074 (1.548)	-	-0.589 (-1.580)

4.8.4 Appendix 4.4: Individual and Panel Error Correction Estimates

Similarly, the lamda-Person Group Error Correction Model also requires one to estimate the individual ECM before computing the group estimate. The individual ECMs are therefore reported in Appendix 4.4 in Tables A4.9, A4.10 and A4.11, corresponding to each of the sub-groups.

Table A4.9

Individual and Panel Error Correction Estimates (OPEC Group)

		Lags	Δ In $(I/Y)_{t-j}$	Δ In iq_{t-j}	Δ In $oprd_{t-j}$	Δ In $orsv_{t-j}$	ect_{t-1}
Algeria	(a)	1	1.390 (0.253)	0.323 (0.576)	0.152 (0.701)	-	3.338 (0.084)*
	(b)	1	1.404 (0.251)	0.023 (0.080)	-	0.488 (0.493)	0.005 (0.944)
Ecuador	(a)	2	1.066 (0.370)	5.050 (0.022)**	0.353(0.708)	-	0.0002 (0.991)
	(b)	2	6.980 (0.007)***	9.310 (0.002)***	-	3.087 (0.077)*	3.327 (0.089)*
Iran	(a)	2	0.087 (0.916)	1.061 (0.372)	0.289 (0.752)	-	0.019 (0.891)
	(b)	2	1.117 (0.356)	1.553 (0.248)	-	2.869 (0.092)*	3.323 (0.091)*
Kuwait	(a)	1	1.723 (0.205)	0.011 (0.917)	0.131 (0.721)	-	4.627 (0.045)**
	(b)	1	0.826 (0.375)	0.002 (0.966)	-	1.456 (0.242)	5.225 (0.034)**
Libya	(a)	2	4.036 (0.064)*	1.109 (0.357)	1.550 (0.246)	-	8.649 (0.010)***
	(b)	2	2.125 (0.156)	0.005 (0.994)	-	0.522 (0.603)	9.357 (0.008)***
Nigeria	(a)	2	0.682 (0.522)	0.257 (0.776)	0.010 (0.989)	-	0.131 (0.722)
	(b)	2	0.303 (0.743)	0.171 (0.843)	-	5.112 (0.041)**	7.728 (0.015)**
Qatar	(a)	2	2.001 (0.174)	0.450 (0.647)	3.222 (0.095)*	-	3.083 (0.101)*
	(b)	2	3.477 (0.061)*	0.196 (0.824)	-	5.358 (0.020)**	9.498 (0.008)***
Saudi	(a)	1	3.713 (0.069)*	1.329 (0.264)	1.177 (0.292)	-	6.003 (0.024)**
	(b)	1	3.337 (0.084)*	0.257 (0.617)	-	2.146 (0.160)	4.401 (0.050)**
UAE	(a)	2	5.262 (0.019)**	3.705 (0.051)**	0.930 (0.417)	-	11.128 (0.004)***
	(b)	2	3.460 (0.060)*	3.546 (0.056)*	-	0.618 (0.553)	7.795 (0.014)**
Venezuela	(a)	2	0.803 (0.468)	0.871 (0.441)	0.123 (0.884)	-	0.727 (0.408)
	(b)	2	0.200 (0.820)	0.220 (0.805)	-	0.684 (0.521)	0.174 (0.682)
Panel	**(a)**		**2.076 (0.055)***	**1.416 (0.250)**	**0.793 (0.455)**	**-**	**3.771 (0.004)*****
	(b)		**2.322 (0.031)****	**1.528 (0.150)**	**-**	**2.233 (0.051)***	**5.083 (0.001)*****

Table A4.10

Individual and Panel Error Correction Estimates (Other Oil Exporting Group)

