

Oil Prices, the Macroeconomy and Financial Markets

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Griffith Business School

Submitted in fulfilment of the requirements of the degree of

Doctor of Philosophy

by

Mohammad Ali Sotoudeh Mollashahi

June 2015

Oil Prices, the Macroeconomy and Financial Markets

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A thesis submitted in fulfilment of the requirements of the degree of

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“We economists don't know much, but we do know how to create a shortage. If you want to create a shortage of tomatoes, for example, just pass a law that retailers can't sell tomatoes for more than two cents per pound. Instantly you'll have a tomato shortage. It's the same with oil or gas.”

– Milton Friedman

Statement of Originality

This work has not previously been submitted for a degree or diploma in any university. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made in the thesis itself.

Mohammad Ali Sotoudeh Mollashahi

June 2015

Publications

This thesis primarily comprises a series of five published papers, co-authored with my principal supervisor. My contribution to each co-authored paper involves the initial concept and empirical design, the collection and analysis of data, and the preparation and submission of manuscripts.

Chapter 4:

Sotoudeh, M.A. and Worthington, A.C. 2015. Macroeconomy and financial market effects of oil price changes: A comparison of large net oil-producer and oil-consumer countries. *Journal of Economic Papers*, 34(1-2), 11–22. doi: 10.1111/1759-3441.12088

Chapter 5:

Sotoudeh, M.A. and Worthington, A.C. 2015. Long-term effects of global oil price changes on the macroeconomy and financial markets: A comparative panel co-integration approach. *Applied Economics Letters*, 22(12), 960–966. doi: 10.1080/13504851.2014.990617

Chapter 6:

Sotoudeh, M.A. and Worthington, A.C. 2015. A comparative analysis of monetary responses to global oil price changes: Net oil producing vs. net oil consuming countries. *International Economics and Economic Policy* (forthcoming). doi: 10.1007/s10368-015-0315-1

Sotoudeh, M.A. and Worthington, A.C. 2015. Nonlinear effects of global oil price changes on consumer cost of living: A comparative study of net oil consuming and net oil producing countries. *Review of Economic Analysis* (under editorial review)

Chapter 7:

Sotoudeh, M.A. and Worthington, A.C. 2015. Nonlinear interest rate effects of global oil price changes: Comparison of net oil consuming and net oil producing countries. *Applied Economics Letters*, 22(9), 693–699. doi: 10.1080/13504851.2014.969821

Other Relevant Outputs

In addition to the published works that formed the primary chapters of this thesis, a number of other co-authored contributions are also relevant to the thesis topics as follows:

Sotoudeh, M.A. and Worthington, A.C. *Estimating the effects of global oil market shocks on Australia's Merchandise trade*. Paper presented at the Australian Conference of Economists (ACE), July 2015, Brisbane, Australia.

Sotoudeh, M.A. and Worthington, A.C. *Oil price, macroeconomics and financial markets: some panel linear causality comparisons*. Paper presented at the Econometric Society Australasian Meeting/Australian Conference of Economists (ESAM/ACE), July 2014, Hobart, Australia.

Abstract

A large body of research suggests that oil price shocks have significant impacts on economies, with diverse consequences depending on the relative production and use and consequently exports and imports. In the main, the expectation is that an oil price increase is positive for oil-exporter countries but negative for oil-importer countries. In fact, some early studies revealed that oil price increases preceded all recessions other than in the 1960s. However, by the mid-1980s, possibly because of the diminishing role of oil in real economic activity, these models began to lose their explanatory power, such that there has been considerable less effort directed at alternative modelling approaches to this fundamental relationship, not least outside the US.

The main question posed in this thesis concerns the nature of the causal relationships between oil prices, the macroeconomy and financial markets and whether they vary between oil importers or exporters. To respond, we first identified a representative sample of large net oil-producer and oil-consumer economies, the former comprising Canada, Norway and Mexico and the later including Brazil, Denmark, Germany, Italy, the Netherlands, Sweden, and the US. We then specified a set of key macroeconomic and financial market variables including the consumer price index, the real exchange rate, monetary aggregates, industrial production, short-term real interest rates and share prices. Our monthly data covers the period 1986M5–2013M1. Finally, to consider the linear and non-linear macroeconomic and financial market responses to oil price movements, we employed a variety of time-series and panel data models including unit root tests, bias-corrected least squares dummy variables model, Westerlund panel co-integration test, linear causality tests, and parametric and non-parametric nonlinear tests.

The results indicate that in the short-term, the macroeconomic and financial market variables of both net oil-consumer and net oil-producer countries respond to global oil price fluctuations very similarly. Furthermore, the macroeconomies of net oil-producer countries are more dependent to oil price movements than do those of net oil-consumers. Conversely, global oil price movements exert stronger effects on the financial markets of net oil-consumer countries. The results specifically imply that in the short-term, monetary aggregate responds directly to the oil price fluctuations. Such responses are country-specific and asymmetrically nonlinear across the panels. Moreover, the short-term linkages between real interest rate and oil price are linear across net oil-consumer countries and asymmetrically nonlinear among net oil-producer

countries. Finally, oil price influences share prices within both panels of sample countries linearly.

In the long term, the macroeconomy of net oil-consumer countries cointegrates with oil price fluctuations where the financial markets of both subsamples exhibit long-term cointegrating relationships with oil prices. In particular, the consumer price index responds mostly linearly in net oil-consumer countries while in net oil-producer countries, such responses are nonlinear. It takes three and a half years on average for the consumer price index to adjust to an oil price shock. Short-term real interest rate also exhibits long-term co-integrating relationship with oil price. A shock in the real interest rate driven by an oil price shock adjusts in less than a year on average. Finally, the oil price affects share prices significantly in the long-term within both subsamples. On average, more than 80 percent of share price responses to oil price shocks are comparable between net oil-consumer and producer countries.

This thesis is the first to compare both country-specific and panel responses of key variables between large net oil-consumer and net oil-producer countries. Our broad sample of countries utilizes the highest frequency available data. However, we face several limitations primarily relating to data availability. First, the lack of proper data restricts us to from broadening the sample further. This restriction also reduces the number of potential macroeconomic and financial market variables. Finally, the nonlinear models do not generally supply any guidance about the source of nonlinearity and hence, this is left to theory.

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Chapter 1. Introduction

1.1. Thesis background

A large body of research suggests that oil price shocks have a significant impact on economies, with diverse consequences in oil-producer and oil-consumer countries. In the main, an oil price increase is good in oil-exporter countries but bad in oil-importers. The background of studies related to oil price effects on economy dates back to 1973's oil price shock, which influenced the global economy very significantly. The first empirical studies evaluated linear negative relationship between oil price and real economic activity in major oil-importer countries such as the US. Subsequently, some other studies expanded their scope to Japan, Germany, UK, Canada, France, Italy, Netherlands and the rest of the world.

The 1973 oil shock, however, was not a “clean experiment”, firstly due to the Bretton Woods agreement which led the countries emerging from international monetary arrangements and secondly, because the policy of price control within the US. Some early studies revealed that oil price increase had preceded all recessions other than in the 1960s in the US. This finding motivated other researchers to focus on the post-World War II period, with similar findings subsequently confirmed in other countries such as the UK and Japan.

By the mid-1980s, possibly because of the diminishing role of oil in real economic activity, linear models began to lose their explanatory power; researchers proposed a nonlinear negative relationship between oil price changes and real GDP. This type of modelling set the asymmetric responses to global oil price changes as an arguable subject. The leading studies revealed that despite the significant effects of positive oil price changes on real GDP, oil price reductions do not exert any significant impact on the US GDP, similarly for Norway and the G7 countries. These findings demonstrated a new empirical approach toward studying the oil price–GDP relationship in the mid-1980s.

During the 1990s, many researchers studied the effects of oil price shocks on the macroeconomy, however, there was a few researches on monetary systems and their relation with oil price shocks (see for example, Hoover and Perez, 1994; Kean and Prasad, 1996; Bernanke *et al.*, 1997; Hooker, 1999, Bernanke and Ilian, 1998). By 1996,

studying the asymmetric effects of oil price shocks and the role of business cycles was highly appreciated by researchers. The empirical and theoretical contributions demonstrated different mechanisms to test the asymmetric effects of oil price shocks. Among all, nonlinear methods in studying such asymmetric effects were highly progressed. These methods are generally referred to as scaled specification and net specification. Where older linear models used to investigate shifts in productive capacity due to resources' contractions and expansions and shifts in aggregate demand due to inflationary effects of oil price shocks, the nonlinear methods could run differently.

Some studies revealed that price shocks in energy sources, which account for 3 percent of GDP, cause a reduction in GDP in the US and some other industrialized countries (see for example, Tobin *et al.*, 1980). Subsequently, numerous studies focused on testing the dependency of the post-oil shock recessions to oil price shocks or monetary responses to their inflationary effects. To clarify the recessionary aspects of oil price shocks, researchers specified several econometric models. Nonetheless, despite the meaningful statistical contribution of these studies, the long-term relationship between oil price shocks and macroeconomic indicators left non-answered.

Studying the economic effects of oil price fluctuations entered the disaggregate level by 2000 (see for example, Davis and Haltiwanger (2001); Edelstein and Kilian (2009); Edelstein and Kilian (2007); Lee and Ni, 2002; Jimenez-Rodriguez (2008) and Jimenez-Rodriguez (2011). Research findings showed that oil price shocks influenced the US industries negatively, reduced the production of oil-intensive industries and decreased the demand for other manufacturing outputs. More specifically, evidences demonstrated that the responses of industrial output are homogenous in Italy, UK, and the US and heterogeneous in France, Germany, and Spain. Investigating additional disaggregate aspects of oil price shocks are still on demand. Yet, there are too many questions in this area left to be answered by researchers.

1.2. Thesis objectives

Although the current literature theoretically explains how oil prices affect macroeconomies and financial markets, they cannot fully support empirical findings due to their partially unrealistic assumptions. On the other hand, in spite of the huge relevant empirical research body, there is no clear achievement comparing macroeconomic and financial market responses to oil price fluctuations between net oil-consumer and

producer countries. Furthermore, the current research body does not broadly cover proper countries, enough variables or extended time lengths. Thus, the reported outcomes are not thoroughly reliable.

This thesis aims to compare the following approaches between large net oil-consumer and producer countries: first, determine key macroeconomic and financial market variables, which are linearly affected by global oil price fluctuations. Second, consider the long-term linear relationship between global oil price fluctuations and macroeconomic and financial market variables. Third, determine those macroeconomic and financial market variables that reject the hypothesis of linear short-term and long-term relationship with global oil price changes. Finally, conduct nonlinear causality test on the variables determined above.

The lack of enough relevant research motivates us to answer the following questions: is there any significant linear causality running from global oil price fluctuations to macroeconomy and financial market of net oil-consumer and producer countries? If so, how dependent are the macroeconomic and financial market variables to global oil price fluctuations? Is there any long-term co-movement between macroeconomy, financial markets and global oil price shocks? If so, how similar are such responses between mentioned groups of countries? Finally, for the variables rejecting the linear hypothesis, is there any nonlinear causation running from global oil price changes? If so, are such responses symmetric in terms of direction of responses to positive and negative oil price movements?

To do so, we need to pursue these requirements: selecting the widest groups of net oil-consumer and producer countries, collecting proper data set which covers macroeconomic and financial markets key variables, and finally, employing suitable econometric approaches. Altogether, we pursue the following research hypotheses in this thesis. H1: global oil price fluctuations Granger-cause of macroeconomic and financial markets variations within both net oil-consumer and producer countries. H2: there is long-term equilibrium between global oil price, macroeconomics and financial markets of net oil-consumer and producer countries. H3: a shock in financial markets driven by an oil price shock is adjusted quicker than that in macroeconomy.

1.3. Thesis structure

The remainder of this thesis comprises eight chapters. Chapter 2. *Overview of the Oil Industry* delivers general information about the background of crude oil and its history.

We briefly consider the oil industry, which covers all of oil production, refining, marketing, and transportation. Most of the chapter is devoted to oil market analysis, including oil supply and demand, and more importantly, oil price chronology.

In Chapter 3. *Literature Review* we examine the literature on empirical and theoretical aspects of oil price changes and their trade-off with economy. This task is done through detailed classification conducted on the current literature to highlight direction and magnitude of economic responses to global oil price fluctuations.

Chapter 4. *Causal Effects of Global Oil Price Fluctuations* consists of a refereed journal paper, which begins the first part of our research discussion. In this chapter, we study the existence of any significant relationship between global oil price changes and macroeconomic and financial market variables. As already mentioned, we aim to compare the results between sample net oil-consumer and producer countries. Consequently, we conduct panel Granger causality tests as well as substitutionary oil price elasticities to separate dependent variables to global oil prices from other sample variables.

To continue the estimations conducted in Chapter 4, we run long-term panel co-integration tests in Chapter 5. *Long-term Effects of Global Oil Price Fluctuations*. This chapter, which includes a refereed journal article, delivers detailed information about the variables, which are in long-term co-integrated relationship with global oil price shocks. Moreover, further econometric tests are applied to investigate adjustment procedure within studied variables against global oil price shocks.

The results obtained from Chapters 4 and 5 deliver linearly dependent variables to global oil price changes, either in short-term or long-term. Due to unclear responses of some macroeconomic and financial market variables, we start our further analysis on such variables in Chapter 6. *Nonlinear Macroeconomic of Global Oil Price Fluctuations* by estimating their nonlinear relationships with global oil price fluctuations. This chapter includes two refereed journal papers and finalizes our findings of the macroeconomic part of study.

In Chapter 7. *Nonlinear Financial Market Effects of Global Oil Price Fluctuations* we continue our nonlinear estimations, however, on specified financial market variables. This chapter, which includes another refereed journal article, studies the nonlinear responses of short-term real interest rate, which partially rejected the linear relationship

with global oil price changes in Chapters 4 and 5. This chapter finalizes our study in financial markets part of the thesis. Finally, Chapter 8. *Conclusion* provides an overview of the thesis, the findings, contributions of the research, limitations, and directions for future research.

Chapter 2. Overview of the oil industry

2.1. Introduction

Crude oil is a strategic material, which plays vital role in our life. Just a glance over our daily life is enough to see how dependent is our modern lifestyle to oil production. Oil is being utilised in variety ways from a source of energy to kinds of materials. Thus, changes in oil market variables seem to influence our life considerably. Oil price index is a representative of oil market variables. That is, variations in such variables form oil price behaviour. The bilateral effects of oil price fluctuations on domestic and international economy is studied through the oil market. Oil market is only a part of the oil industry and includes oil-exporter and oil-importer countries, which make either supply or demand of oil in the market. Consequently, oil as a commodity follows demand and supply rules and hence, its price takes effects from supply-side and demand-side parameters. In this chapter, we first review the history of crude oil since the beginning in Section 2. Then, we study the oil industry, which includes production, refining and consumption in Section 3. Section 4 presents the major global events leading oil price fluctuations through oil supply and demand analysis. Finally, concluding remarks of this chapter is presented in Section 5.

2.2. The history of crude oil

Utilising crude oil has extensive historical background, which dates back to 2000 BC, when Chinese used it for lighting and heating purposes. Accordingly, the first drilling activities to extract crude oil are also reported from China. They could successfully access to oil through 800 feet deep oil wells excavated by beets attached to bamboo poles in 347 AD (ABC Science, 2007).

Later, the updates about crude oil extraction distributed around the world and motivated nations to start oil exploration and extraction using traditional methods. Such strong motivation implies the increasing importance of crude oil for the nations. For instance, Marco Polo witnessed Persians who were mining seep oil when he was traveling through Baku (ABC Science, 2007). As expected, oil has initially been used for lighting and heating. For example, seep oil collected in the Carpathian Mountains of Poland was employed to lighting street-lamps.

During the 16th century, further developments in crude oil applications contributed to economic value. There are evidences indicating that in 1539, the first exported oil from Venezuela was employed in gout treatment for the Holy Roman Emperor Charles V. Accordingly, many cultures began to use oil in medicine and religious ceremonies.

The oil industry experienced massive progress during the 19th century due to technological growth and new inventions. Such progress was mostly evident in drilling and distillation activities. For instance, David and Joseph Rafner drilled the first saltwater well in Western Virginia in 1806. However, the salt well-produced oil was not considered as a desirable product and hence, it was widely marketed for medicinal purposes such as treatment for deafness and toothache. In 1848, the first oil using modern technologies was drilled by Russian engineers in Northeast of Baku. A year later, kerosene was distilled and replaced with whale oil in Canada, which was supposed to be a better fuel for lamps.

Crude oil drilling and distillation activities progressed significantly during 1850's. The first petroleum refinery built up in Pittsburgh began to distil crude oil and to produce carbon oil, which was marketed for lighting lamps. However, such production could not find its customers due to extra smoke and odour produced during burning. In 1854, the first oil well in Europe was drilled in Poland with 30–50 meters depth. Later, multiple distillations and cracking crude coal oil provided odourless, clean-burning kerosene for lamps, which gradually forced whale oil lamps off the market. Finally, in the late 1850's, the first oil well in North America was drilled. At the same time, the first commercial oil well in Pennsylvania was drilled. This activity produced more than three million barrels of crude oil per year for the US.

In the late 19th century, growth of global industrial production formed growing demand for crude oil. Before that, where kerosene was highly demanded, gasoline was an unwanted fraction of petroleum. For instance, in 1885, the first practical automobile powered by internal combustion changed the mentioned oil demand structure. The large scale of automobile production for a decade increased demand for gasoline considerably. Accordingly, drilling and refining activities quickly attracted the attention of international investors. In the Middle East, oil drilling began in Persia in 1901. Furthermore, the huge growth of industrialisation and developing automobile manufacturing induced gasoline to become the product leader of American Petroleum industry.

Crude oil had daily increase in value during the 20th century. The evidences indicate that beside considerable investment on developing refineries and distillations, the exploration methods of oil fields and drilling were developed dramatically. For example, in 1947, the first offshore oil was drilled in the Gulf of Mexico. A year later, the biggest oil field in the world named Ghawar Field, was discovered in Saudi Arabia. This field produced 5.7 millions of barrels per day 30 years later. By increasing the number of countries with rich oil resources, a cartel named Organisation of Petroleum Exporting Countries (OPEC) was formed in 1960. The former members of OPEC were Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela. However, the cartel grew up to 11 members later. The OPEC supposed to maintain oil market stable by putting limitations on members' oil production. Since then, crude oil has become a strategic commodity in the world and exhibited very close relationship with economic variables. Nowadays, daily events influence crude oil price, which causes afterward fluctuations in economic variables.

2.3. Crude oil industry

Oil industry, which is generally known as petroleum industry, includes a wide range of oil-relevant activities such as exploration, extraction, refining, transporting and marketing. These activities could be divided into three major sectors: upstream, midstream and downstream. The upstream oil sector includes crude oil exploration and production. Here we address this sector under crude oil production section. The midstream sector refers to the transportation, storage, and wholesale marketing of crude oil or its refined products. We consider this sector briefly in crude oil refining section. Finally, the downstream sector involves the refining process of crude oil, marketing and distributing crude oil products. This sector involves final crude oil products ready for consumption. Thus, we briefly consider this sector under crude oil consumption section. Similar to all other industries, crude oil industry possesses several externalities, which affect human life negatively. We refer to the most common externalities of crude oil industry at the last section of this part.

2.3.1. Production

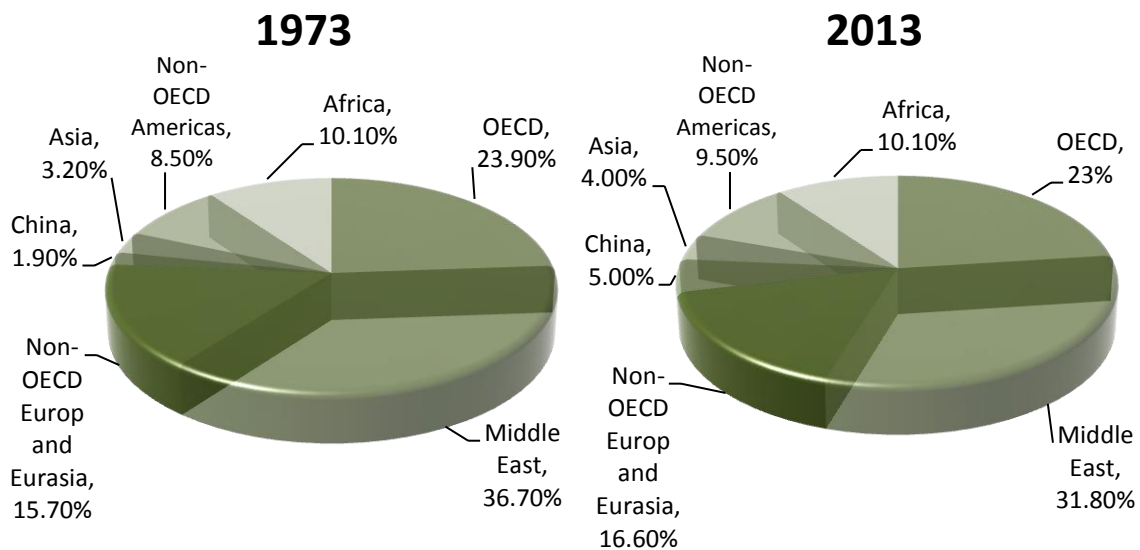
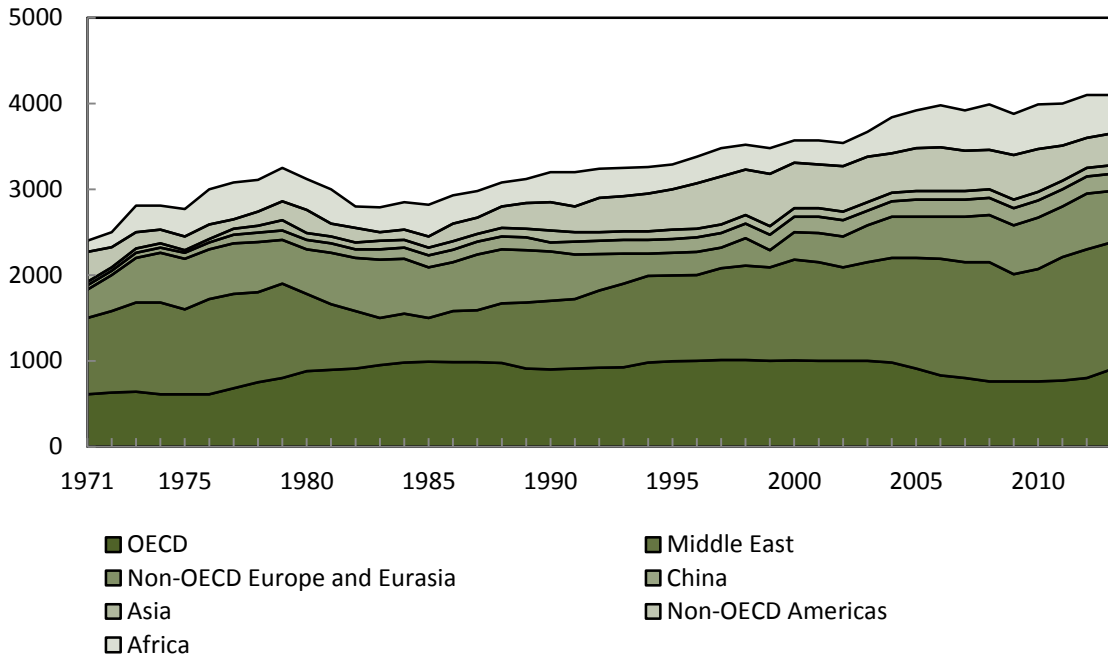
Hydrocarbons, particularly oil and gas, are the most important sources of energy in the world. There are huge hydrocarbon resources satisfying global energy needs well into the 21st century. The estimated oil resources located in unconventional reservoirs, such as heavy oil and oil shales, are much larger than what has been utilised so far. The key

point in oil production is technological development, which allows the industry to extract oil from these unconventional reservoirs. However, other factors such as developing environment-friendly operations, developing nuclear power activities, biofuels, or solar energy are expected to alter the demand and accordingly, change the volume of crude oil production.