		Lags	Δ In $(I/Y)_{t-j}$	Δ In iq_{t-j}	Δ In $oprd_{t-j}$	Δ In $orsv_{t-j}$	ect_{t-1}
Argentina	(a)	2	1.508 (0.255)	1.231 (0.321)	4.057 (0.041)	-	5.817 (0.031)**
	(b)	2	0.174 (0.841)	0.552 (0.587)	-	0.018 (0.981)	4.752 (0.046)**
Colombia	(a)	2	0.443 (0.650)	1.917 (0.183)	0.295(0.748)	-	0.005 (0.941)
	(b)	2	0.163 (0.851)	2.167 (0.151)	-	2.472 (0.120)	0.077 (0.784)
Egypt	(a)	1	0.498 (0.488)	3.150 (0.092)*	0.753 (0.396)	-	5.650 (0.028)**
	(b)	1	3.326 (0.084)*	4.888 (0.040)**	-	6.848 (0.017)**	11.189 (0.003)***
Indonesia	(a)	2	0.711 (0.508)	0.521 (0.604)	0.512 (0.609)	-	2.280 (0.153)
	(b)	2	0.155 (0.857)	0.249 (0.782)	-	0.068 (0.934)	0.295 (0.594)
Malaysia	(a)	3	1.507 (0.278)	0.776 (0.536)	5.285 (0.047)**	-	4.691 (0.058)*
	(b)	3	0.950 (0.456)	1.069 (0.409)	-	1.119 (0.391)	0.450 (0.518)
Mexico	(a)	3	2.587 (0.117)	1.657 (0.244)	1.645 (0.247)	-	2.108 (0.180)
	(b)	3	1.134 (0.349)	3.313 (0.066)*	-	0.001 (0.998)	4.519 (0.051)*
Oman	(a)	1	5.846 (0.026)**	0.360 (0.555)	11.964 (0.002)***	-	0.632 (0.436)
	(b)	1	1.380 (0.255)	2.356 (0.142)	-	0.034 (0.853)	13.505 (0.001)***
Syria	(a)	1	4.165 (0.066)*	6.517 (0.020)**	0.032 (0.859)	-	1.094 (0.309)
	(b)	1	3.825 (0.066)*	7.905 (0.011)**	-	0.004 (0.985)	0.319 (0.578)
Trinidad	(a)	2	0.266 (0.769)	1.016 (0.387)	1.299 (0.303)	-	0.017 (0.895)
	(b)	2	0.299 (0.745)	1.404 (0.278)	-	0.858 (0.444)	2.712 (0.121)
Panel	**(a)**		1.947 (0.10)*	1.905 (0.114)	2.871 (0.081)*	-	2.477 (0.144)
	(b)		1.267 (0.145)	2.655 (0.061)*	-	1.269 (0.211)	4.202 (0.005)***

Table A4.11

Individual and Panel Error Correction Estimates (Net Oil Importing Group)

		Lags	Δ In $(I/Y)_{t-j}$	Δ In iq_{t-j}	Δ In $oprd_{t-j}$	Δ In $orsv_{t-j}$	ect_{t-1}
Brazil	(a)	2	0.108 (0.898)	2.542 (0.114)	1.649 (0.227)	-	1.721 (0.210)
	(b)	2	0.268 (0.768)	1.814 (0.199)	-	0.583 (0.571)	5.760 (0.030)**
China	(a)	1	2.702 (0.117)	1.646 (0.215)	9.597 (0.006)***	-	6.426 (0.020)**
	(b)	1	0.003 (0.958)	1.982 (0.176)	-	1.726 (0.205)	10.259 (0.004)***
India	(a)	2	2.021 (0.169)	2.575 (0.111)	0.549 (0.588)	-	0.998 (0.334)
	(b)	2	1.878 (0.189)	3.821 (0.047)**	-	2.078 (0.162)	0.952 (0.345)
Peru	(a)	2	0.030 (0.969)	0.120 (0.887)	0.528 (0.601)	-	0.580 (0.458)
	(b)	2	3.732 (0.050)**	1.564 (0.243)	-	4.697 (0.027)**	0.592 (0.453)
Romania	(a)	2	1.866 (0.193)	2.650 (0.101)*	1.681 (0.224)	-	1.646 (0.221)
	(b)	2	0.213 (0.810)	0.802 (0.469)	-	0.223 (0.794)	0.404 (0.535)
Thailand	(a)	2	2.705 (0.101)*	1.906 (0.185)	3.494 (0.058)*	-	14.417 (0.002)***
	(b)	2	0.962 (0.405)	1.317 (0.299)	-	0.328 (0.725)	4.355 (0.055)*
Panel	**(a)**		1.572 (0.251)	1.906 (0.121)	2.916 (0.071)*	-	4.298 (0.021)**
	(b)		1.176 (0.445)	1.883 (0.187)	-	1.590 (0.211)	3.720 (0.035)**

4.8.5 Appendix 4.5: Diagnostic Tests

Tables A4.12 and A4.13 reports the diagnostic test results for the error correction model tests carried out in Chapter 4. According to the results, the models have passed almost all diagnostic tests undertaken.