The oil production statistics reveals that Middle East holds the first rank among all other countries in producing oil. Figure 2.1 shows that these countries have produced more than 30 per cent of global crude oil since 1970. However, oil market shocks driven by instabilities within these nations during 1980's caused considerable reduction in their production. On the other hand, although the total global oil production has increased from 2869 million tonnes in 1971 to 4117 million tonnes in 2013, OECD countries have increased their production relatively such that they have always produced nearly 23 percent of global crude oil. The third-ranked group of oil-producers are non-OECD Europe and Eurasia; they have increased global crude oil production from 15.7 percent in 1971 to 16.6 percent in 2013. The rest of the world has also increased their production from 23.7 percent in 1971 to 28.6 percent in 2013. Among this group of countries, China seems to be responsible for such contribution by increasing global oil production by 3.1 percent during 1971–2013.

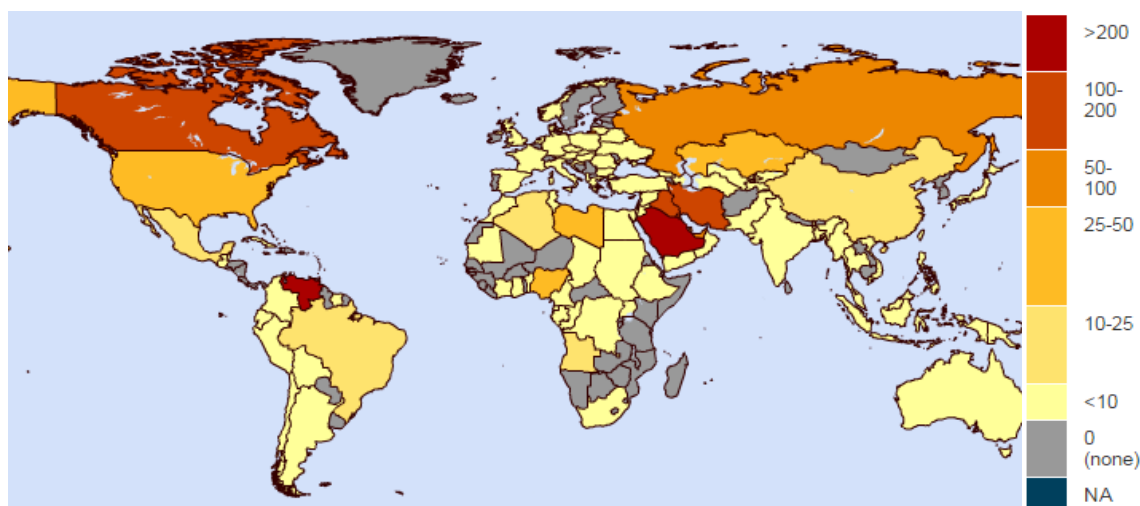
One of the parameters affecting oil industry's upstream is the ability of oil extraction; oil companies are developing these techniques or financing research and development in this area. While such technology might be updated in some countries with lower oil reserves, some major oil-producers such as Middle Eastern countries may suffer from the lack of facilities to increase future oil production. This could be more evident when we consider regional proved oil reserves. Figure 2.2 illustrates regional crude oil proved reserves reported in 2013 using the US Energy Information Administration (EIA) statistics. As the Figure illustrates, seven countries with the largest proved oil reserves contain more than 70% of the world total oil reserves. That is, Venezuela and Saudi Arabia incorporate the highest proved oil reserves equivalent to 297.6 and 267.9 billion barrels, respectively. Then, Canada, Iran, Iraq and Kuwait stand on the second place by containing 573.1 billion barrels proved oil reserves. On the other hand, 117 countries hold zero proved oil reserves and 80 countries hold less than 10 billion barrels proved oil reserves.

Figure 2.1. Crude oil production by region (Million tonnes)



Source: IEA

This also indicates that the Middle Eastern countries have sufficient reserves to produce at the current flow rates for at least the first half of the 21st century. These countries are still working on exploration and deliverability of their existing fields. Utilising new technology has led to increase the world oil reserves during the last years. Since the inception, the oil industry had produced nearly 784 billion barrels of oil by the end of 1996 (Campbell, 2000). Taking such value of 784 billion barrels by 1996 and the global oil production volume afterwards up to date based on the BP’s website, the oil industry has produced more than 1269 billion barrels of oil since the industry began in the late

Figure 2.2. Regional crude oil reserves in 2013 (Billion barrels)

Source: EIA

1800s. It is expected that the oil industry produces nearly 1 trillion barrels of oil during the first decades of 21st century.

2.3.2. Refining

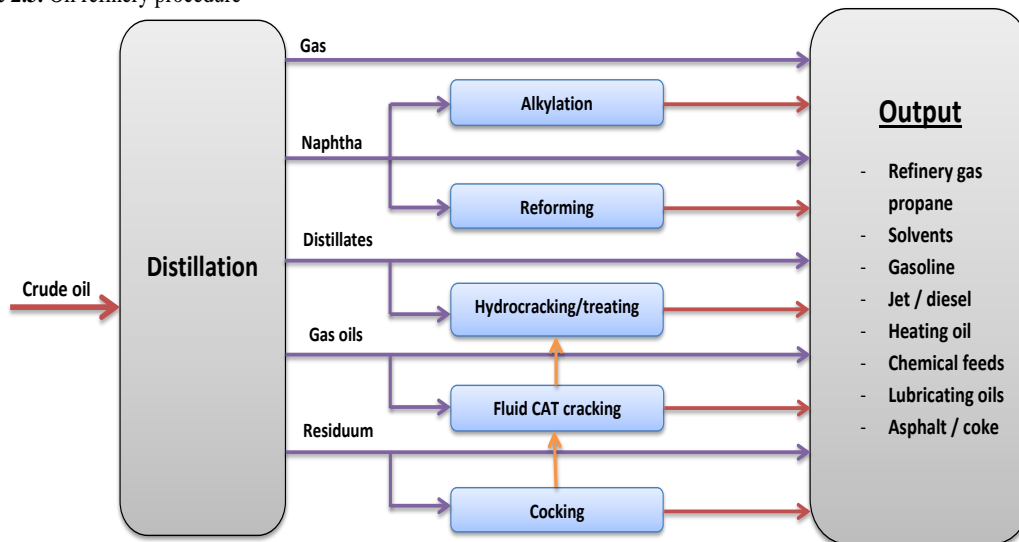
Too many aspects of our today's life is influenced by oil refinement products. Oil is consumed to power our vehicles, to create medicine and to make the plastics, cosmetics, and too many other materials. However, crude oil is not generally useful by itself; only light or sweet crude oil has already been used directly as a burner fuel for steam vessel propulsion. The value of crude oil is due to its refinement products. An oil refinery or petroleum refinery is an industrial process plant where crude oil is processed and refined into useful products such as plastics, detergents, solvents, elastomers and fibres. Thus, without refinery process, crude oil has nearly no value.

As already discussed, oil refining was formerly created in the US and spread to the Asian and South American countries. Now, crude oil is being refined all over the world and many useful materials are produced using refinement process. Currently, the largest oil refinery is Jamnagar in India with an aggregate capacity of 1.24 million barrels per day. Paraguana, the Venezuelan refinery, is the second largest refinery in the world which refines 955 thousand barrels per day. Most of the largest refineries are located in Asia and South America.

Through refinement process, each barrel of crude oil, which is equivalent to 42 gallons, will result in more than 44 gallons of petroleum products. This occurs because the density of original crude oil for some of the refined productions is reduced. The refining

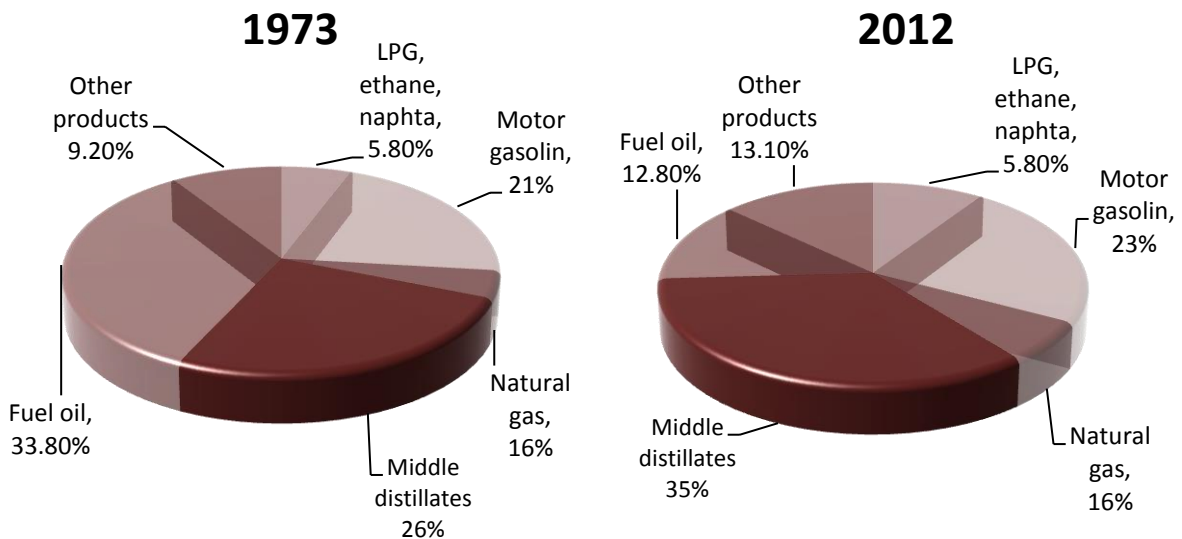
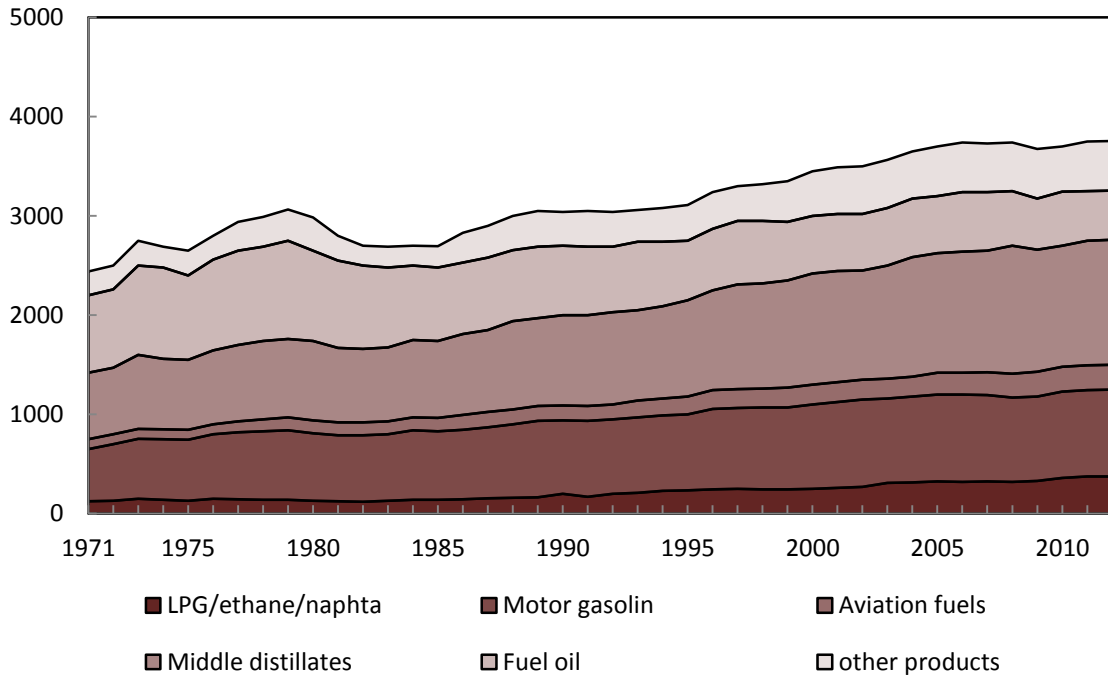
output will obviously have greater economic value than original crude oil. Figure 2.3 illustrates how oil products are divided into three categories: light distillates (e.g. LPG, gasoline and naphtha), middle distillates (e.g. kerosene, diesel) and heavy distillates and residuum (e.g. heavy fuel oil, lubricating oil, wax and asphalt) (Leffler, 1985).

Figure 2.3. Oil refinery procedure



Technological progress in utilisation of oil products has led to considerable shifts in oil refinement process during the time. For instance, one of the major refinement products of crude oil is fuel oil, which is widely used to power engines and create heat. Technologic progress in heat generation, powering engines and overall people's lifestyle has saved great volume of fuel oil since 1971. Figure 2.4 demonstrates changes in the world refinery output during 1971–2012. The Figure shows that in spite of increasing refinery products form 2719 million tonnes in 1971 to 3905 million tonnes in 2012, fuel oil production has significantly reduced from 33.8 in 1971 to 12.8 percent in 2012. This confirms significant shifts in traditional utilisation of oil products and relevant adjustments in refining processes. Finally, producing motor gasoline and aviation fuels has increased by more than 2 percent since 1971, which indicates the increasing application of oil products in transportation sector.

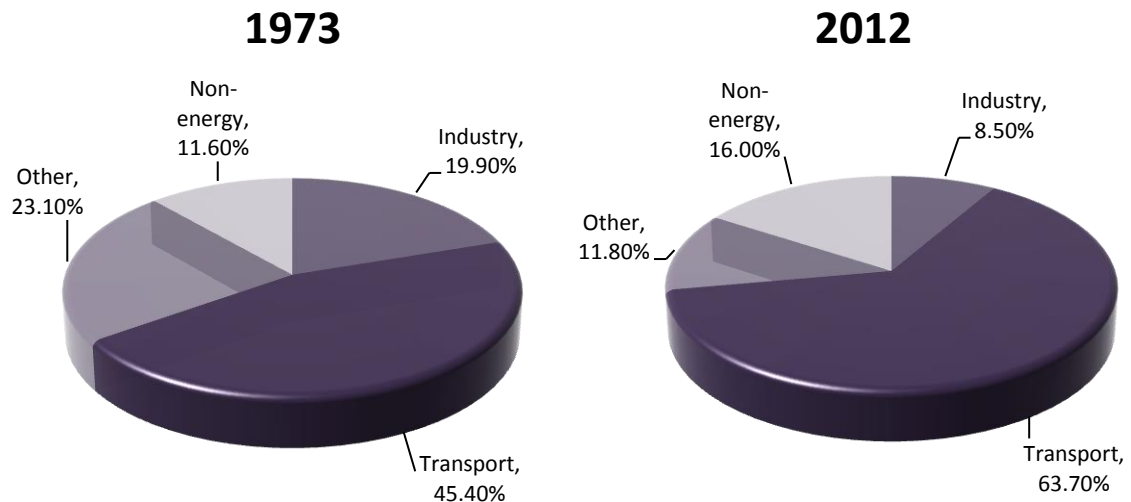
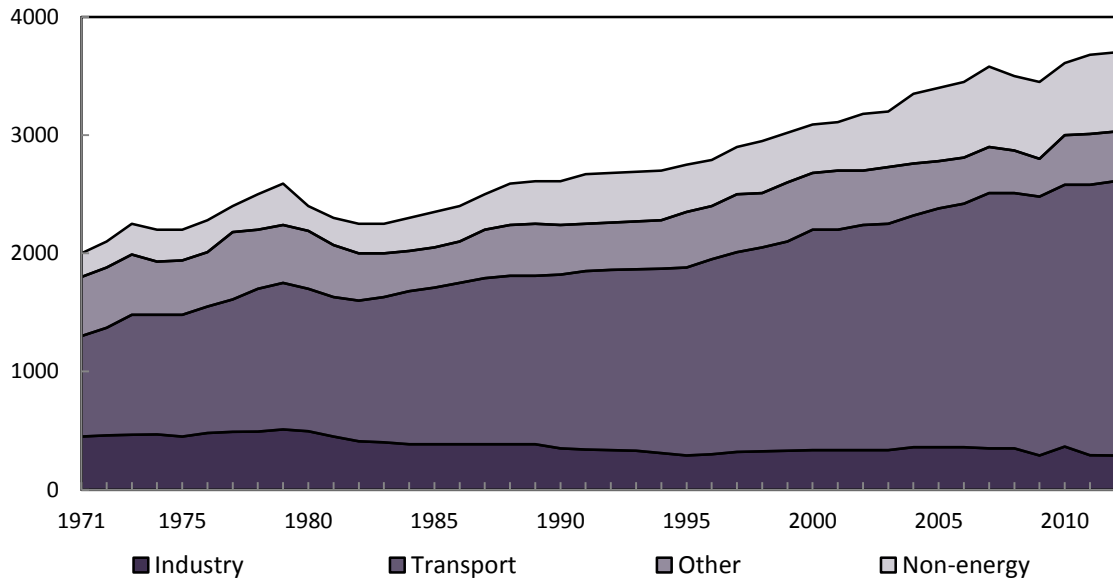
Figure 2.4. World refinery output by product (Million tonnes)



Source: IEA

2.3.3. Consumption

Crude oil consumption generally depends on the refinement products. As already mentioned, crude oil has no value by itself unless in very limited cases; it is mostly consumed in refinement operations to produce new materials. Such refinement products are widely used in agriculture, clothing and textiles, office works, sports, hobbies and games, infants and children, kitchen and household, beauty, furnishings, building and home, automotive and miscellaneous.

Figure 2.5. Total final crude oil consumption by sector (Million tonnes of oil equivalent)

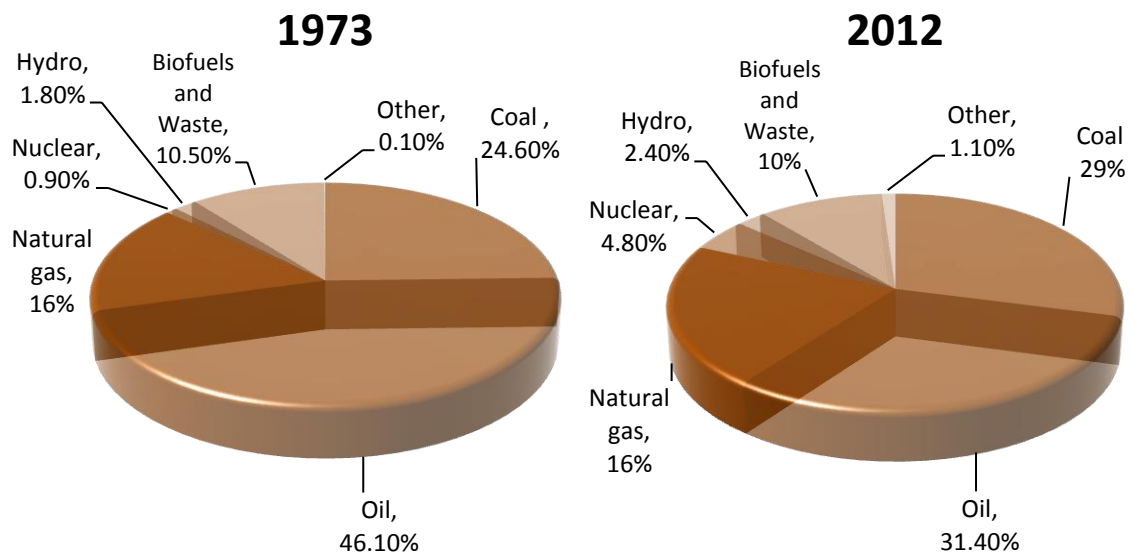
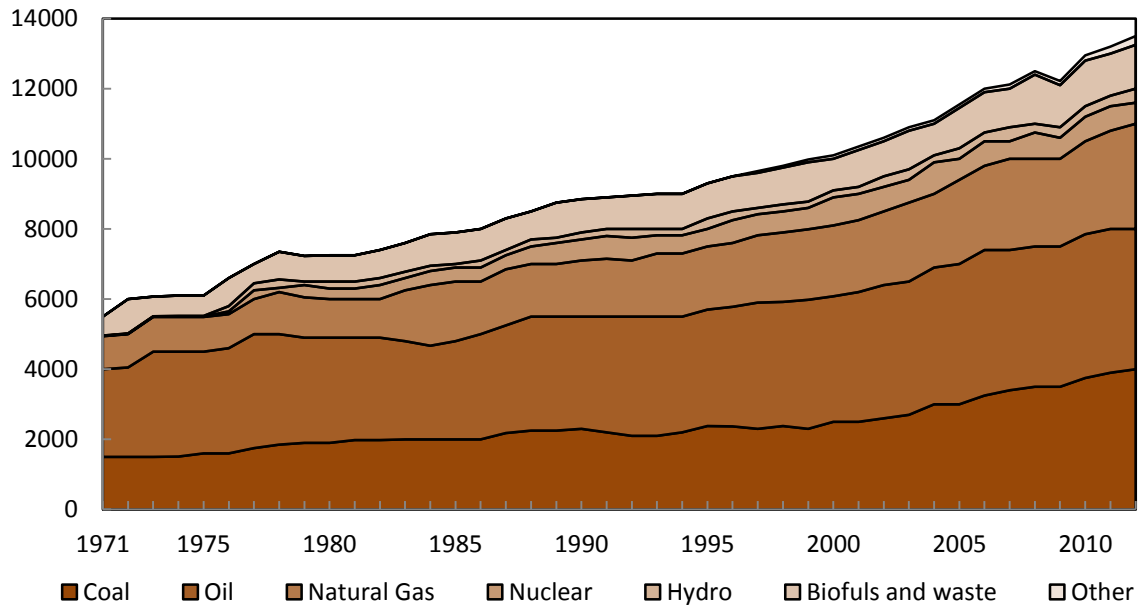
Source: IEA

Although crude oil is much valued due to its mentioned refinement products, only 16 percent of it is allocated to such materials. Figure 2.5 illustrates the final consumption of crude oil by sector during 1971–2012. The Figure clearly shows that all discussed oil-based materials located in non-energy sector, consumed 11.6 percent of crude oil in 1971. The growth in refinery technologies as well as new refinement inventions has progressed crude oil consumption with non-energy applications such that 16 percent of crude oil has been used for non-energy purposes in 2012. Thus, nearly 85 percent of oil is consumed to generate energy.

Figure 2.5 also shows that more than half of crude oil is consumed to operate transportation sector. According to EIA, transportation sector sucks up more than a quarter of delivered energy consumption globally where nearly all of this energy comes from petroleum. Figure 2.5 shows that 45.4 percent of crude oil has been consumed in transportation sector in 1971. This proportion, however, has been increased very significantly to 63.7 percent in 2012. That is, in addition to huge increase in total crude oil consumption from 2251 million tonnes of oil equivalent in 1971 to 3652 in 2012, oil consumption in transportation sector has dramatically increased by 18.3 percent. This indicates extraordinary progress in transportation sector, which is mainly considered as big investment on automobile industries.

In addition to transportation, industry is known to be the second highest oil-intensive sector. Oil is widely used in industries to generate electricity and create heat. Concerning the rapid growth of industrialization during the last decades, we expect that more energy and hence, more crude oil is consumed near the future to operate industries. However, employing new energy-saving technologies and intention to replace coal fuels with petroleum, which are cheaper and have more stable price than oil, has induced significant reduction in industrial consumption of crude oil. Figure 2.5 indicates that 19.9 percent of crude oil has been used in industrial sector in 1971 while only 8.5 percent has been consumed in industries in 2012. This modifies above-mentioned movement toward energy-saving practices in global industrial activities. Likewise, transition to modern technologies and lifestyle in some sectors such as agriculture and commerce has significantly reduced oil consumption in these sectors.

For energy generation purposes, crude oil has always been the major source. However, the statistics indicate that increase in oil consumption to generate energy has followed a decreasing rate. Figure 2.6 compares the contribution of each source of energy to global energy production during 1971–2012. The Figure shows that firstly, the total supply of energy has increased more than double during 1971–2012. Despite the significant rise in absolute consumption of crude oil in generating energy, which has increased from 281486 million tonnes of oil-equivalent to 419849, the contribution of crude oil to global energy production has decreased from 46.1 percent in 1971 to 31.4 percent in 2012. As the Figure clearly illustrates, increasing utilization of coal and natural gas in energy production could be considered as the main reason. Anyhow, the statistics indicate that to continue energy generation, absolute oil consumption needs to be increased.

Figure 2.6. World total primary energy supply by fuel (Million tonnes of oil equivalent)

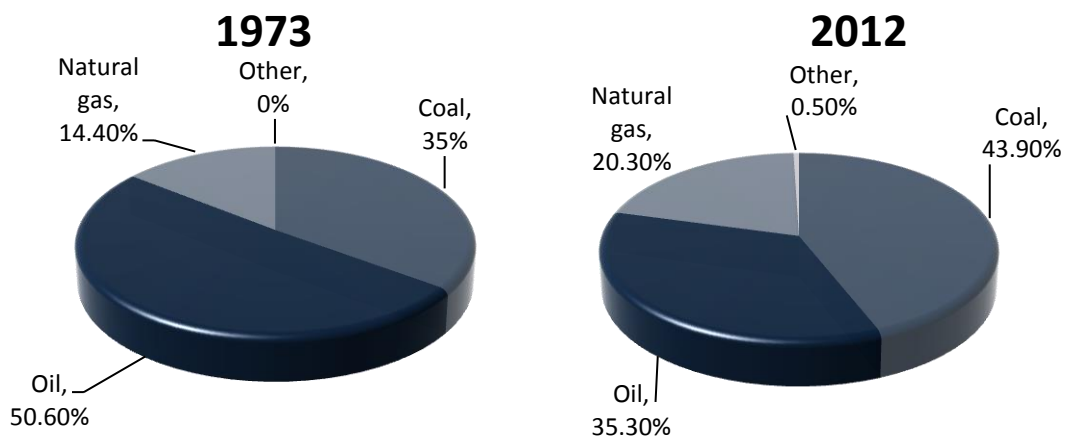
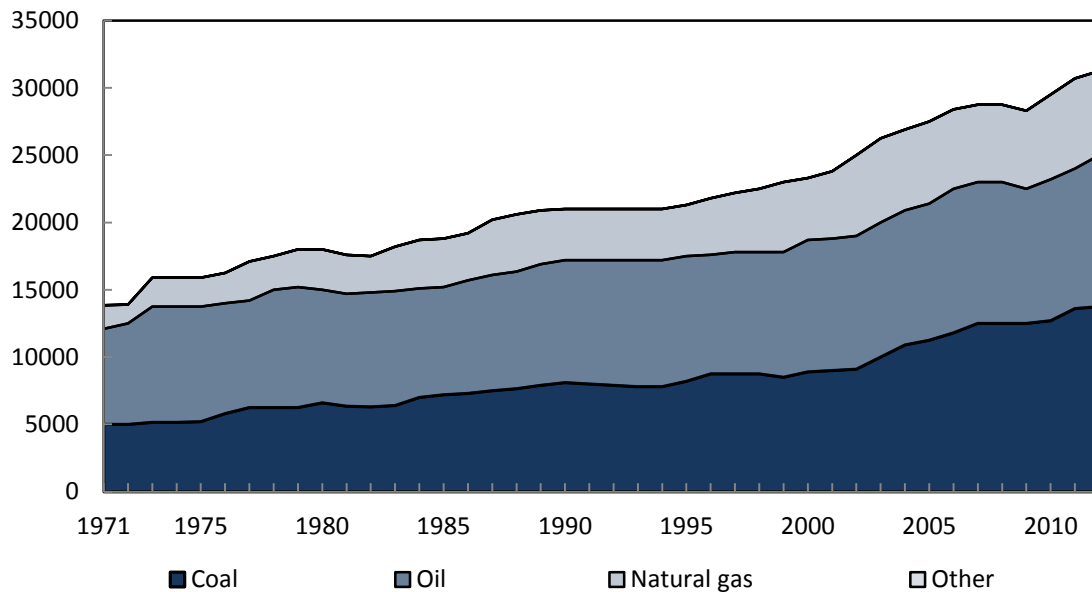
Source: IEA

Finally, restricted resources of oil fields have made serious concerns about future of oil consumption. Based on the report released by the National Petroleum Council (NPC) in the US, the total global demand for energy will grow up by 50–60 percent by 2030 due to increase in the world population and higher average standard of living in many of the developing countries.

2.3.4. Externalities

Beside the great benefits oil industry contributes, it has some negative side-effects on the environment and human life. These negative externalities are existent through within

Figure 2.7. World CO2 emission by fuel (Million tonnes)



Source: IEA

oil production, refinery and consumption processes. Generally, the refining process releases a number of different chemicals to the atmosphere, which threaten people’s health seriously. Usually, waste water, risks of industrial accidents such as fire and explosion, and industrial noise are known to be very common negative externalities. Many governments have regulated restrictions on contaminants that refineries release. Accordingly, most refineries have installed the required equipment to protect the environment effectively.

As another example, burning petroleum releases carbon dioxide, which also causes global warming phenomenon. However, oil is not the only source of carbon dioxide. Increasing intention of industries to use coal fuels instead of petroleum has caused coal to be known as the biggest source of releasing carbon dioxide. Figure 2.7 shows carbon

dioxide emissions by fuel during 1973–2012. According to the Figure, carbon dioxide released from different fuels has doubled during the mentioned period. This is the obvious result of industrialization and increasing global demand for energy. Based on the Figure, more than half of released carbon dioxide has been produced using oil products in 1973. In spite of increasing demand for crude oil and hence, releasing more carbon dioxide during recent years, it seems that crude oil has produced less carbon dioxide than before in 2012 compared with other fuels. On the other hand, carbon dioxide released by coal has considerably increased from 35 percent in 1973 to 43.9 percent in 2012 compared with other fuels.

As already mentioned, negative environmental externalities of utilizing crude oil is not restricted to carbon dioxide emission and global warming. For instance, when oil is recovered as a water-in-oil emulsion, some special chemicals needed to separate oil from water. Rather than the high cost of oil extraction using this method, it is usually damaging the surrounding marine environment. Another dangerous side effect is oil spills. That is, refined fuel spills from tanker ship accidents can damage the ecosystem seriously. Accidents in Alaska, Gulf of Mexico, Galapagos Island, France and many other places are only examples of such kind of oil spills. Oil spills at sea are generally much more damaging than those on land are; they can spread very quickly in a thin oil layer. Accordingly, they can kill sea birds, mammals, shellfish and other organisms.

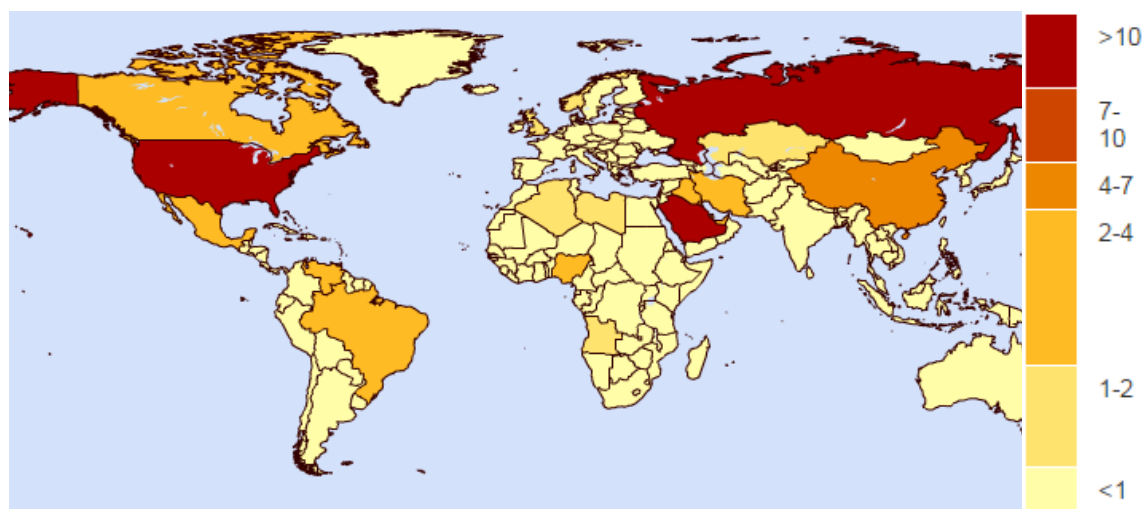
2.4. Crude oil market

Considering oil price fluctuations, one may ask that why oil price is not a constant term. That is because oil is a commodity and similar to all commodities, its price follows supply and demand rules. At the international oil market, oil-producer countries take the supply side and oil-consumer countries take the demand side. Any reason affecting oil supply or demand causes oil price to fluctuate. Where oil spot price is extracted from global oil supply and demand, investors hedge on oil price estimating future oil prices and hence, high volume of oil speculations can form new oil price trends as well. In this section, after general overview of the oil supply and demand, major oil market shocks affecting global oil prices are briefly considered.

2.4.1. Nature of supply

Oil supply is closely tied up to the factors affecting oil production. Some parameters only exert short-term effects while some others have long-term influences. For example, profit motives, spare capacity, the level of crude oil stocks and external shocks are

Figure 2.8. Global daily oil production by country in 2013 (Million barrels)



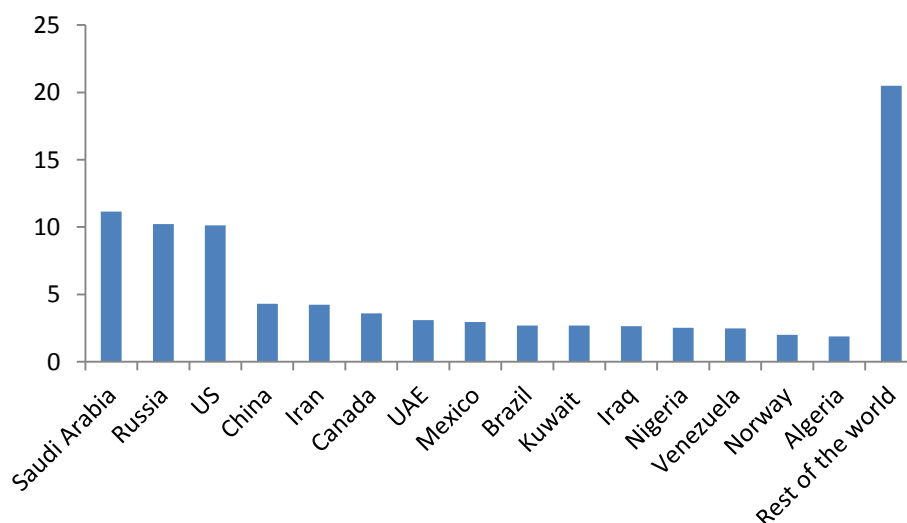
Source: EIA

common factors effective in the short-term. In the long-term, however, proven reserves, exploration investment and relevant technologic progress are mentioned.

Figure 2.8 shows the distribution of oil production around the world by country in 2013. The Figure shows that Russia, the US and Saudi Arabia make the highest contribution to global oil production. Where each country produces more than 10 million barrels per day, there are 205 countries mostly in Africa, South West of America, Europe and East Asia, which produce nothing or less than 1 million barrels per day. However, any oil-producer country may not be oil exporter. Figure 2.9 and Table 2.1 show the leading

Figure 2.9. Leading oil-producers (2011)

(millions of barrels per day)



Source: IEA

oil-producer and leading oil-exporter countries in the world in 2011. It is worth noting that the leading three oil-producer countries (e.g. Saudi Arabia, Russia and US) have produced 36.18 percent of the global produced oil altogether, while the share of the next 12 countries from the worldwide oil production is reported to be 40.22 percent; the rest of the oil-producer countries have produced 23.6 percent of the global oil. Nevertheless, 12 countries out of the 15 leading oil-producer countries are among the leading oil-exporters in 2011; the excluding countries are the US, China and Brazil.

As it can be seen, majority of the top oil exporting countries are among developing Middle Eastern and African countries, which are not usually politically stable. The oil reserves and production power of these countries used to be under control with most of the big oil-consumer countries. However, they could find their own control over their economy and oil industry gradually. One of the most important decisions made by these countries affecting global oil prices has been establishing the OPEC. This cartel has been able to affect the level of oil supply and hence, global oil price through their members' decisions. As already explained, OPEC members are mainly leading oil-exporters in the world and consequently, their decision on controlling oil supply has occasionally been effective.

Table 2.1. Leading oil-exporters (2011)

Country	Millions of barrels per day
Saudi Arabia	8.167
Russia	7.504
UAE	2.609
Kuwait	2.343
Nigeria	2.242
Iran	2.206
Iraq	1.817
Norway	1.752
Angola	1.752
Venezuela	1.490
Algeria	1.482
Qatar	1.455
Kazakhstan	1.377
Canada	1.341
Mexico	0.827

Source: IEA

In addition to general above-mentioned short-run and long-run factors affecting oil supply, there is another factor which may take the most important responsibility in explaining oil supply fluctuations; uncertainty. The current oil market involves four major interdependent areas of uncertainty, which cause oil supply fluctuations: geostrategic risks, macroeconomics fluctuations, the nature of resource risks and the uncertainty of current and future oil production capacity (Cordesman and Al-Rodhan, 2006).

It is generally believed that global energy market is complicated and hence, the analysis of it is uncertain. One of the important facts about the oil supply is that most of the world's known oil reserves exist in regions and countries that are not stable politically. Major oil exporting countries in the Middle East, Africa, South America and the Caspian Sea region have always been experiencing insecurities, which make the oil supply uncertain. This has limited the ability of policy decision makers and strategists in oil-consumer countries. Most of oil-consumer countries are interested to have control over the oil reserves while the geostrategic risks are not likely to change in near future. Many experts believe that in the near future, oil supply and the transportation routes may be challenged by transnational terrorism. Additionally, natural disasters such as hurricanes, earthquakes and tsunamis may also create further uncertainty in global oil supply by causing production, transportation and refining disruptions.

The above-mentioned factors could be added to the economic risk premium, causing oil prices to increase more than before. Higher oil prices may provide incentives for private and public investment in the oil industry. However, a lack of geopolitical stability and an inability to predict how long high oil prices will last will continue to prevent public and private sectors from investing in these areas.

Concerning the strategic risks existed in oil-producer countries, claims about production capacity and oil reserves have become a political tool. Some oil-producer countries have incorrectly alleged they have high proven oil reserves to project strategic importance. Consequently, afterward uncertainty in oil supply has led to considerable increases in oil price where there has not been enough transparency to clearly understand the probable trends in global oil supply. For instance, Iranian revolution in 1979 and the Iran-Iraq war led to a competition in the Gulf countries to announce new levels of proven reserves to demonstrate their strategic importance.

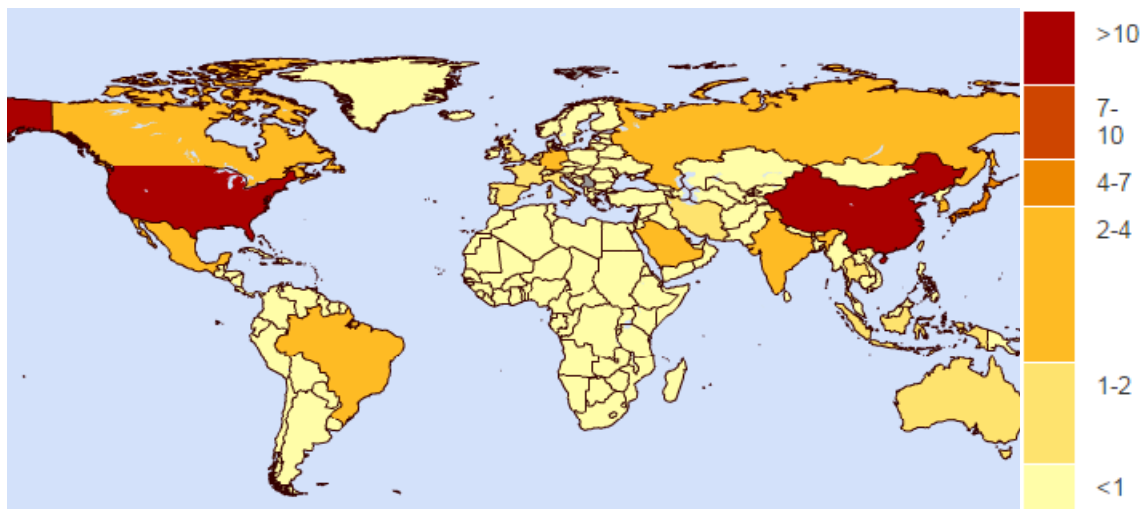
The equilibrium oil supply and oil price in the short-term depends on how much pressure demand puts on limited supply. The point is that over a longer period, only high oil prices are able to bring demand back into balance with supply. To cut oil prices quickly, only a cutback in global economic growth and demand for oil is needed while only high oil prices can stimulate rapid efforts to increase oil supply, find alternative sources of supply and encourage conservation and efficiency (Cordesman and Al-Rodhan, 2006). In the long-term, nations are seriously interested to find substitutes for

crude oil. This indicates that high oil prices are not always bad for the global economy; they could trigger market forces to offset short-term negative effects.

2.4.2. Nature of demand

The second power within oil market equilibrium is oil demand. Oil demand is affected with several factors. Some are cyclical demand, rising living standards, price of substitutes, changes in climate and market speculation. Concerning the population of countries, mentioned factors determine demand of oil in each country. Oil is also consumed in several ways. It is used to power internal combustion engines of cars, ships, aircrafts and other machines, to produce electricity and much more. Hydrocarbons existed in oil produce variety of high valued materials through modern refineries. Thus, oil is consumed either as marginal commodity or as producing derivative.

Figure 2.10. Global daily oil consumption by country in 2013 (Million barrels)



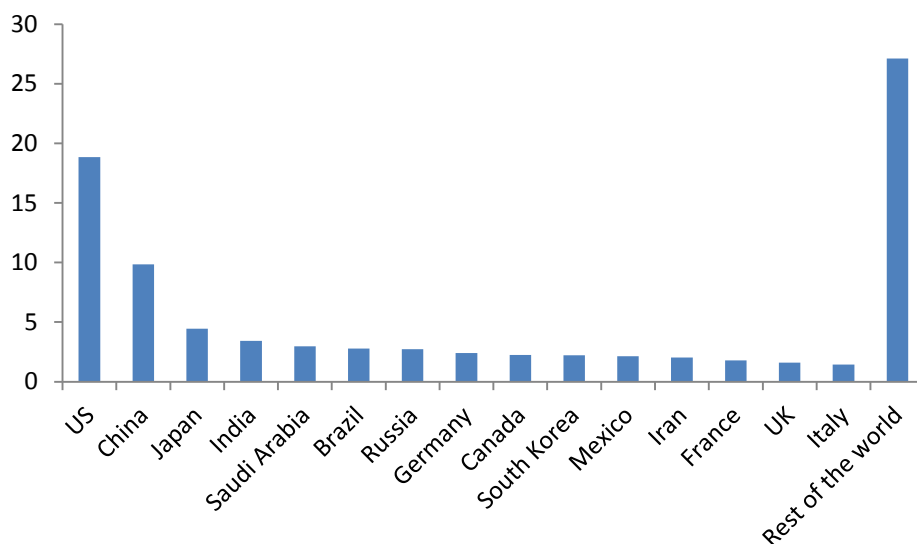
Source: EAI

Based on IEA reports, nearly two third of global crude oil is consumed by leading industrialised countries. Figure 2.10 illustrates the distribution of oil consumption in the world by country in 2013. The Figure clearly shows that the biggest oil-consumer countries in the world are the US and China. As opposed, nearly 204 countries including Africa, South America excluding Brazil, some Eastern Asian and Eastern European countries have the least oil consumption in the world, which are less than 1 million barrels per day. All other countries are placed between mentioned two groups of countries. In conjunction with Figure 2.10, Figure 2.11 and Tables 2.2 and 2.3 address the leading oil-consumer and oil importing countries in the world. The US alone consumes 23 percent of global oil while this ratio for the rest of the world excluding

other 14 top oil-consumer countries is reported to be 31 percent. Consequently, in addition to holding the third rank in global oil production, the US is also the largest oil-importer. Moreover, 5 out of the 15 leading oil-producers are also included among the leading oil-consumers. The National Petroleum Council (NPC) estimates the demand for oil will be 103–138 million barrels per day by 2030.

Figure 2.11. Leading oil-consumers (2011)

(millions of barrels per day)



Source: IEA

Table 2.2. Leading oil-consumers (2011)

Country	Barrels per capita
US	22.05
China	2.67
Japan	12.74
India	1
Saudi Arabia	37.79
Brazil	5.08
Russia	6.94
Germany	10.71
Canada	24.02
South Korea	16.35
Mexico	6.47
Iran	9.84
France	10
UK	9.29
Italy	8.91

Source: Calculated using IEA and World Bank

Any increase in oil price causes falls in oil demand. However, demand fall is not great. The reason is that the short-run demand is relatively inelastic or unresponsive with respect to price (Heal and Chichilnisky, 1991, p. 26). Nevertheless, oil demand makes considerable adjustments over a longer period. It may take several years that oil demand responds to the original oil price rise completely. Consequently, long-term oil demand is more elastic than the short-term one. This phenomenon looks very general and important. It is only enough to consider a simple example; how the demand for petrol as a fuel in motor vehicles changes in response to major increase in the real price of petrol. In the short-term, vehicle owners try to save money by driving slower and saving fuel and walking or cycling for short distances. Conversely, an increase in petrol price in the long-term causes vehicle manufacturers to switch their manufacturing lines to produce more fuel-efficient motors.

Table 2.3. Leading oil-importers (2011)

Country	Millions of barrels per day
US	8.694
China	5.551
Japan	4.329
India	2.483
Germany	2.235
South Korea	2.170
France	1.697
Spain	1.346
Italy	1.292
Netherlands	0.948
Taiwan	0.902
Singapore	0.885
Turkey	0.650
Belgium	0.634
Thailand	0.549

Source: IEA

Another important factor affecting oil demand is national income. It seems that there is no significant difference between short-term and long-term mechanisms of effects of an increase in income on demand for oil. All the consequences of an income change appear within a year or so. Variations in national income are correlated to variations in industrial activity, as well as variations in household wealth. Concerning the highest application of oil in producing energy than any other field, industrial and household changes in energy consumption directly forms demand for oil.