Table A4.12

Diagnostic Test

Country	Serial Correlation		Heteroscadasticity		Normality	
	F-Stat	Probability	F-Stat	Probability	Jaq. bera	Probability
OPEC Member Countries						
Algeria	0.42	0.74	0.69	0.70	8.29	0.01
Ecuador	0.66	0.59	0.36	0.93	3.25	0.19
Iran	2.05	0.17	2.13	0.10	0.18	0.94
Kuwait	1.07	0.37	2.47	0.06	3.05	0.21
Libya	2.47	0.07	0.76	0.59	1.57	0.48
Nigeria	0.56	0.51	1.52	0.26	1.30	0.52
Qatar	1.07	0.41	0.67	0.71	0.99	0.63
Saudi Arabia	0.63	0.60	1.33	0.28	1.21	0.57
UAE	1.47	0.25	0.95	0.45	1.45	0.37
Venezuela	0.57	0.57	0.92	0.53	4.14	0.12
Other Oil Exporting Countries						
Argentina	0.20	0.81	1.87	0.23	2.51	0.35
Colombia	1.03	0.39	1.02	0.47	1.13	0.56
Egypt	0.87	0.44	1.20	0.37	3.15	0.22
Indonesia	1.37	0.32	2.57	0.05	1.58	0.48
Malaysia	0.95	0.44	1.23	0.36	2.13	0.37
Mexico	1.22	0.35	0.62	0.76	1.76	0.39
Oman	0.41	0.69	1.04	0.46	1.01	0.68
Syria	1.09	0.37	0.95	0.40	1.25	0.50
Trinidad	1.36	0.31	1.06	0.45	1.58	0.56

Table A4.13

Diagnostic Test

Country	Serial Correlation		Heteroscadasticity		Normality	
	F-Stat	Probability	F-Stat	Probability	Jaq. bera	Probability
Net Oil Importing Countries						
Brazil	1.31	0.29	0.87	0.51	1.92	0.41
China	1.72	0.22	1.10	0.23	0.26	0.87
India	0.99	0.40	0.70	0.69	0.61	0.73
Peru	0.56	0.58	0.83	0.59	2.07	0.44
Romenia	1.42	0.27	0.91	0.54	1.87	0.47
Thailand	1.86	0.19	1.02	0.27	1.94	0.43

Chapter 5

5 Summary and Conclusions of the Thesis

This chapter summarises the analysis conducted in this thesis including reviewing the specific results obtained within the three key chapters. The first key chapter (Chapter 2) analyses the relationship between aggregate oil consumption, income and prices, and the estimates obtained are used to project oil demand up to 2030 based on different forecast scenarios. The second key chapter (Chapter 3) focus on the co-movements and causality relationship between oil prices and economic growth in non-OECD countries while the third key chapter (Chapter 4) evaluates the resource curse hypothesis by analysing the long-term effect of natural resource abundance on economic growth using oil production and oil reserve as proxies for natural resources. The thesis has engaged various econometric tools in addressing the research questions and the results obtained therein are used to draw a number of conclusions and policy reccommendations. The following sub-section revisits the specific research questions outlined in Chapter 1 and explains how the thesis addresses them.

5.1 The Research Questions Revisited

(RQ 1) How best can the impact of technical progress (TP) and other exogeneous factors be captured when estimating oil demand relationships?

It is often argued that increased efficiency otherwise referred to as technical progress has been one of the factors responsible for the declining growth in oil demand, particularly in the industrialised regions of the world. Following arguments in the energy economics literature on how to appropriately capture the impact of technical progress along with other exogenous factors when modelling energy demand, this study suggests that technical progress is best captured both endogenously via aymmetric price response and exogenously via a stochastic trend - as Hunt et al. (2003a and 2003b) referred to as the Underlying Energy Demand Trend (UEDT).

While many studies in the literature captured endogenous technical progress via asymmetric prices in oil demand models, a relatively fewer studies considers the exogenous effects which are mostly captured using a simple deterministic trend. As revealed by the estimated UEDTs shown in Chapter 2, a simple deterministic trend is generally not sufficient to capture the impact of exogenous technical progress and other exogenous factors.

This study therefore supports the idea that prices provide a key motivation for the development of new technology, which can be captured by asymmetric price specification, but there are other exogenous factors which have been captured by the UEDT - thus, technical progress can best be captured both endogenously and exogenously in oil demand models.

(RQ 2) What are the long-term effects of price and income on global oil demand, and what is the possible pattern of future oil consumption?

The study categorized the global economy into six geographical regions as contained in BP Statistical Review of World Energy (2011). The regions are; North America, South and Central America, Europe and Eurasia, Middle East, Africa and Asia Pacific. The structural time-series modelling technique is adopted to estimate price and income elasticities for each region and the results obtained shows that the long-run elasticities for the various regions range between 0.20 and 1.06 for the income variable and -0.02 and -0.20 for the price variable accordingly. The results reveal that oil consumption responds more to income in North America than any other region while it responds least to income in the Middle East.

Using the estimated coefficients obtained and applying the reference case scenario assumption, global oil consumption is projected to rise from 87.38 mb/d in 2010 to 110.27 mb/d in 2030. The forecast reveals that growth in oil consumption will mainly be supported by the less advanced regions - by 2030, oil consumption is projected to more than double in the Middle East (121%) and increase by more than two-thirds in Africa (72%), while oil consumption in South and Central Anerica and Asia Pacific are projected to rise by 26% and 25% respectively over the forecast period. Oil consumption in the more advanced regions of North America and Europe/Eurasia is projected to slightly grow by about 4% and 10% respectively.

According to the forecast, by 2030, Asia Pacific will over-take North America to become the region with the highest oil consumption (31%), followed by North America with 22% while Europe/Eurasia, Middle East, South/Central America and Africa will constitute 19%, 16%, 7% and 5% of global oil demand respectively. The analysis further reveals that per capita oil demand in North America peaked in 2010 while it is expected to peak in 2023 in South/Central America, 2024 in Asia Pacific and 2026 in Europe/Euroasia. Per capita oil consumption is expected to continue to grow beyond 2030 in Middle East and Africa.

(RQ 3) What is the short and long-run causality relationship between oil prices and GDP of non-OECD countries and does the impact for net oil exporting countries differ from that of net oil importing countries?

In both a time-series and a panel context, the thesis empirically investigates the co-movements and causality relationship between oil prices and GDP in 28 non-OECD countries, grouped according to whether a country is a net oil exporter or net oil importer.

After confirming that both series are integrated of the same order, it is established that a long-run cointegrating relationship exist between them in both time series and panel context. Furthermore, the time-series analysis shows oil prices Granger-causes GDP for almost all the countries analysed while the panel estimate shows oil prices Granger-causes GDP for the group of net oil exporting countries and fails to Granger-cause GDP for the net oil importing countries. The conclusion from the analysis is that oil prices have a strong influence on economic output of non-OECD countries, particularly the net oil exporting countries.

(RQ 4) Does oil abundance lead to lower economic performance in oil rich exporting countries, and what are the long-term effects of oil abundance on levels of per-capita output?

The thesis also investigates the resource curse hypothesis by applying heterogeneous panel technique using oil production and oil reserve as proxies of natural resource. Again, the panel groupings is done according to whether a country is a net oil exporter or net oil importer and mixed results are found depending on the measure of resource abundance.

After controlling for the impact of institutional quality and investment, the analysis provides evidence of resource curse for the net oil exporting countries using oil production as a proxy for resource abundance while no evidence of resource curse is found using oil reserve as a proxy for resource abundance. It is concluded that oil abundance does not lead to negative per-capita output in oil exporting countries as shown by the oil reserve measure of resource abundance.

5.2 Closing Remarks and Discussion

Looking forward to 2030, this thesis points to declining oil consumption in the industrialized regions of the world that, as the 'low' case scenario (from oil demand projections in Chapter 2) suggests might be quite far-reaching if new and improved technologies to help address the environmental challenges become economically viable. These might include a revolutionary break-through in car engine technology that moves towards the use of alternative fuels in the transportation sector or the increased production of unconventional gas. New technologies are opening up possibilities for unconventional gas to play a major role in future global energy mix; a development that EIA (2012) argued would ease concerns about the reliability and security of energy supply. Considering gas is the closest substitute of oil, this development might have a direct effect on oil demand projections as cheaper gas is substituted for oil.