The use of energy in the industrial sector could be divided into two categories: overhead use and process use (Heal and Chichilnisky, 1991, p. 30). Overhead use of energy covers use in offices, factory lighting and heating, communication, research and development. Process use, on the other hand, includes the use of energy in production

process. It is expected that the level of national income significantly influence energy consumption in industrial sector and hence, change demand for oil. A similar approach applies to the private sector's use of energy. Each household has certain minimal demand for energy; heating, lighting and cooking are the simplest examples. Higher income levels will form additional demand for energy. For example, higher income leads more travel, or purchasing larger cars or more electronic equipment. All consume more energy. Thus, we would again expect a variation of demand in response to income increase.

In addition to real price of oil and national income, the substitution elasticity between oil and other factors of production, particularly capital, could affect demand of oil significantly. For instance, suppose energy and capital equipment are substitutes for each other, then an energy price increase leads to an increase in demand for capital equipment. Conversely, assume that they are complements, so that an energy price rise leads to less use of capital. The importance of substitution elasticity is that the complementary or substitutionary relationship will tell us how demand for capital equipment is likely to respond to energy price increase. Consequently, we will know the process by which the economy adjusts to changes in energy prices and hence, demand for oil.

2.4.3. Historical oil market shocks

The price of crude oil is fluctuated like price of all other commodities through demand and supply mechanisms. That is, oil price responds to changes in crude oil demand and supply. There are always some reasons affecting oil supply and demand, some immediately and some gradually.

The direct effects of a rise in the price of imported oil are shown immediately in import and consumer price indices. Indirect effects, on the other hand, come through higher prices for domestically-produced and consumed energy oil. However, changes in cost for labour and capital would add to the final responses of oil price. For a net oil importing country, the inflationary impacts of an oil price increase might be more sensible if the exchange rate devalued. This, however, improves the competitiveness, which offset the negative effects on output. In a net oil exporter country, on the other hand, the reverse exchange rate effects on inflation could be true (Matthiessen, 1982, p. 63).

Governments and central banks can also contribute to such demand deflationary and cost-inflationary responses of oil prices in both oil importing and oil exporting countries. A government of an oil importing country may decrease the inflationary effects of oil price increase by reducing indirect taxes or influencing wage settlements. This may adjust the demand reduction and adverse employment effects through increasing subsidies and other transfers, or by increasing government expenditure elsewhere. In addition, monetary policy could be used to exert upward pressure on real interest rates. Furthermore, real exchange rate could be adjusted to recover competitive position of a country. On the other hand, the oil exporting countries might adjust their aggregate production or government spending using oil revenues. All mentioned examples as well as other possible policy responses are important in assessing the overall macroeconomic impact of oil price increase. In this section, we briefly study the behaviour of oil price in face of major events during the time.

Before 1970

Up to 1970, the price of oil was moving on a downward trend. Figure 2.12 shows that the real price of oil has substantially decreased from 26.8 dollars per barrel in 1948 to 20.08 dollars in 1970. Several factors may explain decreasing oil price such as discoveries of large new deposits, negative real interest rates, expectations about price movements, and the role of the major oil companies as the main purchasers. In spite of high levels of oil consumption in the 1950's and 1960's, proven reserves by 1970 were twice more than that in 1960 (Heal and Chichilnisky, 1991, p. 54). This indicates a series of discoveries. Furthermore, rising supply faster than demand led to a downward pressure on prices.

Prior to 1970, the major Western oil companies took the buyer position through cartels. They began co-ordinating their crude oil purchasing strategy. Thus, the oil market became likely a buyer's market. Because the oil-producer countries had no strong control over the oil market, the oil companies were able to use their market power to control the price of crude oil. They could even force cuts in the nominal price in the selling countries several occasions.

Consequently, it seems that it is not difficult to explain why prices were falling prior to 1970. Supply was rising faster than demand, real interest rate were low or negative, expectations were of a continuing surplus and of downward pressure on prices, and the major oil companies formed an active buying cartel.

1970–73

In the early 1970's, the trend of oil price movement changed. A number of factors contributed to this change: in one hand, a sharp change in traders' perceptions of the supply-demand balance led to changes in expectations. On the other hand, the relative monopsony and monopoly powers of buyers and sellers were changed respectively. Furthermore, some transfers of control and ownership over major Middle Eastern oil reserves could affect the oil price positively. Similar to the analysis delivered in the last section, once a new trend was established, the self-reinforcing motivations can continue such price trend.

Based on annual review of world energy British Petroleum, the rate of discovery of oil reserves has been declined in the 1960's and 1970's. Over this period, despite the significant increases in global oil price, energy demand was rising considerably. Furthermore, huge exploration and development activities carried out alongside the increasing oil prices. However, it is worth noting that the major discoveries were bringing into production of previously uneconomic deposits of oil and a few new major deposits had been discovered (Heal and Chichilnisky, 1991, p. 58). During this period, oil began to be scarce and found its economic value. Thus, buyers and sellers became aware of oil scarcity and found its strategic value.

As another important factor, US economy became more dependent to oil imports due to rising oil consumption and falling oil production. According to IEA, the US oil imports grew from about 1 million barrels per day in 1971 to 6 million barrels per day in 1977. The US used to be one of the world's principal oil-producers, however, its oil demand increased rapidly. Thus, a substantial new customer entered the world oil market.

In early 1970's, the balance between oil supply and demand changed. More importantly, the Middle Eastern policies changed considerably as well. That is, the region began to develop its political independence of the West and to assert further control over its own economic resources. Consequently, the oil exporting countries attempted to control their own economic resources. This might be considered as a factor, which could strengthen oil supply-demand disequilibrium.

Such tendency to have control over production and pricing decisions within the host countries in the late 1960's and early 1970's led to a cutback in production rates. The reason could be concerns of new price controllers, which were more than previous

decision makers to conserve their economy's resource base, and to assure a long-run supply of oil from their territory. Prior to this, oil companies had been producing at very high rates in order to remove as much oil as possible from the deposits under their control. Consequently, a sharp reduction in the production of some OPEC members exerted extra pressure on oil prices. This was an important start point for the oil-producer countries to realize that a coordinated pricing policy could greatly increase their control power and hence, global oil supply.

1973–80

In 1973, the oil price began to increase. Figure 2.12 shows that the real oil price experiences a steep upward journey commences from 24.39 dollars per barrel in 1973 and reaches to 104.49 dollars in 1983. This price increase had little immediate effects on demand. However, very soon it became clear that the new price levels would be sustained. This indicated that oil-pricing policies had entered a new era. Thus, several processes took into account. Firstly, new technologies on fuel efficiency in vehicles, aircrafts and industrial processes began to develop. Secondly, new arrangements set toward minimizing heating and cooling costs. At the same time, the increased relative prices of energy-intensive activities began to shift consumer demand toward alternatives with less relation to the price of energy. However, none of mentioned factors affected the oil demand before the late 1970's. The time consuming aspect of technological changes caused reductions in the energy intensity of the goods and services and hence, decrease in oil demand in industrial countries.

In supply side, the 1973 price increase induced important long-run forces; it initiated a major increase in non-OPEC oil production. The reason is that at higher oil prices, the motivation of oil exploration and development were greatly increased and led to dramatic rise in exploration activities. At the same time, some known oil deposits with too high extraction costs became quite attractive such that new deposits discovered and brought to production.

Finally, the demand for OPEC oil fell substantially at the end of this decade; total demand declined and non-OPEC production increased. At this situation, as we already discussed, because the demand for oil is very price inelastic in the short-term, OPEC decided to reduce its total output to match the lower demand (Heal and Chichilnisky, 1991, p. 62). Thus, oil supply became ready to decrease at the end of this period.

1980–90

This period saw a significant fall in the real price of oil. According to the Figure 2.12, the real price of oil decreased from 104.49 dollars per barrel in 1983 to 40.67 dollars in 1990. In many respects, exactly the same factors as 1970's oil price climb were responsible for this event, of course acting as reverse in this period. During this period, non-OPEC supply of crude oil continued to grow. The growth was steady and set in motion by the price increase of the 1970's, which initiated major exploration and of investment activities. Many projects in these areas have lead times of the order of a decade. Thus, the consequences of the 1970's price increases for supply were going to appear in the oil market in the mid 1980's.

Likewise, on the demand side, the 1970's price increase consequences induced a long-term change in oil use patterns and demand characteristics. OPEC's share of world oil production had reduced to about one-third, having been as high as 55 percent in the early 1970's. Furthermore, OPEC share of world oil exports had decreased from 90 percent in 1973 to 60 percent in 1987. This indicated OPEC's failure to control the oil market in the mid 1980's, which had gradually been started since 1973. It was an inevitable consequence of the forces set in motion by the price increases of the 1970's.

1990–2000

Due to reduction in producing crude oil, uncertainty associated with the Iraqi invasion of Kuwait and the Gulf War, the global price of crude oil decreased in 1990. The most significant part of uncertainty was arising from proximity of the invasion to Saudi Arabia as the world's largest oil-producer. Accordingly, the Kuwait liberation operation called the Gulf War caused oil prices entering a period of steady decline (Williams, 2011). Thus, real oil price reached to its lowest level since 1973. During 1994–97, oil price turned up through both supply and demand factors. In demand side, world's crude oil consumption increased by 6.2 million barrels per day. This recovered oil prices after such significant reduction in 1994 and continued until 1997. In supply side, considerable reduction in Russian crude oil production contributed to the recovery of oil prices. During 1990–96, Russia reduced oil production by five million barrels per day.

During 1990–97, OPEC continued price control policy. However, the usual problems in maintaining production discipline among member countries as well as some mistakes in timing of quota changes caused OPEC to succeed not too much. Consequently, the prices rapidly reduced in 1997 and 1998 while Asia was suffering from economic crisis.

In December 1997, OPEC increased its quota by 10 per cent while very soon, Asia Pacific reduced consuming oil to its lowest level since 1982. These changes caused oil price to enter to a downward spiral such that in spite of OPEC cuts once in April and once in July, oil price continued reduction until the end of 1998.

The supply side controls in late 1990's has had the most important role in recovering oil prices created in 1996 by above-mentioned demand side factor. In early 1999, OPEC's policy in reducing oil production started in 1998 began its effects and hence, oil prices increased. This motivated OPEC to reduce oil production once again; it decreased oil quotas by 1.71 million barrels per day in April 1999. Overall, concerning previous reductions in oil production, OPEC decreased crude oil quotas by about 3 million barrels per day during early 1998 and middle 1999.

2000–12

Considering the factors caused oil price shocks during recent years, oil price shocks are mostly preceded by factors affecting crude oil supply. At the first decade of the 21st century, rapid progress in the world aggregate supply driven by the US and the world economic growth increased crude oil price to its level in 1981 (Williams, 2011). However, several increases in OPEC's quotas in 2000 created downward trend in oil price. Furthermore, Russia increased oil production during this time, which is mainly considered as non-OPEC increase in oil production; this contributed to such decreasing trend of oil in early 2000's. In 2001, weakness in the US economy as well as increase in non-OPEC production put further pressure on prices to move down. Consequently, OPEC entered into a series of reductions in member quotas once again by September 2001. This could be enough to recover oil prices. However, the terrorist attack in 11 September 2001 weakened the effectiveness of OPEC's policy.

The attack had negative effects on oil price such that West Texas Intermediate spot prices for the US were down 35 percent by November 2001. Given the political situation, OPEC did not cut members' quotas until January 2002. Nevertheless, it reduced its quota by 1.5 million barrels per day in 2002, which was joined by several non-OPEC producers including Russia to cut further. The effect of such reduction in oil production was moving oil prices into the \$25 range by March 2002. Oil price recovering motivated non-OPEC producers to restore their cuts, however, prices continued to rise due to significant decrease in the US inventories later in 2002. Finally,

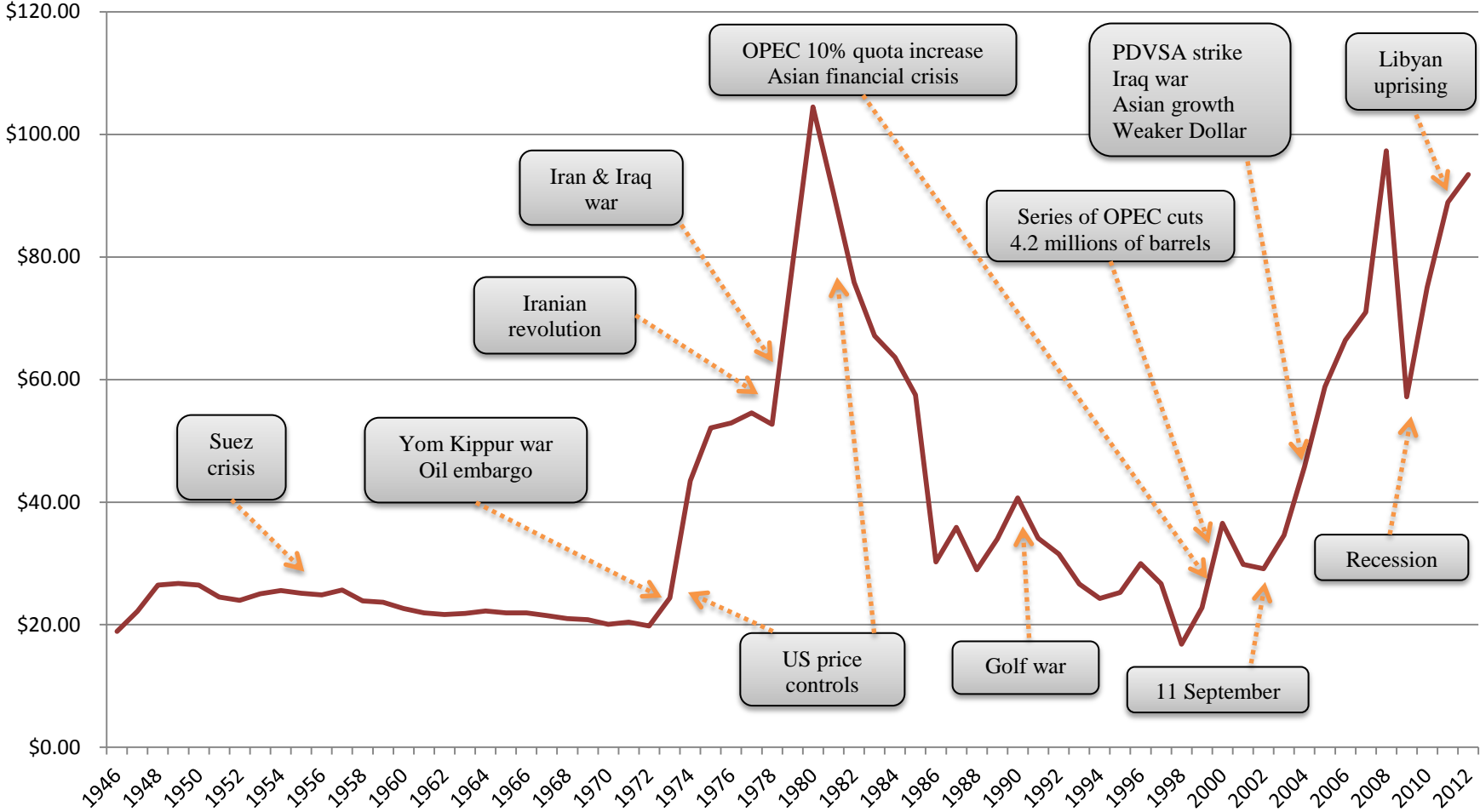
a strike at PDVSA caused Venezuelan production to plummet. This boosted increasing oil prices at the end of 2002.

While in January and February 2003, OPEC increased quotas by 2.8 million barrels per day, military action commenced in Iraq on March. Thus, oil price was influenced positively through the loss of Iraq and Venezuela once again in early 2003. In demand side, on the other hand, improvement in the US economy as well as increase in Asian demand for crude oil exerted further pressure on oil price. Consequently, beside continuing increase in oil price during 2003, excess production capacity significantly reduced from 6 million barrels per day in mid-2002 to below 2 million barrels in mid-2003. In addition to changes in crude oil production and consumption during the next years, weakening dollar as well as rapid growth in Asian economies and hence, their boosted petroleum consumption caused further increase in oil price during 2004–5.

One of the most important factors determining oil price is the level of petroleum inventories in oil-consumer countries. Inventory levels used to be an excellent tool for short-term price forecasts. It seems that the world inventory management has been one of the OPEC's policies for several years. Consequently, the primary reason behind cutting back on production in November 2006 and again in February 2007 seems to be concerns about growing OECD inventories. At the beginning of the longest US recession in 2008 since the Great Depression, global oil price was still growing up. However, spare capacity decreased to below a million barrels per day very quickly and speculation in the crude oil futures market was exceptionally strong. Consequently, due to falling petroleum demand the price fell throughout the remainder of 2008 to the below \$40.

Once again, OPEC cut members' quotas by 4.2 million barrels per day in January 2009 and hence, prices rose steadily. This was supported by increasing oil demand in Asia. Another supply side factor caused a significant jump in oil prices: In late February 2011, Libyan civil war concluded the loss of Libyan oil exports. Similar instabilities in the Middle East and North Africa contributed to such oil price increases as supply side factors such that the oil price reached to more than 93 dollars per barrel.

Figure 2.12. Oil price chronology (2011=100)



Source: Inflation data

2.5. Concluding remarks

Crude oil is considered as a strategic material, which has close linkages with global economy. Studying the oil industry during the history confirms its progressive strategic value. Where it has first been used widely for heating and lighting, it delivers extensive modern materials applicable in all aspects of human life. In this chapter, we realized that crude oil has no value by itself. In order to find some ideas about the worth of crude oil, we briefly studied oil industry, which involves several related activities being summarized to upstream, midstream and downstream sectors. The key parts of such sectors could be addressed as production, refining and consumption. Again, studying oil industry through within above framework revealed the high portion of oil-based activities in satisfying global needs. However, during the utilization process, several negative side effects might be appeared which is considered as oil industry's externality.

Due to the economic nature of this project, we concentrated our efforts on realizing general oil market behaviour and oil price chronology. Likewise all other markets, crude oil market takes effects from its global supply and demand. Oil supply is tied up to the oil production. The variables affecting oil supply, either in short-term or long-term could be summarized as below: profit motives, spare capacity, the level of crude oil stocks and external shocks, proven reserves, exploration investment, technologic progress, cartels such as OPEC and most importantly, uncertainty, which is driven geostrategic risks, macroeconomics fluctuations, the nature of resource risks and the uncertainty of current and future oil production capacity. These factors can shift oil supply and hence, global oil price moves positively or negatively.

Through within the other side of the oil market, crude oil demand indicates the nations' desire onto utilizing crude oil. Some of the demand-side parameters may affect global oil demand could be cyclical demand movements, rising living standards, price of substitutes, changes in climate, market speculation, short-term and long-term oil demand elasticity, national income and the volume of industrialization. Studying the history of oil market shows that oil-consumer cartels have occasionally had effective influences on global oil price. Anyhow, changes in one or a group of variables belonging to oil supply or demand determine final oil price. One key point in analysing oil price behaviour within supply-demand framework is that most of the global oil production activities are concentrated in regions with the lack of stability. Due to the controlling power of countries located in these regions over their oil production and hence, global oil supply, most of the oil price shocks are driven by oil supply shifts.

Finally, oil relevant policies conducted by national governments strengthen the effects of above-mentioned variables on global oil price. Studying oil price chronology since the beginning reveals that oil price has been one of the most fluctuating variables. Most of the important events driving oil price fluctuations are considered to be political instabilities. Overall, the strategic value of crude oil never disappears while it is estimated that using the current oil reservoirs will be continued for the next several decades.

Chapter 3. Literature review

3.1. Introduction

The substantial increase in oil prices during the past years and the fear of continuing oil price rises for the future and their effects on economy have always been causes for concern. The discussion of the effects of oil price shocks on Economy is not new. The oil crisis of 1970 stimulated the interests of economists in this subject. Since then, extensive studies into how oil price shocks affected the economy have focused on wide range of investigations around oil price shocks in terms of the level of effects, the origins of shocks, the type of effects and the future of price movements.

Concerning the available research literature in this area, it is clear that studies in empirical level have been more interested than theoretical divisions. However, a progressive trend in establishing global frameworks include empirical outcomes is not evident. All studies, far from the level of investigation and their theoretical or empirical phase have employed one of the following issues in their analyses; symmetry and asymmetry, linearity and nonlinearity and finally, aggregation and disaggregation. The remainder of this chapter has special consideration into the mentioned issues as well as available literature with empirical atmosphere. Consequently, three mentioned issues that have always been debatable are presented first and the available research through macro to micro classification is analysed afterward.

3.2. Main issues in relevant literature

3.2.1. *Symmetry and asymmetry*

The first issue is the symmetric or asymmetric effects of the oil price changes on particular variables. There are different interpretations of symmetry and asymmetry. Some have considered this issue as the reaction speed of target variables to the oil price increase or decrease. For instance, Balke *et al.* (1998) by focusing on relationship between petroleum product market and crude oil market, found that the price of petroleum products is raised more quickly in response to an oil price increase than the case of petroleum products price reaction to an oil price decrease. In fact, the price of petroleum products responds to the oil price movements asymmetrically. In this area, Bacon (1991), Karrenbrock (1991) and Balke *et al.* (1998) showed evidence of

asymmetric response of gasoline price. They found that gasoline price rises more quickly in response to an oil price increase than the case it falls due to reduction in oil price.

The second interpretation of asymmetric response to the oil price movements is diverse reaction. For example, in mentioned study of Balke *et al.* (1998), in spite of asymmetric return of petroleum products' price to the oil price movement when the speed of reaction was the case, petroleum products' price was symmetric when the size of reaction was the matter. Furthermore, Huntington (1998) found that other energy (natural gas, electricity, coal) prices and GDP show a symmetric feedback to the petroleum products' price movements, while crude oil prices affect petroleum products' price asymmetrically.

Finally, asymmetry is the diverse reaction of a variable to the oil price movements directionally. As one of the first instances, Mork (1989) found that the real effects of the oil price increase is different from those of decrease where the latter does not have a statistically significant impact on the US economic activity. Park and Ratti (2008) showed that oil price shocks have a symmetric effect on real stock returns in European oil-importing countries, while there was not such evidence for the US and Norway. Davis and Haltiwanger (2001) showed that aggregate responses to the oil shocks are symmetric, while disaggregate reactions were asymmetric. These results have extracted from changes in job pattern feedback to the oil price increase and decrease. Keane and Prasad (1996) believed that oil price increase causes depression in real wages for the all workers, while relative wages for the skilled workers increased. As a result, labour movement across sectors in result of changes in real wage level might lead unclear responses to the oil price movements.

Briefly, symmetry and asymmetry have several definitions and the effects of the oil price movements on economy within each definition are various. In other word, macroeconomic variables do not perform unique symmetric or asymmetric response to the oil price shock.

3.2.2. *Linearity and nonlinearity*

Applying nonlinear modelling started when linear models could not explain the influences of oil price reductions in second half of the 1980s. In fact, the declining oil prices during such period had smaller positive effects on the economic activity than

predicted by linear models. Studies such as Rodríguez and Sánchez (2005) confirmed that by the mid-1980s, the estimated linear relationship between oil price and real economic activity began to lose significance.