The impact of higher oil prices on the oil importing countries of the non-OECD is minimal despite the rise in oil consumption from those countries. The reasons, varying in importance and country include greater energy efficiency, improved monetary and fiscal policies and deeper financial markets. As highlighted by Arbatli and Vasishtha (2012), emerging economies now have better instruments for responding to commodity shocks as their economies relies more on import of primary commodities. The oil exporting countries can also reduce the negative effect that over-reliance on oil revenue can have on their economies with better fiscal and monetory policies geared towards improved savings, particularly in periods of high oil prices, making the right investment that will support development of the real sector and also having a well-developed financial market. These measures will help diversify their economies and minimise the effect of oil price collapse.

The major oil exporting countries needs to adopt a more logical approach to macro-economic policy formulation and implementation. As indicated in Chapter 4, oil price/revenue volatility is among the major contributory factors to poor economic performance in these countries and, as pointed out by Iwayemi and Fawowe (2011), the negative effect of volatility is often aggravated by a rising interest rate which lowers productive investment and ultimately negatively affects output. Macro-economic policies therefore should be better coordinated towards minimising the negative effect of oil price volatility while encouraging productive investment.

Revenue management institutions could play a very important role in managing volatility and providing long-term investable funds. This can be achieved through the establishment of a Sovereign Wealth Fund (SWF) which can manage the immediate impact of oil price volatility and save revenue for investment and use by future generations. Fortunately, most of the major oil exporting countries have established the SWF, holding various degrees of financial assets. This is a step in the right direction and should be sustained.

According to information obtained from the Sovereign Wealth Fund Institute (2013), countries such as Venezuela and Nigeria are lagging behind other OPEC member countries in terms of their asset holdings. While Algeria, Libya, Qatar, Kuwait, UAE and Saudi Arabia have an asset base of more than $65 billion in their SWF,[98] Nigeria and Venezuela only have $1 billion and $800 million respectively. Angola has around $5 billion while Ecuador is not listed among countries with SWF reserve. As explained a little earlier, the SWF remains one of the most effective means of long-term diversification and also control the effect of volatility. Therefore, the non-MENA countries of OPEC (despite their huge infrastructural requirement and large population) needs to do more to build-up their asset base, particularly now that for the past three years, the annual average price of a barrel of oil has been above $100. Officials in charge of policy formulation in these countries should allow for revenue above a particular benchmark of oil price be channeled to the SWF reserve. To sight an example of how this can be achieved; assuming the price of oil continues to move along the same path (at around $100/barrel), countries such as Nigeria and Venezuela that produces more than 2 million barrels of crude oil per day can easily save $1.8 billion every year if they channel $25/bbl on half of their daily production to the SWF reserve.[99] This is

[98] Infact UAE and Saudi Arabia have an asset base of more than $500 billion

[99] Most of oil exporting countries engage in joint operating agreement with multinational oil companies and the parties involved lift the crude oil produced according to their equity share. The 'half the daily production' sighted in the text is a very conservative estimate as

based on a crude oil price benchmark of $75 in their annual budget estimates and any revenue above the benchmark would be channeled to the SWF. This will go a long way in making funds available for long-term investment while controlling for the adverse effect of volatility.

OPEC, as an institution, can also play a major role in minimizing the impact of oil price volatility on the oil exporting countries. The only instrument OPEC has ever used is fixing of 'OPEC quotas' which is alloting a certain volume of production to each member state. Even though OPEC has recorded relative success over the past decade in terms of price stability, clearly more needs to be done as the market does not react as OPEC would like, as there are always doubts whether such quotas would be respected. In fact, it has been argued[100] that Saudi Arabia's excess capacity is what keeps OPEC afloat all these years and by using its excess capacity, Saudi Arabia has played the role of discipliner who, from time to time, punishes members exceeding their quotas. One of the major pillars of Saudi Arabia's oil policy is to maintain a back-up capacity in order to enhance the stability of the world oil market. This, Saudi needs to do more effectively by positioning her leadership as a price maker in the international oil market towards relative price stability over the short and mid-term period which, to a large extent, would foster growth and development for the oil exporting countries in particular and the global economy at large.

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most of the countries end up with around 65% of overall production.

[100] See Fattouh (2007)

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