There are three leading empirical nonlinear models, which have widely been applied, in relevant literature. These models are the asymmetric specification (Mork *et al.*, 1994), the scaled specification (Lee *et al.*, 1995) and the net specification (Hamilton, 1996). The most important factor in applying nonlinear models was reestablishing the negative relationship between increase in the oil price and economic downturns. Firstly, Mork *et al.* (1994) documented the asymmetry in the inverse relationship between the oil price and aggregate economic activity for countries beyond the US. In particular, they found asymmetry in the case of Norway and all G7 countries but Italy. Later, Hamilton (2003) and Jimenez-Rodríguez (2004) found evidence of a nonlinear relationship between the two referred variables for the US economy. Furthermore, nonlinearity have been investigated in a different manner by Lee *et al.* (1995) and Ferderer (1996). For instance, Ferderer (1996) constructed a measure of oil price volatility and plugged it into the empirical model alongside the level of oil prices. The author added that this procedure is usually found in isolating the level and volatility channels.

Nonlinear relationship between oil price movements and economic variables is not always considered through nonlinear models. In some cases, such relationship is evaluated by nonlinear causality tests (see Baek and Brock, 1992; Ciner, 2001).

3.2.3. *Aggregation and disaggregation*

Another classification of the current literature is dividing them to the aggregate and disaggregate levels. The former includes those researches which investigated the traditional supply shocks and demand adjustments theoretically or generally regressing GDP on the oil price and several more variables empirically (Jones and Kaul, 1996). In this area, a large body of studies suggests that oil price movements have a significant effect on economic activity (Hamilton, 1983, 1996, 2003; Gisser and Goodwin (1986); Mork (1989); Hooker (1996), Burbidge and Harrison (1984); Mork *et al.* (1994); Jiménez -Rodríguez and Sánchez, 2005, 2009 and Kilian (2008a)).

Within the current literature, we find that an oil price shock is considered aggregately when it appears as a supply-side shock. Using a combined aggregate and disaggregate model, Lee and Ni (2002) argued that changes in oil price as input cost affect more-oil-

intensive industries such as petroleum refinery or chemical industries very significantly. This mechanism demonstrates supply-side channel, which is named aggregate mechanism. Furthermore, lower output growth and a higher inflation after an oil price increase have been reported in aggregate level studies.

In contrast to the aggregate level studies, disaggregate level studies are mainly focused on the effects of the oil price shocks among markets, sectors and industries. However, due to data limitation, fewer efforts have been devoted in this area. Some have examined the effects of the oil price shocks at this level (see for example, Davis and Haltiwanger, 2001; Edelstein and Kilian 2009; Edelstein and Kilian, 2007; Lee and Ni, 2002; Jimenez-Rodriguez, 2008 and Jimenez-Rodriguez, 2011). With regards to disaggregate part of Lee and Ni (2002) for instance, changes in the oil price affect consumer income in less-oil-intensive industries such as automobile. In addition, due to changes in consumer purchasing priorities, industries are obliged to shift their production. This mechanism, which demonstrated demand-side channel, is classified in disaggregate level.

3.3.Effects of oil price changes at the aggregate level

At the aggregate point of view, oil price movements affect economic variables at the macro level. In other word, oil price consequences are generally analysed within the demand–supply framework and the target variables cover the whole economy. It is generally believed that oil price movements affect economic activity negatively at the same time it influences stock market performance (Papapetrou, 2001; Hondroyiannis and Papapetrou, 2001). To investigate the subject in detail, it is seen that oil price affects some variables directly and some others indirectly. Relevant studies concerning direct and indirect mechanisms of effect are represented as below.

3.3.1. Direct mechanisms

Oil price changes may affect the aggregate economy through channels, which have been considered differently in the current literature. In a classification of such mechanisms, Jones *et al.* (2004) have divided mentioned groups to theoretical and empirical, while Barsky and Kilian (2004) with a broader view, have divided these channels to direct and indirect. Following Barsky and Kilian, we investigate available literature in macro level through direct and indirect mechanisms. Some direct mechanisms demonstrated in current literature are as follows.

Production function

The first pathway that transfers oil price changes to the economy is the production function. Investigating the current literature shows that the major work has been focused on the application of this channel. Researchers generally believe that when the oil price increases, oil usage will be reduced due to increase in cost share of oil. Thus, in a production function with several variables related to the labour, capital and oil price with steady state assumption, GDP will be decreased. The difference among studies in this field comes back to assuming steady state conditions, degree of development in each sample, oil exporting or oil importing, degree of economic openness and more. As a result, there are various issues about the size of effects on national income or economic growth.

Within valued researches in this area, it is referred to an early as well as a more recent one, which have used production function analyses broader than other studies. As the former, Rotemberg and Woodford (1996) estimated four aggregate inter-temporal general equilibrium models named “perfectly competitive product markets”, “monopolistically competitive product markets”, “a model with customer markets” and “a model with implicit collusion for the US economy”. They assumed oil price shock as an exogenous change, which affects the economy through demand-side.

In general, they believed that imperfectly competitive models such as implicit collusion in the product market provide much greater extent explanation for the effects of the oil price changes on the output and real wages than competitive product market models. For example, they showed that the competitive model predicts a very small decline in real wage following an oil price increase and predict a reduction in output following a positive innovation in the oil price, while the model with implicit collusion implies greater output decline due to an increase in markups in result of an oil price increase. They showed that output never falls by more than 0.06 percent in response to one percent increase in the oil price.

As opposed to the US related studies as a developed country, Schubert and Turnovsky (2011) demonstrated the effects of an oil shock on a small developing country, which was oil-importer. Using a one-sector neoclassical model of an open economy which imports a foreign good and oil as intermediate inputs in domestic production, they found that short-term effects of an oil shock depends on the economic internal production structure and its access to the world financial market, while the long-term

impacts are more sensitive to domestic production framework. They believed that the share of the oil to the labour in output and the elasticity of substitution in production are critical in explaining long-term effects of the oil price changes. They finally added that the Cobb-Douglas production function is much more important in investigating the short-term effects of the oil price changes as well as measuring the adjustment speed following a structural change include an oil price increase.

Mark-up

Mark-up is the amount added to the cost price of goods to cover overhead and profit. It is assumed that, output is a function of value added and the oil price. In addition, value added is assumed to be a function of labour and capital. In perfect competition condition, an increase in the oil price will never affect value added as the oil price changes do not shift demand curve. However, in imperfect competition condition, oil price increase causes lower factor demand and as a result, value added is decreased due to mark-ups. Several other factors affect the magnitude of influences as well.

As an example, using simulation models of an aggregate economy, Rotemberg and Woodford (1996), estimated the effects of the oil price shocks on GDP. They found that a 10 percent increase in the oil price reduces the output by 2.5 percent after 5–6 quarters, while the output reduction would be 0.5 percent in perfect competition. They represented that collusive capacity in economy allows producers to increase markups in a higher level than what perfect competition suggests. Consequently, the output is reduced. In addition, their impulse–response function supports empirical observations of the oil shocks effects on the output.

But, their assumption of imperfect competition as a necessity to explain the effects of the oil shocks on GDP has been rejected by Finn (2000). She represented that there is not any prevention in explaining the evidence provided by Rotemberg and Woodford (1996) through using perfect competition theory. She added that Rotemberg and Woodford (1996) do not provide a basis for the usefulness of using perfect or imperfect competition assumption. Through her model, which assumes energy as a necessity for the capital utilization, she introduced an indirect channel for the oil price effects of economic activity, which is different from traditional production function approaches. She found that the oil price increase causes economic contraction by creating an adverse technologic shock. However, the quality of energy–capital relationship determines the power and the persistency of such negative shock.

Capital–energy complementarities

If the oil intensive capital–oil relationship assumed complementary, an increase in oil price will lower real GDP through decrease in demand for capital services. It means that the value of used capital equipment decreases. Hulten *et al.* (1987) and Bohi (1991) analysed this channel. However, they could not provide enough support for this hypothesis. Keane and Prasad (1996) found that the short-term effect of oil price increase on aggregate employment is negative, while its long-term effect is positive. They argued that factor complementarities could be a major reason for mentioned difference. In addition, as explained earlier, Finn (2000) argued that energy is an essential factor for the utilization of capital. This assumption helps oil price movements to work through the capital stock and affect capital utilization in economic models.

Interest rates

Interest rate has been introduced by a number of studies as a separated transmission channel (Ferderer, 1996; Hooker, 1996c, 1999; Balke *et al.*, 2002; Andreopoulos , 2006). Using a financial accelerator model, Balke *et al.* (2002) analysed this notion in detail. They proved that in spite of other researches outcome imply the monetary policy as the sole source of asymmetry in oil shocks–GDP relationship, interest rate is the most important channel to transfer asymmetry from the oil price movements to the GDP. About the importance of real interest rate as a transmissible channel, Andreopoulos (2006) showed that the real interest rate is granger cause of unemployment, particularly during NBER expansions. Consequently, real interest rate seems to be a primary channel in transferring oil price changes to economy.

3.3.2. *Indirect mechanisms*

Sectoral factor movements

Based on sectoral shifts model of Hamilton (1988), when the oil price increases, other purchases from energy using commodities like automobiles will be decreased and factors will move between sectors afterward. If this movement is costly, the amount of value added reduces. The response of the output should be symmetric. However, this notion is still unclear specifically after collapse of OPEC prices in 1986. Cologni and Manera (2008) represented that as factor movements are not quick, unemployment and underutilization of resources appear.

Within an aggregate framework, Finn (2000) used alternative specifications through focusing on capital utilization as a function of energy. She argued that when the oil price climbs, energy and capital utilization falls through capital utilization function. Then, production and marginal product of labour reduces. As a result, due to reduction in future marginal product of capital, investment goes down. In addition, labour supply and wages are depressed and finally, output is contracted. Her results were parallel reasonably with empirical outcomes and explained the differences in sectoral input reallocations as a transmission mechanism.

The effects of the oil price shocks at industry level also depend on the industries' assortment. Davis and Haltiwanger (2001) showed that the major part of labour reallocation occurs within 3-digit industries, while Lee and Ni (2002) noted that 3-digit industry level studies may not show intra-industry movements. They also acknowledged that their study focuses just on manufacturing industries, while the outcomes were more accurate if service industries included. Also, Jones *et al.* (2004) showed that much of factor reallocations occur across 4-digit international standard industrial classification (ISIC) level industries and are hidden from more aggregate 3-digit manufactures which were employed with Bohi (1989) for instance. Furthermore, Keane and Prasad (1996) showed that employment shares and relative wages are changed across 3-digit industries.

In addition to industries' assortment, skilled labour skill is another important factor in sectoral movements. Bohi (1989) argued that skill differential is the major reason for not equal wages among sectors. Less skilled labours have to move to industries with lower level of skill requirements such as retail trade or services, while employment opportunities are higher for skilled workers. For instance, workers with longer tenure length—the number of years in the current job—experience larger reduction in real wage. Consequently, skilled workers are accurate substitute for energy in production function. These results are parallel with Lilien (1982) and Hamilton (1988).

Using a vector auto regressive model, Davis and Haltiwanger (2001) showed the effects of the oil price movements on job destruction and job creation at 4-digit ISIC level. Their examination distinguished aggregate and disaggregate channel. Based on aggregate channel, which includes potential output, transfer of income and wage stickiness, an increase in the oil price raised job destruction and reduced job creation. Symmetrically, a reduction in the oil price depressed job destruction and moved up job

creation. However, disaggregate channel responded to the oil price changes asymmetrically. Briefly, oil price movements would raise both job destruction and job creation.

Delays in investment

When the oil price jumps up, firms postpone investment for a while in order to explore the oil price shock is transitory or permanent. With regards to Bernanke (1983), delays in investment reduce the value added slightly. Cologni and Manera (2008) believed that firms might invest on more energy-efficient sectors and decline their capital spending moderately if the growth in energy price looks to be permanent. Similarly, Park and Ratti (2008) showed that the acceleration in the world real oil price raises the short-term interest rate in the US and 8 out of 13 European countries; but, with a lag of one or two months. Altogether, the effects of lagged investment on economy because of an oil price shock seem to be an indirect transmission channel.

Monetary responses to inflationary effects of oil shocks

Concerning this mechanism, oil price shock will cause inflation first. Cologni and Manera (2008) showed that if consumers expect that oil price increases are transitory, they save less and borrow more. As a result, increasing demand lead further upgrade in price level (real balance effect). After appearing inflation, monetary tightening will contract GDP and recession happens afterward. Cologni and Manera (2008) argued that in result of an oil shock, energy-intensive parts of real capital obsolete and replacing them takes time. Thus, the inflationary pressure would be higher.

The most important subject after the recession of 1973 was the attribution of monetary policy and oil price shock in recession. To address this notion, a large body of research focused on the role of monetary or interest rate in GDP and unemployment regressions. For instance, Bernanke *et al.* (1997) found that the recessions of 1973, 1979 and 1990 are attributable to the monetary policy, not oil price shocks. Their results were re-examined recently with Hamilton (2011) to find out the relative contributions of monetary policy and oil price shocks to the observed recessions. He argued that if monetary policy causes recession, alternative monetary policies avert it. However, based on the patterns of historical behaviour of the funds rate, he could not show such a policy. In addition, He mentioned that the 7-month lag order in Bernanke *et al.* study where major body of studies consider 3–4 quarters lag orders is not enough to show the

effects of the oil price shock on the output. In fact, he proved that practical limitations do not permit monetary policy to avert the effects of oil shocks on GDP.

To criticize Bernanke *et al.* (1997), Balke *et al.* (1998) by using a similar simulation experiment demonstrated that first of all, the response of GDP to the oil price shock is significant. Second, oil shocks effects on GDP and short-term interest rates are asymmetric, even with a fixed monetary policy. In fact, they proved this important notion that monetary policy is not the only operating channel for asymmetric responses to the oil price shocks. Additionally, Jones *et al.* (2004) criticized the econometric methodology of Bernanke *et al.* (1997). For instance, eliciting Leeper and Zha (2003), they argued that such econometric methodology, which runs counterfactual simulations with VAR system is not qualified as a modest policy deviation due to probable changes in private agents and optimization algorithms.

In order to find out whether monetary policy or the oil price shocks are responsible for afterward oil shocks recessions, Hooker (1999) by using bivariate and multivariate VAR specification inferred that oil price is directly responsible for the pre-1980s recession, while for the post-1980s GDP responses, monetary policy or some other variables cause oil price shocks to affect GDP indirectly. Focusing on oil price–inflation relationship, Hooker (2002) explored a structural break in the US Philips Curve where oil price shocks were responsible. He demonstrated that in spite of greater sensitivity in the oil prices to inflation after 1979 which has been shown in Bernanke *et al.* (1997), monetary policy displays lighter responses to the GDP after 1979 than before this time. Using an alternative approach to Bernanke *et al.* (1997), Barsky and Kilian (2004) showed that due to endogenous responses to demand shocks rather than supply shocks, monetary contractions were major reason for the recessions in 1973 and 1979. However, referring Bernanke and Ilian (2012), due to sharp contraction in monetary policy in early 1973, recessions produced with monetary policy might not respond endogenously to the oil price shocks.

Altogether, it seems that monetary response to the oil price shocks and its effects on recession should be considered for each country separately. There is not a constant idea about the role of monetary policy as a transmission mechanism. The reason could be the importance of various factors in recessions as well as oil price shocks. Furthermore, applying different econometric approaches in relevant researches can be considered as another reason.

Wage–price spiral effect

Wage–price spiral is a situation that nominal wage moves up in result of an earlier price increase and again, the price climbs up in result of a rise in nominal wage. Bruno and Sachs (1985) showed that the inflation causes reduction in the real wage if an oil price shock appears. Also, Cologni and Manera (2008) represented that consumers increase their demand from non-energy goods and services in result of an increase in the oil price. The higher cost of living in this situation will cause workers to ask for higher wages. Thus, a reduction in real money affects household welfare, consumption and output negatively (second round effect). Additionally, if central bank responds to the increased demand of nominal wages, the inflation appears again. However, Bohi (1989, 1991), Keane and Prasad (1996), Rotemberg and Woodford (1996) did not show a support for such inflation. Similar to some other mechanisms, it seems that other factors are effective in usefulness of this channel as a transmission mechanism.

3.4. Effects of oil price changes in disaggregate level

As opposed to aggregate level, disaggregate level covers intersection movements. In other word, there are intersection trade-offs in response to an oil price shock which empower or weaken the effects of the oil price shocks in some sectors. We have classified the current literature in this field into the market level, sector level and industry level.

3.4.1. Market level

The number of relevant studies in the capital market stands behind of products market and labour market. Studies on stock market responses to the oil price shocks are valued due to the importance of measuring economic profits in response to the oil price shock. In fact, asset prices are the present discounted value of future net income of firms. As a result, a shock affects the flow of income and stock prices afterward, even before its actual impacts appear. Oil price may have a negative impact on stock market through direct and indirect channels as below.

Direct mechanisms

Direct mechanism means transferring the effects of the oil price changes on the stock market without any intermediation. Based on the current literature, the oil price increase creates uncertainty in stock market and share price reduces afterward.

Uncertainty in future oil volatility has a negative impact on the US stock market returns. Using a VAR model with three types of oil shocks include oil supply shock, aggregate demand shock and oil-specific demand shock as well as four main industries include petroleum and natural gas, automobiles and trucks, retails and precious metals, Kilian and Park (2009) showed that the response of the US real stock returns depends on the underlying causes of the oil price changes. They argued that in order to understand the changes in stock prices, the most important shocks are those, which make changes in precautionary demand for oil. These shocks reflected uncertainty in the future oil supply. They believed that shocks in precautionary demand follow political instability as well as changes in stock prices in the Middle East. As a result, due to changes in political conditions in the Middle East, precautionary demand moves up sharply, real price of oil jumps up and real stock prices drop down. However, oil price shocks in result of other reasons such as unexpected global expansion may not lead changes in precautionary demand and stock prices.

Global oil-demand shocks concern the uncertainty in future oil-supply shocks and affect stock market prices significantly. Apergis and Miller (2009) chose a sample of eight countries include Australia, Canada, France, Germany, Italy, Japan, UK and the US. They employed vector error correction and vector auto regressive models for three types of shocks in their sample: oil supply shocks, global aggregate-demand shocks, and global oil-demand shocks. They found that the highest amount of variation in stock returns belongs to Italy with less than 17 percent. This explanatory power for the rest of countries had changes from a low of 7.78 percent to a high of 12.12 percent. In terms of short-term and long-term effects, they showed that just over 12 percent of stock prices are explained with oil price changes in a 12-month period similar to the long-term (60 months). Altogether, they provided little evidence of stock market returns to the all three types of shocks. They believed that small magnitude of direct effects of the oil price changes on stock returns may indicate that other control variables such as exchange rates, interest rates and consumer durable pendings have explanatory power over stock market returns.

In a recent study, Vo (2011) by using daily oil price time series and S&P 500 stock market index, proved that oil futures and stock market are related and their volatility is also transmitted. He showed that on average, 1 percent increase in volatility in the oil market would increase the volatility in the stock market by about 0.14 percent a day later in steady state condition. Similarly, 1 percent increase in stock market volatility

would raise the volatility in oil market by about 0.27 percent a day later. He also found that the correlation between stock market and oil future prices would be higher when the markets are more volatile. He argued that there are two opposite effects in relationship between stock market and oil future prices. The first, which is negative indicates that higher oil prices raise production costs and decrease business profits as well as stock returns. The second implies that higher stock market reflects higher future demand for oil. Due to the oil supply limitation, oil price should go up. Thus, a positive relationship would be existed between the two markets.

Finally, using GARCH model for the US stock market as well as oil market, Odusami (2009) showed that oil price shocks have significant nonlinear negative effect on the aggregate stock returns. He separated the distribution of aggregate US stock returns into “smoothly arriving news” information and “discrete Poisson news” (which refers to unusual news) arriving from the crude oil market. He explained that the most significant source of jumps in the US stock market returns is unexpected news related to fluctuations to the oil price changes. Furthermore, his model implied that current and lagged returns on crude oil futures have a negative significant effect on the US stock market returns.

Indirect mechanisms

Oil price shocks affect stock prices through several channels indirectly. Based on the standard stock valuation models (Mohamed, 2012; Jones and Kaul, 1996; Nasseh and Strauss, 2000), the value of a stock equals to the sum of discounted expected future cash flows. These cash flows reflect economic conditions such as inflation, interest rate, production costs, income, economic growth, investors and consumer confidence and so on. Oil shocks affect these macroeconomic variables and stock prices afterward.

When industrial production is used as a proxy for cash flows, the results are fitted with the theory of rational valuation. Jones and Kaul (1996) examined the stock market efficiency by using an arbitrage pricing theory (APT) model. The theory suggests that changes in expected future cash flows and future returns of underlying assets are exactly reflected in stock prices. They found that cash flows affect stock returns positively. In addition, Park and Ratti (2008) showed that when real US stock returns are allowed to affect real stock returns in European markets, oil price shocks have a statistically significant impact on real stock returns in all European countries at the same time or with a lag of one month.

Consequently, the oil price shocks can affect stock returns through cash flows. Additionally, industrial production is an important route to transfer oil shocks effects as well as cash flows. Finally, a bilateral relationship between stock markets of countries may accelerate the effects of the oil shocks on stock returns.

Oil price volatility and stock returns

Oil price volatility may have a negative effect on stock returns. Kaul and Seyhun (1990) studied the effects of oil price volatility on the returns of stocks listed in New York Stock Exchange (NYSE) over 1949–1984. They found that inflation has no significant effect on stock returns, while oil price has negative and industrial production has positive significant effect on stock returns.

3.4.2. Sector level

Sector level studies have generally applied multifactor models. Some researches in this field include Mohamed (2012), Nandha and Brooks (2009), Nandha and Faff (2008), El-Sharif *et al.* (2005), Boyer and Filion (2007) and Sadorsky (2001). Major issues are explained as below.

Oil price changes and energy-intensive sectors

Oil intensity has been the most important index in literature of sector level studies. There is a general outcome based on the current literature, which states that the oil price changes affect oil-intensive sectors positively, while the effects on non-oil-intensive sectors may be statistically significant. However, the nature and sensitivity of the effects differ between sectors and countries.

For instance, Mohamed (2012) divided 12 European sectors include Automobile and Parts, Financials, Food and Beverages, Oil and Gas, Health Care, Industrials, Basic Materials, Personal and Household Goods, Consumer Services, Technology, Telecommunications and Utilities to oil and non-oil-intensive sectors. Using a multifactor pricing model and Granger causality test, he concluded that there is a strong positive linkage between oil price changes as well as oil-intensive European sectors such as Food and Beverages and Oil and Gas. He argued that oil price changes affect production cost as well as firm profitability. As a result, the mechanism of effect in these sectors is based on supply-side of the economy. On the other hand, he argued that the oil price increase follows the increase in the world demand due to economic growth and increasing confidence of the customers and investors. Thus, oil price movements

affect some non-oil-intensive sectors such as financials and telecommunication through demand-side.

There are evidences show that linkage between oil price and equity values in the non-oil and gas sectors is weak, while oil price returns, market returns and interest rate returns are correlated with oil and gas share price returns positively and the correlations are statistically significant. Using a conventional multifactor model, El-Sharif *et al.* (2005) considered the relationship between the price of crude oil and equity values in the oil and gas sector as well as four other sectors namely mining, banking, transport and software and computer in UK as the largest oil-producer in Europe. They conclude that industries are not homogeneous and different variables can affect industry returns in disparate ways. They believed that oil and gas stock returns are influenced by several risk factors such as changes in crude oil price; the stock market as a whole; and (to a lesser extent) the exchange rate.

Finally, some studies do comparisons between sectors in terms of oil-intensity. For instance, using 25 global industry indices through standard financial times stock exchange (FTSE) global classification System in a capital asset pricing model (CAPM), Nandha and Faff (2008) found that oil price increase has a negative effect on equity returns for all sectors except mining, and oil and gas industries. Furthermore, they proved that such a relationship is symmetric and there is a little evidence which supports asymmetric linkages.

Sector-specific effects

Some studies have investigated the effects of the oil price changes on particulare sectors. For instance, Sadorsky (2001) through conducting on Canadian paper and forest products sector, showed that market returns, exchange rates and commodity prices have large and significant effects on stock price returns, while short-term interest rate fluctuations have no significant effect. Moreover, he showed that the paper and forest products shares are riskier than the market's.

Sector-specific variables are affected with macroeconomic variables as well. Boyer and Filion (2007) showed that macroeconomic factors as well as firm specific variables affect 105 Canadian oil and gas corporations. Their sample includes 99 producers and 6 integrated firms. They found that interest rate, exchange rate, market returns, oil and natural gas prices as macroeconomic factors affect total return of oil and gas sector in

Canada. Moreover, the proven reserves, volume of production, debt level, operational cash flows and drilling success are other effective firm-specific factors. One of their interesting findings was that those firms that raise their production of oil and/or gas have lower stock returns in the market. Using theory of real options, they explained that growing oil price causes reduction in risk as well as return. Moreover, systematic risk in energy corporations is smaller than common ones in Canada.

Some particular sectors are highly correlated with the oil price shocks. Nandha and Brooks (2009) studied the transportation sector equity returns in 38 different countries. They calculated transportation indices through industrial classification benchmark (ICB). They found that for developed countries include European and G7 countries, there is a strong linkage between oil price changes and transportation sector returns, while such relationship is not supported in other regions such as Asia Pacific, Emerging and Latin America. They estimated two models: basic and asymmetric. Based on the first model, there is a significant negative oil price sensitivity of transport returns in Greece, Japan and the US, as well as significant positive oil price sensitivity of transportation returns in Denmark. Asymmetric model showed similar outcomes and confirmed the existence of significant oil price sensitivity of transportation returns in Australia, Austria, China, Finland and Norway.

Altogether, sector-specific factors are shown to be in high correlation with oil price shocks as well as macroeconomic variables. However, the oil price sensitivity differs between sectors hugely. One reason is the degree of dependency to the oil as marginal or transitory commodity.

3.4.3. Industry and firm level

As opposed to all other areas of study within the current literature, which is mainly focused on the impact of the oil price shocks at the aggregate level, the number of industry level studies is relatively low. It is widely believed that when the oil price increases, lower usage of oil in manufacturing causes reduction in capital and labour productivity (input cost effect). In addition, higher cost of imported oil will decrease the disposable income (income effect) and investment thereafter. On the other hand, industrial production is used in all related studies. One of the differences between using GDP and industrial production is that if the oil price increases, GDP reduces due to income effect (because GDP is a domestic value added and oil imported cost should be

deducted), while labour supply and industrial production moves up (Lee and Ni, 2002). It worth noting that input cost effect will decrease both GDP and industrial production.

In spite of Davis and Haltiwanger (2001) who believed that much of the labour reallocation following an oil price shock occur within 3-digit industries, Lee *et al.* (1995) do note that their 3–digit data cannot illuminate such inter-industry movements. Looking at just manufacturing sectors, they did not pick up reallocations between manufacturing and service industries, if such occur. Focusing on the US industries in 3-digit ISIC revision level include petroleum refinery, industrial chemicals, paper products, rubber and plastic, steel and nonferrous metals, apparels, automobiles, machinery and tools, Lee and Ni (2002) found that most industries respond to the oil price shock similarly. There is little correlation between severity of oil price-triggered output reduction and the oil intensity of industries. By using an identified multivariate VAR model, they found that while both demand and supply of industries are affected by the oil price shocks, the supply of more-oil-intensive industries reduces as well as the demand of many other industries, especially the automobile industry.

Demand–supply analyses of the oil price shocks are in their highest level of importance. Lee and Ni (2002) believed that in supply-side, the oil-intensive industries will reduce their production if an oil price shock appears. Nevertheless, in demand-side, industrial production movements are not clear due to responsibility of less oil intensive industries. One reason is that the production of less-oil-intensive industries moves down if the demand of more-oil-intensive industries reduces. However, an increase in demand of more-oil-intensive industries may raise demand and supply of less-oil-intensive industries (automobile and steel industries for instance).

Besides the mentioned studies have been focused on 3-digit industries, Jimenez-Rodriguez (2011) applied her model for nine 2-digit industries in European Monetary Union (EMU) include France, Germany, Italy, Spain, the UK and the US during 1975–1998. Using the structural VAR analyses, she found that the macroeconomic structure is statistically significant in transferring the effects of the oil price shocks to the industrial output. In other word, she emphasised that in addition to heterogeneity in industrial structure of each country, differences in macroeconomic structure affect the transmission mechanism in EMU countries.

However, some studies have not supported any significant linkage between oil price movements and economic variables at industry level. For example, Bohi (1989, 1991)

by doing a cross sectorial research, found no correlation between the declines in industry level outputs and the energy-intensities of the industries during energy crises. In another study, Fan and Jahan-Parvar (2012) by using average monthly value weighted returns of 49 industry level portfolios during July 1926 to May 2010, found that small number of US industry level returns can be oil price predictable. Futures prices of oil have no significant prediction power, while oil spot prices predict approximately 20 percent of industry returns. Using cyclical components with VAR and VECM approach for Greece, Filis (2010) showed that in spite of significant negative effects of the oil price shocks on stock market returns and CPI, there is no evidence for effects of industrial production on stock market and CPI, while Ewing and Thompson (2007) proved that industrial production and stock market affect oil price as well as consumer price. Sakellaris (1997), Kilian and Park (2009), Herrera *et al.* (2011), Jimenez Rodriguez (2008, 2011), Driesprong *et al.* (2008) and Sadorsky (2008) are some other studies in this area.

The small number of studies at industry level are likely scattered around a few particular subjects. Moreover, the achieved results are not consensus. Overall, oil intensity seems to be a key factor at the industry level. The macroeconomic structure of each country is accompanying oil intensity factor as well in taking effects from oil price shocks. It is evident that studying the effects of the oil price shocks at industry level needs to be expanded hugely.

3.5. Concluding remarks

Investigating the effects of the oil price shocks on economy has significantly simulated interests of researchers, particularly after the oil crisis of 1973. Since then, valued efforts have been devoted to explore the mechanisms through which affect economic sectors as well as macroeconomic variables. Current literature in the field of oil price shocks and their effects on economy is deviated into theoretical and empirical. Our investigation within empirical studies revealed that in spite of high concentration on problematic issues in both aggregate and disaggregate levels, there are still dark points which need more efforts to be lightened. For instance, the differences between oil-producer and oil-consumer countries responding to an oil price shock are still not clear. Concerning reviewed literature, a few questions and relevant methodology to address them are proposed which are explained in the next chapters.

Chapter 4. Causal effects of global oil price fluctuations

What follows is the author-manuscript (pre-print) version of the paper reproduced in accordance with the copyright policy of the publisher. The original publication is available at <http://onlinelibrary.wiley.com/doi/10.1111/1759-3441.12088/abstract>. My contribution to this paper involves initial concept and empirical design, collection and analysis of data and preparation of the manuscript.

This paper considers variation in the effects of oil price changes on the economies of large net oil-producer and large net oil-consumer countries using a bias-corrected, least squares dummy variable approach, Granger causality tests and monthly data from May 1986 to January 2013. We find that oil prices Granger cause most macro aspects of net oil producers but not those of net oil consumers. In contrast, oil prices exert a greater influence on financial markets in net oil consumers than in net oil producers. Overall, we identify substantial differences in the responses of the macroeconomy and financial markets to oil price changes in the two groups of countries.

4.1. Introduction

The literature on the macroeconomic and financial market effects of oil price changes reveals mixed findings arising from differences in estimation method, the identification of shocks, the specification of variables, the sampling of countries and period, usually on a country-by-country basis. One point of distinction in this body of research is between oil-importing countries and oil-exporting countries, that is, between countries that import or export large volumes of oil. The conventional (and rather simple) argument is that depending on the structure of their economies, the macroeconomies and financial markets of oil importers (exporters) will suffer (benefit) from oil price increases and vice versa for oil price decreases.

Invariably, the former includes countries like the US, China, Japan, India, Germany and South Korea and the latter countries like Saudi Arabia, Russia, the United Arab Emirates, Kuwait, Nigeria and Iran. However, this distinction is not always clear and

does not accurately reflect the potential impact of oil price changes given the disjunction between oil production and exporting and oil consumption and importing. For example, only 11 of the world's 15 leading oil-producer countries are also leading oil-exporters, and certainly in a different way for a country that exported with a relatively low level of domestic consumption or one that exported with a high level of domestic oil consumption. Likewise, despite being a leading oil producer, the US is also the largest oil importer. In fact, altogether five of the 15 leading oil producers are also among the leading oil consumers. Surely, the economies and financial markets of these countries will react differently according to whether they are a large oil producer and a small oil consumer or a large oil consumer and a large oil producer.

In terms of related research, oil-producer countries can arguably benefit from oil price shocks, while the effects on oil-consumer countries are generally more complicated (e.g., Korhonen & Ledyeva 2010). There is also evidence concerning the heterogeneity of the causal effects of oil price movements on industrial production (e.g., Lee & Ni 2002, Jiménez-Rodríguez 2011). Where industrial production is widely used as proxy for economic activity, such results indicate the existence of indirect effects during transmission of the oil price changes — in both oil-consumer and oil-producer countries — which affect the total influence of oil price changes on an economy. Of the many possible contributing factors, macroeconomic structure is important (Jiménez-Rodríguez 2011, Schubert & Turnovsky 2011). Likewise, other studies demonstrate the adverse effects of oil price movements on economic performance generally (Cunado & Perez de Gracia 2005, Elmi & Jahadi 2011, Mork et al. 1994 and Nandha & Brooks 2009).

Elsewhere, while oil price shocks affect financial markets nonlinearly (Apergis & Miller 2009 and Ciner 2001), any indirect effects of the oil price changes may weaken these direct effects. For instance, Apergis and Miller (2009) show that oil price changes explain just over 12 per cent of stock prices. Financial market responses to the oil price movements are also not necessarily the same across countries. For instance, Park and Ratti (2008) show that acceleration in the world real oil price raises short-term interest rates in the US and 8 of 13 European countries with a delay of one or two months, and provide evidence of a symmetric effect on real stock returns in oil-importing countries, but none on the US or Norway. However, there is more evidence on the adverse responses of financial markets to oil price movements (for example, Abu-Bader & Abu-Qarn 2008, Ayhan Kapusuzoglu 2011, Biswas 2008, Boulila & Trabelsi 2004, Sanchez

& Hassan 2011 and Wolde-Rufael 2009). Altogether, financial markets, and especially interest rates, are known to be important channels in transferring the effects of oil price changes to GDP (see e.g., Balke et al. 2002, Bohi 1991, Finn 2000 and Keane & Prasad 1996).

Accordingly, in this paper, rather than the rather blunt and misleading distinction between large oil exporters and large oil importers in existing analyses, we focus instead on significant net oil production and consumption as measured by the share of GDP. We also aim to correct the existing imbalance in findings given the usual focus on oil importers (here net consumers) and not on oil exporters (here net producers), mainly because reliable and consistent data are usually more difficult to obtain for the latter. To compare the direct causal effects of global oil price changes on the economies of net oil-consumer and net oil-producer countries, we employ a least-biased econometric approach. Utilizing a dynamic panel approach enables us to consider the endogenous behaviour of variables, which is not possible using a simple country-by-country model.

The remainder of the paper is structured as follows. Section 2 discusses the data. Sections 3 and 4 detail the method and discuss the estimation results, respectively. Section 5 provides some brief concluding remarks.

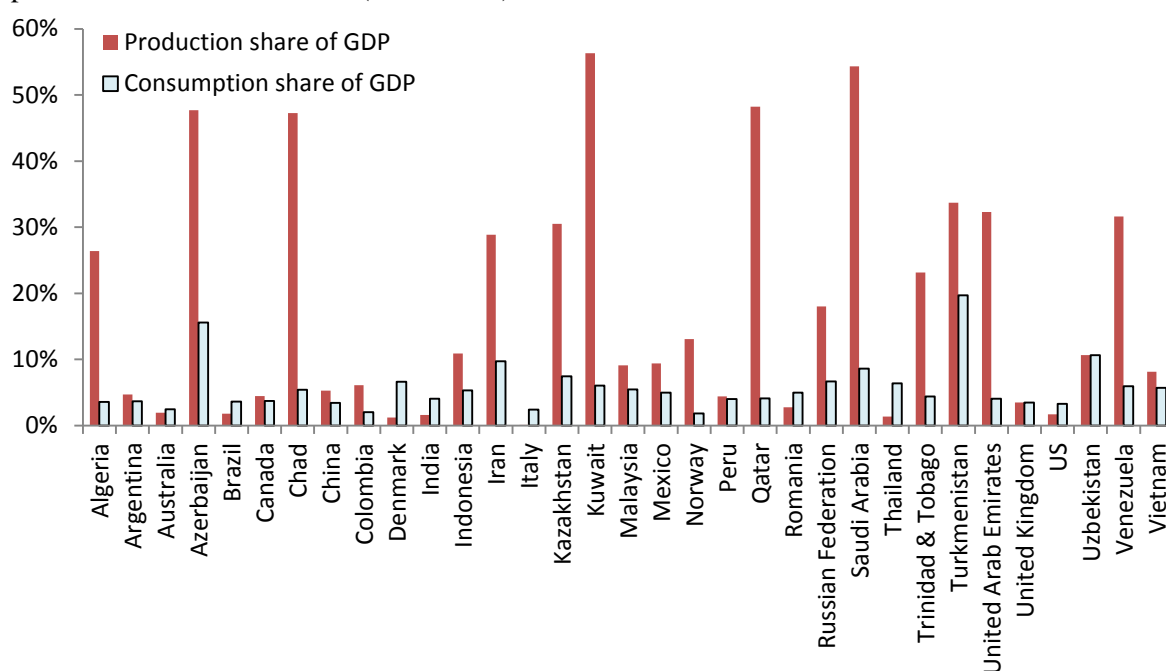
4.2. Data description

Our sample data consist of global oil prices and selected macroeconomic and financial market variables for seven net oil-consumer and three net oil-producer countries. Our sample selection criterion is the share of net oil production (consumption) in GDP. As illustrated in Figure 4.1, we calculate this for a wide range of oil-producer and oil-consumer countries. After considering the availability of the necessary data among these countries, we designate the US, Brazil, Denmark, Italy, Germany, the Netherlands and Sweden as net oil consumers and Canada, Mexico and Norway as net oil producers. Table 4.1 provides summary statistics of oil production and oil consumption in the final sample of countries.

We use monthly data covering the period 1986M5–2013M1. Table 4.2 describes the variables employed. Our variables include the global oil price (*OP*), industrial production (*IP*), consumer price index (*CPI*), real exchange rate (*RER*), share price (*SP*) short-term real interest rate (*IR*) and monetary aggregate (*MA*). Data for *CPI*, nominal exchange rate, *IP*, and *SP* are from the Organisation for Economic Co-operation and

Development (OECD). The OECD is also the source of *IR* data for the entire sample excluding Brazil. We collect *IR* for Brazil from the Portal de Financas website. We deflate *IR* using country-specific consumer price index. For Canada, Denmark, Mexico, Norway, Sweden, Brazil and the US, the *MA* statistics—including narrow money M1—are from the OECD website. For Germany and Italy, we collect M1 from the Deutsche Bundesbank and Banca d'Italia, respectively. As a proxy for *MA* in the Netherlands, we could only obtain M3 from the De Nederlandsche Bank.

Figure 4.1. Determination of net oil-producer and net oil-consumer countries among oil-producer/consumer countries (1976–2011)



Source: Calculated using IEA and World Bank data

Table 4.1. Oil consumption and production share of GDP in sample countries (1976–2011)

Country	Oil consumption (‘000 barrels/day)	Oil production (‘000 barrels/day)	Average net oil consumption share of GDP (%)	Average net oil production share of GDP (%)
Brazil	984–2,629	173–2,193	1.89	...
Denmark	176–326	4–390	0.80	...
Germany	2,362–3,341	...	2.10	...
Italy	1,532–1,976	27–127	2.42	...
Netherlands	610–1,122	...	3.09	...
Sweden	305–564	...	2.21	...
USA	15,235–20,802	6,734–10,580	1.66	...
Canada	1,540–2,298	1,598–3,522	...	0.72
Norway	176–235	279–3,418	...	11.57
Mexico	730–2,030	894–3,766	...	4.55

Source: IEA and World Bank.

Finally, we use the monthly West Texas Intermediate (WTI) oil price index, available in the World Bank website. All data are indexed to the 2010 monthly-average.

To test whether our panel data are stationary, we apply Im-Pesaran-Shin (IPS) and Fisher-type Augmented Dickey-Fuller (ADF) tests given their assumptions on finite sample size, which are appropriate for our sample [see Moon & Phillips (1999) and Phillips & Moon (2000) concerning assumptions about the required sizes of N and T]. Following Choi (2001) in applying Fisher-type ADF test, we estimate panel-specific unit root statistics by combining the inverse chi-square, inverse normal, inverse logit and modified inverse chi-square statistics. Additionally, we only estimate the t -bar statistic to perform the IPS test. It is worth noting that the Fisher-type ADF test is preferred to the IPS test. The results displayed in Tables 4.3–4.4 indicate that the first differences of all variables are stationary at the 1 per cent level of significance.

Table 4.2. Variables

Name	Description
OP	Global oil price
IP	Industrial production
CPI	Consumer price index
MA	Monetary aggregate
RER	Real exchange rate
SP	Share price
IR	Short-term real interest rate

Table 4.3. Panel unit root test for the variables in levels and first differences

Variable	Fisher-type ADF				IPS			
	Constant		Trend		No trend		Trend	
	P statistic	p-value	P statistic	p-value	t-bar	p-value	t-bar	p-value
CPI	11.6928	0.9262	21.2389	0.3832	-0.3102	1.0000	-1.4195	0.7277
RER	107.8673	0.0000	53.9184	0.4624	-3.9392	0.0000	-2.6756	0.0001
MA	0.6048	1.0000	5.0252	0.0001	6.1873	1.0000	1.0616	1.0000
IP	10.9837	0.9466	75.6517	0.0000	-1.2064	0.8866	-2.9287	0.0000
IR	13.0385	0.8757	38.4749	0.0077	-1.2864	0.8164	-2.7238	0.0000
SP	2.3427	1.0000	9.2929	0.9793	-0.1270	1.0000	-1.8381	0.1206
OP	4.8110	0.9998	28.0935	0.1072	-0.9054	0.9898	-2.6777	0.0000
DCPI	670.6648	0.0000	667.2005	0.0000	-16.4909	0.0000	-16.6190	0.0000
DMA	694.0444	0.0000	692.1074	0.0000	-14.2574	0.0000	-15.4447	0.0000
DIP	720.8731	0.0000	720.8731	0.0000	-27.1242	0.0000	-27.1331	0.0000
DIR	720.8731	0.0000	720.8731	0.0000	-15.4823	0.0000	-15.4701	0.0000
DSP	720.8731	0.0000	720.8731	0.0000	-15.6516	0.0000	-15.6707	0.0000
DOP	720.8731	0.0000	720.8731	0.0000	-12.8518	0.0000	-12.8396	0.0000

Notes: CPI, RER, MA, IP, IR, SP and OP indicate consumer price index, real exchange rate, monetary aggregate, industrial production, short-term interest rate, share price and oil price, respectively. “D” indicates the first difference. P-values show the probability of the existence of the unit root (null hypothesis).

4.3. Empirical methodology

4.3.1. Bias-corrected LSDV model

To investigate all possible dynamic relationships within a panel of cross sectional units, the panel vector autoregressive (PVAR) approach has widely been applied in the literature. This approach has the least bias when cross sectional units and time dimensions tend to be infinite. Thus, for the case we are studying, the finite cross sections do not allow us to employ PVAR estimators due to biased estimations. In this regard, Juessen and Linnemann (2010) have compared the widely applied techniques in estimating PVAR models with large time dimensions using Monte-Carlo simulation. They show that as all instrumental variables and generalized method of moments (GMM) estimators are severely biased in models with restricted number of cross-sectional units, bias-corrected least squares dummy variables (LSDV) model is easy to implement and is best suited for samples with a large time dimension. However, it still does not suit our case as this model employs the moderate number of panels. To consider a model with further corrections applicable for small panels, we implement the bias-corrected LSDV model demonstrated by Bruno (2005). Consider the following dynamic panel data model:

$$y_{it} = \gamma y_{i,t-1} + x'_{it}\beta + \eta_i + \epsilon_{it}; \quad |\gamma| < 1; \quad i = 1, \dots, N \text{ and } t = 1, \dots, T \quad (4.1)$$

Table 4.4. Panel unit root test for the logarithms of the variables in levels and first differences

Variable	Fisher-type ADF				IPS			
	Constant		Trend		No trend		Trend	
	P statistic	p-value	P statistic	p-value	t-bar	p-value	t-bar	p-value
LNCPI	625.3032	0.0000	78.3469	0.0000	-9.5194	0.0000	-2.2595	0.0436
LNRER	109.6133	0.0000	20.6842	0.4159	-3.0183	0.0000	-2.1814	0.0083
LNMA	36.0673	0.0151	25.6360	0.1782	-1.7689	0.1945	-1.6877	0.3085
LNIP	17.5089	0.6197	85.0365	0.0000	-1.6192	0.3665	-3.1389	0.0000
LNIR	2.3538	1.0000	8.9033	0.9840	0.7301	1.0000	-1.0059	0.9759
LNSP	67.7872	0.0000	65.5638	0.0000	-1.7980	0.2460	-2.7075	0.0000
LNOP	6.5507	0.9979	34.0636	0.0257	-1.0858	0.9490	-2.8415	0.0000
DLNCPI	693.7707	0.0000	696.6657	0.0000	-15.6902	0.0000	-17.8183	0.0000
DLNRER	720.8731	0.0000	720.8731	0.0000	-16.5112	0.0000	-16.6683	0.0000
DLNMA	720.8731	0.0000	706.5190	0.0000	-17.3064	0.0000	-17.4158	0.0000
DLNIP	720.8731	0.0000	720.8731	0.0000	-28.0221	0.0000	-28.0526	0.0000
DLNIR	705.3003	0.0000	694.8344	0.0000	-11.9881	0.0000	-12.0337	0.0000
DLNSP	711.4782	0.0000	708.8134	0.0000	-15.5644	0.0000	-15.6226	0.0000
DLNOP	720.8731	0.0000	720.8731	0.0000	-14.5203	0.0000	-14.5000	0.0000

Notes: CPI, RER, MA, IP, IR, SP and OP indicate consumer price index, real exchange rate, monetary aggregate, industrial production, short-term interest rate, share price and oil price, respectively. “D” and “LN” indicate the first difference and logarithm, respectively. P-values show the probability of the existence of the unit root (null hypothesis).

In this model, y_{it} is the dependent variable, x_{it} is the $\{(k-1) \times 1\}$ vector of strictly exogenous explanatory variables, η_i is an unobserved individual effect and ϵ_{it} is an unobserved white noise disturbance with constant variance σ_ϵ^2 . Upon data collection during the time and across individual units, Equation 4.1 is modified as below:

$$y = D\eta + W\delta + \epsilon \quad (4.2)$$

where $D = I_N \otimes \iota_T$ is the $(NT \times N)$ matrix of individual dummies (ι_T is the $(T \times 1)$ vector of all unity elements); y and $W = (y_{-1} : X)$ are the $(NT \times 1)$ and $(NT \times k)$ matrices of stacked observations, η is the $(N \times 1)$ vector of individual effects, ϵ is the $(NT \times 1)$ vector of disturbances; and $\delta = (\gamma : \beta)'$ is the $(k \times 1)$ vector of coefficients. To select the usable observations from within unbalanced panel data for our dynamic model, a selection index is designed as below:

$$s_{it} = \begin{cases} 1 & \text{if } (r_{it}, r_{it-1}) = (1, 1) \\ 0 & \text{otherwise} \end{cases} \quad (4.3)$$

where $r_{it} = 1$ if y_{it} and x_{it} are observed and $r_{it} = 0$ otherwise, i denotes the size of time series and t refers to time dimension. Define $s_i = [s_{i1} \dots, s_{iT}]'$ the $(T \times 1)$ -vector for each i and the $(T \times T)$ diagonal matrix S_i the vector s_i on its diagonal. Thus, the $(NT \times NT)$ block-diagonal matrix S is $S = \text{diag}(S_i)$. Now, we rewrite Equation 4.2 using above definition as below:

$$Sy = SD\eta + SW\delta + S\epsilon \quad (4.4)$$

In this equation, δ is the LSDV estimator, which is calculated through the following formula:

$$\delta_{LSDV} = (W'M_s W)^{-1} W'M_s y \quad (4.5)$$

where

$$M_s = S\{I - D(D'SD)^{-1}D'\}S \quad (4.6)$$

is the symmetric and idempotent $(NT \times NT)$ matrix, which is removing individual means and keeping usable observations.

As explained, the above LSDV estimator is biased and we need the bias approximation term to calculate unbiased estimators. Through the estimation procedure of bias approximation term, which has been explained in detail in Bruno (2005) and Bun and

Kiviet (2003), one of the Anderson and Hsiao (1982), Arellano and Bond (1991) or Blundell (1998) estimators is employed to measure bias approximation term. Assuming B_i indicates one of such estimated bias approximations, the bias-corrected LSDV model is estimated through the following formula:

$$LSDVC_i = LSDV - \hat{B}_i \quad (4.7)$$

where LSDVC denotes our target bias-corrected LSDV and $i=1, 2, 3$ addresses one of the Anderson and Hsiao (1982), Arellano and Bond (1991) or Blundell (1998) bias approximations. Using LSDVC instead of the biased LSDV estimator, we now estimate the parameters presented in Equation 4.2.

4.3.2. *Linear causality and elasticity*

To test the linear causality between variables, the Granger (1969) causality test has widely been applied within the macroeconomic literature. There are also other linear causality tests such as the Sims test or the Modified Sims test, which are being used in economics literature as well. However, as Guilkey and Salemi (1982) show, the direct Granger causality test rejects a false null hypothesis 3.26 per cent and 2.64 per cent more than Sims and Modified Sims tests, respectively. We followed the Granger Causality test to consider the causality of oil price movements to macroeconomic and financial market variables. The direct Granger causality test, as a powerful tool, describes both the existence and direction of causality. In regression of y_{it} on lagged values of y_{it} and OP_t , OP_t would not be Granger-cause of y_{it} if the coefficients of OP_t are jointly zero. Consider the following equation:

$$y_{it} = \sum_{j=1}^m \varphi_j y_{i,t-j} + \sum_{j=1}^m \theta_j OP_{t-j} + D_{it} + e_{it} \quad (4.8)$$

where φ_j and θ_j are coefficients, y_{it} and OP_t indicate the dependent variable and global oil price, respectively. D_{it} denotes deterministic trend and e_{it} is the random error term. Rejection of the null hypothesis of $\theta_1 = \theta_2 = \dots = \theta_n = 0$ indicates that OP_t is the Granger cause of y_{it} . To apply linear Granger causality test using our finite panel data model, we use the first difference of the variables (which are stationary). Furthermore, to test whether the coefficients are statistically significant, we calculate bootstrapped Chi-square statistics.

Considering Bruno (2005), we measure the oil price elasticity by estimating the following dynamic model:

$$dln(y_{it}) = \alpha.dln(y_{i,t-1}) + \beta.dln(OP_t) + u_i + \varepsilon_{it} \quad (4.9)$$

where u_i is the individual effects while no distributional assumption is made apart from being fixed over time; and ε_{it} is independently and identically distributed (iid) over the whole panel. It is worth noting that u_i and ε_{it} are independent for each i over time. Finally, α and β are parameters to be estimated. Using Equation 4.9, β is the substitutionary oil price elasticity of y_{it} . It is worth noting that generally, the application of log differences of the variables causes losing some important long-term information of data at level and hence, inserting an error correction (EC) term to the Equation 4.6 incorporates back a great part of such missed information. However, as we only study the short-term interactions of global oil price changes with other sample variables through above Equation, explaining the long-term error correction procedure will lengthen our study excessively. Consequently, we estimate Equation 4.9 to calculate the short-term substitutionary elasticity of the variables. We also estimate the significance of this estimated parameter by bootstrapping simulation.

4.4. Empirical results

4.4.1. Linear Granger causality

To test the linear causal effects of the oil price changes on the macroeconomic and financial market variables, we estimate the bias-corrected LSDV model presented in the previous section. It is worth noting that with regard to Hamilton (2011), which indicates that 3–4 quarters of lag orders are not sufficient to show the effects of oil price shocks, we start with a 24-month lag and use the Akaike Information Criterion (AIC) to choose the optimum lag order. Tables 4.5–4.6 demonstrate such results. As shown in Table 4.5, oil price movements Granger cause almost all of the variables.

The results presented in Table 4.5 are identical across net oil-consumer and net oil-producer countries in two cases. First, OP Granger causes IP , RER and SP in both panels. These findings are consistent with Cunado and Perez de Gracia (2005), Dissou (2010), Jiménez-Rodríguez (2008), Jimenez-Rodriguez and Sanchez (2009) and Papapetrou (2001). Second, there is no evidence confirming the causal effects of oil price movements on CPI . This finding appears to contradict earlier studies, which generally conclude the inflationary effects of oil price shocks. However, there is other

evidence that may explain our results. For instance, Korhonen and Ledyeva (2010) argue that economic activity in oil-producer countries suffers from the indirect effects of positive oil price shocks. They note that such indirect effects in oil-consumer countries are more heterogeneous. Given their outcomes, it is possible that a panel data model, which covers a set of net oil-consumer and net oil-producer countries, provides such results. Conversely, Cunado and Perez de Gracia (2005) show that oil price shocks in local currencies exhibit stronger effects on *CPI*. Anyhow, where our findings in rejecting the causal effects of global oil price changes on *CPI* may indicate heterogeneous responses to global oil price changes across different countries, we require further consideration to clarify this issue.

Table 4.5. Panel linear causality test results

Causality	Net oil-consumer countries			Net oil-producer countries		
	Test statistic (Chi-square)	p-value	Result	Test statistic (Chi-square)	p-value	Result
$\Delta OP \rightarrow \Delta CPI$	0.51	0.9730	Non-causality	4.38	0.3569	Non-causality
$\Delta OP \rightarrow \Delta IP$	37.82	0.0000	Causality	10.08	0.0391	Causality
$\Delta OP \rightarrow \Delta RER$	124.25	0.0000	Causality	65.10	0.0000	Causality
$\Delta OP \rightarrow \Delta MA$	6.07	0.1942	Non-causality	22.94	0.0001	Causality
$\Delta OP \rightarrow \Delta SP$	43.79	0.0000	Causality	8.44	0.0768	Causality
$\Delta OP \rightarrow \Delta IR$	15.63	0.0036	Causality	0.17	0.9965	Non-causality

Note: p-values estimated by bootstrapping simulation.

The results presented in Table 4.5 suggest that *OP* exhibits adverse causal effects across both net oil-consumer and net oil-producer countries. First, *OP* Granger-causes *MA* in net oil-producer countries while we cannot reject the null of no causality in net oil-consumer countries. This finding at least provides a conclusion for the existing mixed evidence on monetary responses to oil price changes. To nominate such ambiguity, it is enough to see where Bernanke *et al.* (1997) suggest applying monetary policy to eliminate the recessionary effects of oil price shocks, Hamilton and Herrera (2004) cast doubt on the effectiveness of such a policy. Abderrezak (2005) finds no evidence suggesting causal linear effects of the oil price movements on the money supply in Algeria. Second, *OP* Granger causes *IR* in net oil-consumer countries, but not net oil-producers. The former is in agreement with Papapetrou (2001) while the latter is consistent with Lowinger *et al.* (1985), which states that only very large increases in oil price affect interest rates. Overall, it would appear that oil price changes greatly affect most parts of the macroeconomy in net oil-producer countries. In contrast, global oil price changes affect the financial markets of net oil-consumer countries more significantly.

Table 4.6 details the inverse causal relationship between OP and other variables. An important point is that as we have employed global oil price movements, we do not expect that changes in any of our domestic variables cause significant movements in global oil prices. The results indicate that we cannot reject the null hypothesis of no causality for CPI and IR in both panels. These findings contradict Arora (2011), Arora and Tanner (2013) and Askari and Krichene (2010), which support the existence of interest rate effects on oil price changes. Additionally, SP is not Granger caused by OP in net oil-producer countries. All remaining variables significantly Granger cause oil price movements. Based on the results in Table 4.6, it is clear that financial markets in net oil-producer countries have no effect on oil price movements unlike net oil-consumer countries.

Table 4.6. Inverse panel linear causality test results

Causality	Net oil-consumer countries			Net oil-producer countries		
	Test statistic (Chi-square)	p-value	Result	Test statistic (Chi-square)	p-value	Result
$\Delta CPI \rightarrow \Delta OP$	0.86	0.9299	Non-causality	1.94	0.7471	Non-causality
$\Delta IP \rightarrow \Delta OP$	8.51	0.0744	causality	7.82	0.0986	causality
$\Delta RER \rightarrow \Delta OP$	15.77	0.0013	causality	424.27	0.0000	causality
$\Delta MA \rightarrow \Delta OP$	13.82	0.0079	causality	16.87	0.0020	causality
$\Delta SP \rightarrow \Delta OP$	207.33	0.0000	causality	4.83	0.3054	Non-causality
$\Delta IR \rightarrow \Delta OP$	2.31	0.6789	Non-causality	2.34	0.6727	Non-causality

Note: p-values estimated by bootstrapping simulation.

4.4.2. Elasticity

We use the bias-corrected LSDV model again to estimate the oil price elasticity of macroeconomic and financial market variables and consider the significance of the parameters through bootstrapping simulation. Tables 4.7–4.8 present the results.

As shown, there are some similarities and differences in net oil-consumer and net oil-producer countries in terms of the estimated elasticity values. For example, changes in RER and SP are elastic in both panels, such that 10% increase in OP reduces RER by 0.3% and 0.4% in net oil-consumer and net oil-producer countries, respectively. These results confirm the findings of our causality tests. Furthermore, the results concur with Dissou (2010), who shows that a 20% increase in the global prices of oil products causes an appreciation of the aggregate real exchange rate by 0.4%. Our reported

negative sign for *RER* elasticity is consistent with El-Sharif *et al.* (2005). They show that exchange rate returns negatively correlate with oil and gas share price returns. We also find that a 10% increase in *OP* raises *SP* by only 0.3% in net oil-consumer countries and 1.3% in net oil-producer countries. These results are also consistent with El-Sharif *et al.* (2005).

Table 4.7. Oil price elasticity (net oil-consumer countries)

Elasticity	Value	95% confidence interval	S.E.
E_{CPI}	0.0053	-0.0070 – 0.0175	0.0062
E_{IP}	0.0260*	0.0167 – 0.0352	0.0047
E_{RER}	-0.0383*	-0.0512 – -0.0253	0.0066
E_{MA}	-0.0126**	-0.0224 – -0.0028	0.0050
E_{SP}	0.0384*	0.0128 – 0.0640	0.0130
E_{IR}	0.0460*	0.0108 – 0.0812	0.0179

Note: * and ** significant at the 1 and 5 per cent levels, respectively. P-values estimated by bootstrapping simulation.

However, the differences in results between the two panels appear economically sensible. To start with, the oil price substitutionary elasticity of *CPI* is not significant in net oil-consumer countries, and although very small, statistically significant in net oil-producer countries. Next, in net oil-consumer countries, a 10% increase in *OP* causes *MA* and *IR* to change by -0.1% and 0.4%, respectively, whereas such causal effects are not statistically significant in net oil-producer countries. The negative sign of *MP* elasticity supports the findings of Cologni and Manera (2008) in recommending a contractionary monetary policy to control the inflationary effects of unexpected oil price shocks. It is apparent that most net oil-consumer countries have earnestly applied this policy during the last few decades.

Table 4.8. Oil price elasticity (net oil-producer countries)

Elasticity	Value	95% confidence interval	S.E.
E_{CPI}	0.0098*	0.0037 – 0.0159	0.0031
E_{IP}	0.0137	-0.0051 – 0.0324	0.0095
E_{RER}	-0.0430*	-0.0589 – -0.0270	0.0081
E_{MA}	-0.0084	-0.0303 – 0.0135	0.0111
E_{SP}	0.1315*	0.0756 – 0.1874	0.0285
E_{IR}	0.0306	-0.0159 – 0.0770	0.0237

Note: * significant at the 1 per cent level. P-values estimated by bootstrapping simulation.

Comparing the results between the two panels, the macroeconomy and financial markets in net oil-consumer countries are generally more sensitive to changes in global oil price than net oil-producers. In net oil-producer countries, however, only the macroeconomy is sensitive to global oil price changes. With the exception of *CPI*, all other macroeconomic variables in net oil-consumer countries are sensitive to the oil price changes. Finally, other than the strong elasticity of *IR* in net oil-consumer countries and

its insignificant elasticity in net oil-producer countries, we conclude the stronger sensitivity of financial markets to global oil price changes in net oil-consumer countries.

4.5. Conclusion

It is generally expected that oil price changes affect the economies of both net oil-consumer and net oil-producer countries, but in opposite directions. For instance, a significant reduction in oil price may benefit the former and hurt the latter. For the net oil-consumer countries, lower oil prices are similar to a tax cut, which increase consumer disposable income. This allows central banks to expand money aggregate. Due to upgrading cash flows, lower interest rates as well as lower inflation cause higher economic activity and higher share prices. Jumping industrial production finally leads economic growth. In contrast, higher oil prices are common reasons for appearing recessions in net oil-consumer countries. Such relationships are supposed to be adverse in net oil-producer countries. In other words, while higher oil prices may cause recession in net oil-consumer countries, economic growth may appear in net oil-producers. However, our findings suggest behaviour even more diverse in relation to oil price changes. To compare the dependency of the macroeconomies and financial markets of net oil-producer and net oil-consumer countries to oil price movements, we employ panel linear Granger causality test and substitutionary oil price elasticity. Using the consumer price index, industrial production (as a proxy for economic activity), the real exchange rate and monetary aggregates as selected macroeconomic indicators, and share prices and short-term real interest rates as financial market indicators, we find that the macroeconomies of net oil-producer countries are more dependent on oil price movements than those of net oil-consumers. This is due to the significant causal effects of global oil price changes on industrial production, the real exchange rate, monetary aggregates, and the significant elasticity of the consumer price index in net oil-producer countries. This contrasts strongly with the situation in net oil-consumer countries. In contrast, the strong effects of global oil price changes on share prices and short-term real interest rates in net oil-producer countries and not net oil-consumer countries reveal that global oil price movements exert stronger effects on the financial markets in the former.

Our findings clearly reveal some similarities and differences between net oil-producer and net oil-consumer countries in relation to oil price movements. For both panels, there is a bi-directional relationship between oil price movements and industrial production as well as with the real exchange rate. However, there is no evidence confirming Granger

causality between global oil price changes and the consumer price index. Lastly, the short-term interest rate does not Granger-cause oil price movements in either set of countries. Apart from the zero value of the oil price elasticity of industrial production in net oil-producer countries, all other elasticity values confirm these findings.

We also obtain some other interesting findings. First, monetary aggregate and oil price movements exhibit bi-directional causality among net oil-producer countries, whereas we only observe one-way causation running from monetary aggregates to oil price changes in net oil-consumer countries. Second, there is no causality between oil price changes and short-term real interest rates in net oil-producer countries, although oil price changes do affect short-term real interest rates in net oil-consumer countries. Finally, oil price movements and share prices exhibit a bi-directional relationship in net oil-consumer countries, running from the oil price to share prices in net oil-producers.

In terms of policy implications, our findings suggest that policy in net oil-producer countries will differ markedly from that in net oil-consumer countries. The positive responses of monetary aggregates to global oil price changes in net oil-producer countries indicates that these countries will seek monetary policy as a rapid-acting response to control the effects of global oil price changes. We find that oil price changes cause monetary aggregates to rise. One scenario in explaining the afterward effects of growth in monetary aggregates is that when it increases, consumers' purchasing power may climb up and this will insert extra pressure on aggregate demand. If such increasing aggregate demand is not replied by equivalent increase in aggregate supply, inflation occurs. Our estimated positive value of substitutionary elasticity of consumer price index in net oil-producer countries, which is statistically significant, confirms the appearance of inflation in short-term in these countries. This issue, however, is not observed in net oil-consumer countries. Indeed, the significant influences of oil price changes on short-term real interest rate in net oil-consumer countries demonstrates that these countries will approach policy primarily through taking control of short-term real interest rates and attempting to switch investment from the short to the long-term: the significant increase in the short-term real interest rate suggests reducing short-term investments. The lack of evidence supporting the existence of oil price changes' effects on monetary aggregates or consumer price index rejects the assumption of switching short-term investment to commodity market. Thus, short-term investments might have been transferred to the long-term. As further study, we suggest considering the possible non-linear causation of oil price changes as well as examining the existence of any

asymmetric relationships. The analysis of causation in domestic oil prices would also be a useful extension of this research.

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Chapter 5. Long-term effects of global oil price fluctuations

What follows is the author-manuscript (pre-print) version of the paper reproduced in accordance with the copyright policy of the publisher. The original publication is available at <http://dx.doi.org/10.1080/13504851.2014.990617>. My contribution to this paper involves initial concept and empirical design, collection and analysis of data and preparation of the manuscript.

In this article, we evaluate the long-term co-integrating relationships between global oil prices (OP) and selected macroeconomic and financial market variables between large net oil-consuming (NOC) and net oilproducing (NOP) countries. Our findings indicate that as opposed to NOP countries, the macroeconomies of NOC countries have long-term cointegrating relationships with OP. However, the financial markets of both country panels exhibit long-term co-integrating relationships with OP. Finally, excluding the case of the consumer price index, the sample economies, whether NOC or NOP, respond to global OP shocks very similarly.

5.1.Introduction

At least since the 1973 global oil crisis, a significant volume of research has considered the economic behaviour of oil price (OP) movements. However, there is insufficient evidence comparing the macroeconomic and financial market effects of OP shocks across different groups of countries, most specifically, oil producers and oil consumers. For the most part, studies have suggested that oil price shocks exert a significant impact on both oil-importing and oil-exporting economies, with increasing oil prices as a factor cost negatively affecting oil-importing countries and as revenue positively influencing oil-exporting countries.

The analysis of an asymmetric inverse relationship between oil price changes and aggregate economic activity for Norway and G7 countries in Mork (1989) is the seminal

international study in this area. Current international studies address a wide range of aggregate and disaggregate economic effects of OP shocks. As examples, Nandha and Brooks (2009) find that OP changes strongly affect the transportation sector of European and G7 countries, while Jiménez-Rodríguez (2011) uses nine 2-digit industries in the European Monetary Union (EMU) to emphasize the role of macroeconomic structure in transferring the effects of OP shocks to industrial output. Elsewhere, Apergis and Miller (2009) conclude that OP changes explain just over 12 percent of global stock prices. Finally, Park and Ratti (2008) show that acceleration in world real oil price raises short-term interest rates in the US and in 8 of 13 European countries.

A major question the current literature has not addressed is whether macroeconomic and financial market effects of global OP changes are identical across large NOC and NOP countries. To explore the closeness of the match between NOC and NOP economies and their responses to global OP changes, we estimate both panel and unit-specific co-integrating relationships and measure the correlation coefficients of responses to OP shocks. The contribution of this paper is of great interest to policy decision makers and economic researchers.

5.2.Data and methodology

We select countries with the highest frequently available data including the US, Brazil, Denmark, Italy, Sweden, Germany, and the Netherlands as NOC countries and Canada, Norway and Mexico as NOP countries. Our monthly data covers the period January 1970–August 2013. We collect data for the consumer price index (CPI), the real exchange rate (RER), industrial production (IP) and share prices (SP) from the Organisation for Economic Co-operation and Development (OECD) website. Short-term interest rate (IR) data is collected from Portal de Financas for Brazil and from the OECD website for the remainder. Monetary aggregates (MA) including narrow money are from the OECD website for Canada, Denmark, Mexico, Norway, Sweden, Brazil and the US. We also collect M1 from Deutsche Bundesbank and Banca d'Italia and M3 from De Nederlandsche Bank for Germany, Italy and the Netherlands, respectively. Finally, we use West Texas Intermediate (WTI) crude oil price (OP) which is collected from the World Bank website and is inflation adjusted. Data are indexed to their monthly-averaged 2010 values.

5.2.1. Panel co-integration framework

We apply the Westerlund (2007) method to test for the presence of an error-correcting process. To start with, consider an error-correction model as below:

$$\Delta y_{it} = \delta'_i d_t + \alpha_i (y_{it-1} - \beta'_i OP_{it-1}) + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{it-j} + \sum_{j=0}^{p_i} \gamma_{ij} \Delta OP_{it-j} + e_{it} \quad (5.1)$$

where y_{it} is the matrix of dependent variables, $y_{it-1} - \beta'_i OP_{it-1}$ denotes the error-correction term with coefficient of α_i , d_t indicates a deterministic trend and $t=1, \dots, T$ and $i=1, \dots, N$ are time and cross-sectional units, respectively. Finally, p_i denotes the number of lag orders, which is calculated using Akaike Information Criterion (AIC). The individually-averaged statistics are measured as follows:

$$G_\tau = \frac{1}{N} \sum_{i=1}^N \frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)} \quad (5.2)$$

$$G_\alpha = \frac{1}{N} \sum_{i=1}^N \frac{T \hat{\alpha}_i}{\hat{\alpha}_i(1)} \quad (5.3)$$

where $\hat{\alpha}_i(1) = 1 - \sum_{j=1}^{p_i} \hat{\alpha}_{ij}$. $\hat{\alpha}_i$ is the least square estimation of α_i .

Subsequently, we first estimate the common error-correction term ($\hat{\alpha}$) and its standard error ($SE(\hat{\alpha})$) using the following regressions:

$$\Delta \tilde{y}_{it} = \Delta y_{it} - \hat{\delta}'_t d_t - \hat{\lambda}'_t OP_{it-1} - \sum_{j=1}^{p_i} \hat{\alpha}_{ij} \Delta y_{it-j} - \sum_{j=0}^{p_i} \hat{\gamma}_{ij} \Delta OP_{it-j} \quad (5.4)$$

$$\tilde{y}_{it-1} = y_{it-1} - \tilde{\delta}'_t d_t - \tilde{\lambda}'_t OP_{it-1} - \sum_{j=1}^{p_i} \tilde{\alpha}_{ij} \Delta y_{it-j} - \sum_{j=0}^{p_i} \tilde{\gamma}_{ij} \Delta OP_{it-j} \quad (5.5)$$

We then calculate the pooled cross-sectional statistics as follows (Westerlund, 2007):

$$P_\tau = \frac{\hat{\alpha}}{SE(\hat{\alpha})} \quad (5.6)$$

$$P_\alpha = T \hat{\alpha} \quad (5.7)$$

5.3. Empirical results

5.3.1. Panel unit root tests

Because of the unbalanced panel of 10 cross sectional units and more than 500 time periods, we select Fisher-type Augmented Dickey-Fuller (ADF) and (to some extent) Im-Pesaran-Shin (IPS) tests, respectively (see Moon and Phillips, 1999 and Phillips and Moon, 2000). Table 5.1 indicates that all of the variables are integrated of order one, excluding RER and hence, we specify them in levels.

Table 5.1. Panel unit root tests

Variable	Fisher-type ADF		IPS	
	Constant	Trend	No trend	Trend
	P statistic	P statistic	t-bar	t-bar
<i>CPI</i>	11.6928	21.2389	-0.3102	-1.4195
<i>RER</i>	107.8673*	53.9184	-3.9392*	-2.6756*
<i>MA</i>	0.6048	5.0252	6.1873	1.0616
<i>IP</i>	10.9837	75.6517	-1.2064	-2.9287*
<i>IR</i>	13.0385	38.4749	-1.2864	-2.7238*
<i>SP</i>	2.3427	9.2929	-0.1270	-1.8381
<i>OP</i>	4.8110	28.0935	-0.9054	-2.6777*
<i>DCPI</i>	670.6648*	667.2005*	-16.4909*	-16.6190*
<i>DMA</i>	694.0444*	692.1074*	-14.2574*	-15.4447*
<i>DIP</i>	720.8731*	720.8731*	-27.1242*	-27.1331*
<i>DIR</i>	720.8731*	720.8731*	-15.4823*	-15.4701*
<i>DSP</i>	720.8731*	720.8731*	-15.6516*	-15.6707*
<i>DOP</i>	720.8731*	720.8731*	-12.8518*	-12.8396*

Note: "D" denotes the first difference operator. * indicates significance at the 1% level.

5.3.2. Panel co-integration

Tables 5.2 and 5.3 summarise the Westerlund (2007) co-integration test results. The results indicate that OP is in long-term co-integrating relationship with the macroeconomy and financial market of NOC countries. In NOP countries, however, such relationships are evident only with regard to financial markets.

Where no evidence demonstrates the long-term macroeconomic adjustments in response to OP shocks in NOP countries, such effects in NOC countries' responses are summarized as follows: first, the individually-averaged statistics for *CPI* is not statistically significant, while the pooled cross-sectional statistics are strongly significant. The reason might be the normalisation of the *G*-statistic which causes frequent rejection of the null hypothesis. Second, *RER* and *MA* do not exhibit a long-term relationship with *OP*. This finding is consistent with the current literature. Finally,

both individually-averaged and pooled cross-sectional statistics strongly reject the null of no co-integration for *IP* in NOC countries. This finding indicates that in spite of domestic oil production in some NOC countries, their *IP* is strongly influenced by global *OP*.

On the other hand, *OP* is co-integrated with *IR* and *SP* within both NOC and NOP countries. Both individually-averaged and pooled cross-sectional statistics are reported to be statistically significant. However, *SP* in NOP countries is only panel co-integrated with *OP*.

Table 5.2. Panel co-integration test results (NOC countries)

Dependent variable	Statistic	Value	Z-value	Lags	Result
<i>CPI</i>	G_{τ}	-2.355	-0.036	17.57	Panel co-integration
	G_{α}	-10.811	0.467		
	P_{τ}	-11.513	-6.774*		
	P_{α}	-17.784	-3.819*		
<i>IP</i>	G_{τ}	-3.409	-3.396*	11.29	Co-integration
	G_{α}	-18.833	-2.654*		
	P_{τ}	-8.302	-3.102*		
	P_{α}	-14.359	-2.342**		
<i>RER</i>	G_{τ}	-2.479	-0.366	2.14	No co-integration
	G_{α}	-11.288	0.281		
	P_{τ}	-6.539	-1.086		
	P_{α}	-11.349	-1.042		
<i>MA</i>	G_{τ}	-1.545	2.674	10.86	No co-integration
	G_{α}	-5.220	2.642		
	P_{τ}	-1.117	5.113		
	P_{α}	-1.149	3.359		
<i>SP</i>	G_{τ}	-3.132	-2.492*	24	Co-integration
	G_{α}	-15.228	-1.251***		
	P_{τ}	-7.764	-2.487*		
	P_{α}	-12.472	-1.527***		
<i>IR</i>	G_{τ}	-3.493	-3.667*	16.86	Co-integration
	G_{α}	-20.518	-3.310*		
	P_{τ}	-10.543	-5.664*		
	P_{α}	-32.941	-10.360*		

Note: Lags are AIC optimized. G_{τ} and G_{α} test the null of $\alpha_i = 0$ for all i 's versus the alternative of $\alpha_i < 0$ for at least one i . P_{τ} and P_{α} test the null of $\alpha_i = 0$ for all i 's versus the alternative of $\alpha_i < 0$ for all i 's. *, ** and *** indicate significance at the 1%, 5% and 10% levels, respectively.

5.3.3. Macroeconomic and financial market responses to *OP* shocks

Figure 5.1 summarizes impulse-response test results across NOC countries. The results indicate that *IP* and *IR* exhibit positive and similar responses to *OP* shocks excluding *IP* in Germany and *IR* in Brazil. Furthermore, *SP* displays similar negative responses to *OP* shocks across all countries while there is no similarity in responses of *CPI* to *OP*

shocks. On the other hand, based on impulse-response test results for NOP countries illustrated in Figure 5.2, the negative responses of SP in Norway and Mexico and the positive responses of IR in Canada and Norway to OP shocks are reported to be very similar.

To consider the extent of similarity between sample countries in responding to OP shocks, we calculate correlation coefficients of impulse-responses to OP shocks (see Appendix). The results demonstrate that IR and IP respond to OP shocks with the highest level of similarity, respectively (correlation coefficients of 0.88–0.99 for IP and mostly over 0.9 for IR). Afterwards, the responses of SP to OP shocks are mainly similar. Conversely, CPI responses to OP shocks are reported to be country-specific.

Table 5.3. Panel co-integration test results (NOP countries)

Dependent variable	Statistics	Value	Z-value	Lags	Result
CPI	G_{τ}	-2.709	-0.731	16.33	No co-integration
	G_{α}	-11.307	0.180		
	P_{τ}	-3.969	-0.354		
	P_{α}	-5.804	0.884		
IP	G_{τ}	-2.331	-0.075	9.67	No co-integration
	G_{α}	-7.684	1.102		
	P_{τ}	-2.639	1.166		
	P_{α}	-6.825	0.595		
RER	G_{τ}	-2.408	-0.089	4	No co-integration
	G_{α}	-12.472	-0.117		
	P_{τ}	-4.607	-1.084		
	P_{α}	-15.225	-1.777		
MA	G_{τ}	-0.281	4.444	9.67	No co-integration
	G_{α}	-0.523	2.926		
	P_{τ}	0.431	3.691		
	P_{α}	0.456	2.394		
SP	G_{τ}	-2.725	-0.767	12	Panel co-integration
	G_{α}	-14.887	-0.732		
	P_{τ}	-4.924	-1.447***		
	P_{α}	-15.273	-1.791**		
IR	G_{τ}	-3.389	-2.180*	18	Co-integration
	G_{α}	-18.892	-1.752**		
	P_{τ}	-4.147	-0.558		
	P_{α}	-16.011	-1.999**		

Note: Lags are AIC optimized. G_{τ} and G_{α} test the null of $\alpha_i = 0$ for all i 's versus the alternative of $\alpha_i < 0$ for at least one i . P_{τ} and P_{α} test the null of $\alpha_i = 0$ for all i 's versus the alternative of $\alpha_i < 0$ for all i 's. *, ** and *** indicate significance at the 1%, 5% and 10% levels, respectively.

5.3.4. *Long-term adjustment procedure*

Among co-integrated macroeconomic variables in NOC countries, *CPI* is adjusted toward long-term equilibrium during 3.5 years in average. The monthly *CPI* adjustment speed varies from 4.8 percent in Denmark to 1.1 percent in Italy. Also, *IP* is adjusted toward long-term equilibrium by less than a year which indicates monthly adjustment speed of 8.5 percent in average. Such equilibrium, however, seems unstable regarding Figure 5.1.

On the other hand, the financial markets of NOC and NOP countries are adjusted toward long-term equilibrium quite similarly: where 3–10 percent of *SP* disequilibrium is adjusted monthly within NOC countries, 3–6 percent of such disequilibrium is adjusted each month in NOP countries. In addition, *IR* is adjusted toward long-term equilibrium in less than 1.5 years in average within both NOC and NOP countries. Thus, no gap is evident in adjustment speed of NOP and NOC countries' financial markets toward long-term equilibrium with OP.

5.4. Conclusions

Our findings indicate that firstly, where there is no evidence confirming the existence of panel co-integrated relationship between OP and macroeconomy of NOP countries, such linkages are reported to be significant across NOC countries. Secondly, the financial markets of both groups of countries are in long-term co-integrated relationship with OP. The results demonstrate that the financial markets respond to OP shocks very similarly. Finally, long-term adjustment speed of financial markets toward long-term equilibrium is identical across both panels. Additionally, in NOC countries, where *CPI* is adjusted toward long-term equilibrium during 3.5 years in average, *IP* needs less than a year to be adjusted in response to the OP shocks. For further study, it is recommended to consider nonlinear effects of OP on macroeconomy and financial markets as well as domestic oil prices, particularly in NOP countries.

Figure 5.1. Impulse-responses to OP shock and their 95 percent level of confidence (NOC countries)
CPI

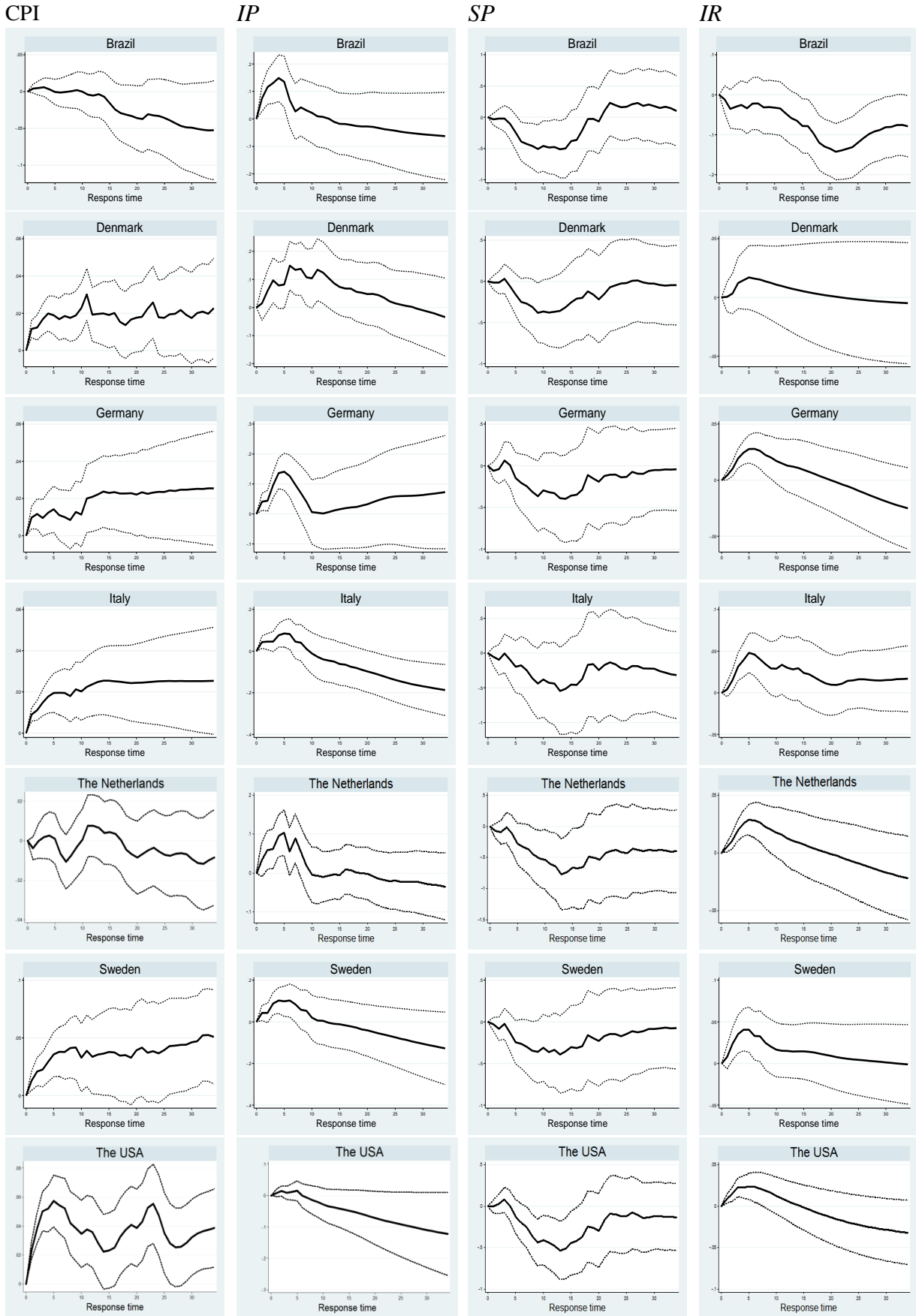
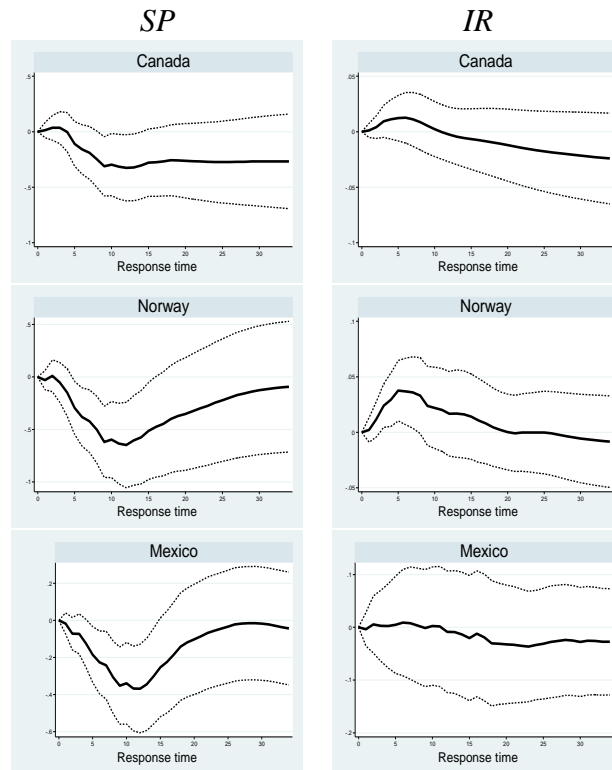


Figure 5.2. Impulse-responses to OP shock and their 95 percent level of confidence (NOP countries)



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Appendix

Table I. Correlation coefficients of impulse-responses for *CPI*

	Brazil	Denmark	Germany	Italy	Netherlands	Sweden	USA
Brazil	1						
Denmark	-0.1700	1					
Germany	-0.8511	0.30142	1				
Italy	-0.7237	0.45246	0.8729	1			
Netherlands	0.63498	0.17305	-0.2008	-0.1788	1		
Sweden	-0.7218	0.47660	0.62034	0.76732	-0.5107	1	
USA	0.24805	0.09687	-0.4102	-0.2401	-0.1288	-0.0890	1

Table II. Correlation coefficients of impulse-responses for *IP*

IP	Brazil	Denmark	Germany	Italy	Netherlands	Sweden	USA
Brazil	1						
Denmark	0.59372	1					
Germany	0.43132	-0.0715	1				
Italy	0.92589	0.80713	0.26784	1			
Netherlands	0.90768	0.61050	0.55706	0.90623	1		
Sweden	0.90968	0.83675	0.28310	0.99196	0.90770	1	
USA	0.93119	0.78705	0.18688	0.99061	0.88109	0.97873	1

Table III. Correlation coefficients of impulse-responses for *SP*

	Brazil	Denmark	Germany	Italy	Netherlands	Sweden	USA	Canada	Norway	Mexico
Brazil	1									
Denmark	0.91849	1								
Germany	0.83998	0.90595	1							
Italy	0.65466	0.75138	0.85242	1						
Netherlands	0.48782	0.68766	0.82504	0.88395	1					
Sweden	0.88328	0.94398	0.96031	0.77583	0.75127	1				
USA	0.78252	0.90319	0.95201	0.90792	0.91306	0.90851	1			
Canada	0.08452	0.39543	0.51769	0.67931	0.83578	0.44222	0.63993	1		
Norway	0.82115	0.93933	0.93335	0.75495	0.79816	0.95781	0.93039	0.54634	1	
Mexico	0.96153	0.96307	0.87765	0.71697	0.59868	0.93227	0.84927	0.26478	0.91623	1

Table IV. Correlation coefficients of impulse-responses for *IR*

	Brazil	Denmark	Germany	Italy	Netherlands	Sweden	USA	Canada	Norway	Mexico
Brazil	1									
Denmark	0.68375	1								
Germany	0.61198	0.96817	1							
Italy	0.69697	0.88569	0.76717	1						
Netherlands	0.65613	0.98004	0.99679	0.79721	1					
Sweden	0.65002	0.93692	0.91353	0.82837	0.92812	1				
USA	0.75142	0.95087	0.97143	0.75707	0.98059	0.92512	1			
Canada	0.73969	0.95430	0.96800	0.76386	0.97950	0.94243	0.99522	1		
Norway	0.71254	0.98974	0.95403	0.90971	0.96817	0.93390	0.94206	0.94825	1	
Mexico	0.93294	0.85320	0.81701	0.78909	0.84840	0.8279	0.90696	0.90104	0.87530	1

Chapter 6. Nonlinear macroeconomic effects of global oil price fluctuations

Part I

What follows is the author-manuscript (pre-print) version of the paper reproduced in accordance with the copyright policy of the publisher. The original publication is available at <http://dx.doi.org/10.1007/s10368-015-0315-1>. My contribution to this paper involves initial concept and empirical design, collection and analysis of data and preparation of the manuscript.

In this paper, we examine monetary responses to global oil price changes across a panel of seven major net oil consuming countries and three major net oil producing countries using monthly data from January 1986 to August 2013. Employing a variety of linear and nonlinear causality tests, our main findings are as follows. First, oil price movements directly affect monetary aggregates in both net oil consuming and net oil producing countries. Second, nonlinear causality tests reveal strong causal influences from oil prices to monetary aggregates. Third, nonlinear parametric and nonparametric models reveal oil price changes account for significant changes in monetary aggregates in Denmark, Germany, the Netherlands, and the US among net oil consuming countries and in Canada and Mexico among net oil producing countries. Finally, monetary aggregates in these countries respond nonlinearly only to oil price increases.

6.1. Introduction

The study of the effects of oil price changes on economies dates back at least to the early 1970s when the 73/74 oil crisis was associated with severe economic recession throughout much of the world. A large number of studies have considered oil price changes and their possible interaction with other macroeconomic variables (e.g., Barsky and Kilian, 2004; Hamilton, 1996, 2003; Hooker, 1996; Kilian, 2008, 2009; Kilian and Park, 2009). Since then, major oil price shocks have triggered the significant intersectoral reallocation of resources, and afterwards in key

economic variables such as monetary flow (e.g., Davis and Haltiwanger, 2001; Hamilton, 1988; Jones *et al.*, 2004; Keane and Prasad, 1996; Lee and Ni, 2002). Studies that conclude that oil price shocks induce recession through different direct and indirect channels, mostly regard monetary tools as indirect mechanisms for this effect (e.g., Barsky and Kilian, 2004; Bernanke *et al.*, 1997; Cologni and Manera, 2008; Hamilton, 2011; Hooker, 1999). While oil price changes exert significant effects on monetary aggregate, it is proved that the reverse causality is also existent (e.g. Anzuini *et al.*, 2013; Belke *at al.*, 2013; Ratti and Vespignani, 2015; Ratti and Vespignani, 2013a; Ratti and Vespignani, 2013b).

However, few of these existing studies consider these mechanisms in countries outside the US or in oil-exporting countries. For example, oil price decreases positively affect economic activity in oil-importing countries, whereas such effects may be either positive or negative in oil-exporting countries (see e.g., Jiménez-Rodríguez and Sánchez, 2005). As another example, Korhonen and Ledyeva (2010) show that oil-producing countries tend to generally benefit from oil price shocks, while the effects in oil-consuming countries are rather more ambiguous. Consequently, monetary responses to oil price changes may differ for oil importing and exporting countries.

Theoretically, increasing oil prices within oil importing countries leads consumers to expect that such variations are transitory and hence they save less and borrow (and spend) more. The subsequent increase in demand exerts pressure on the price index, in response to which central banks tighten the money supply to control the price level. In oil exporting countries, however, an increase in the oil price is mainly a supply-side change in that the positive income effect of the oil price increase injects money into the economy. Thus, increasing oil prices are contractionary in oil importing countries and expansionary in oil exporting countries. The reverse holds for a decrease in the oil price. However, the empirical evidence supporting these theoretical effects in a combined study of oil consuming and oil producing countries is very limited.

Most studies in this area consider monetary variables as a transmission channel between oil price shocks and the economy (e.g., Barsky and Kilian, 2004; Bernanke and Ilian, 1998; Bernanke *et al.*, 1997; Cologni and Manera, 2008; Hamilton, 2011; Hooker, 1999; Hoover and Perez, 1994; Leduc and Sill, 2004). For instance, Leduc and Sill (2004) showed that monetary policy is responsible for about 40 percent of the reduction in output from an increase in the oil price. However, other studies analysed monetary

responses to the oil price shocks either separately or associated with other related variables, such as interest or exchange rates (e.g., Abderrezak, 2005; Balke *et al.*, 1998; Jones *et al.*, 2004; Lee *et al.*, 2001; Leeper and Zha, 2003; Miguel *et al.*, 2009; Wu and Ni, 2011). All these findings justify the importance of implementing monetary policy in association with oil price volatility.

However, a few studies have considered the causal effects of the oil price changes on monetary factors. In seminal work, Bernanke *et al.* (1997) used vector auto-regressive (VAR) specifications to show that the US monetary response to oil price shocks was more significant than any other economic variable, concluding that it was the monetary changes which causes the declines in GDP growth, not the oil price shocks themselves. Likewise, Lee *et al.* (2001) found that monetary tightening resulting from oil price shocks was responsible for 30–50 percent of the negative changes in Japanese output. Wu and Ni (2011) concluded that the oil price Granger caused monetary aggregates in the US, arguing that as the monetary responses to the oil price changes take some time, finding the proper lag order was very important.

Not all studies confirm the existence of meaningful relationships between oil price changes and monetary factors. Hamilton and Herrera (2004), in criticizing Bernanke *et al.* (1997), showed that the potential for monetary policy to avert the contractionary consequences of oil price shocks was not as great as Bernanke *et al.* (1997) suggested. Hamilton and Herrera (2004), Carlstrom and Fuerst (2006) also rejected the argument in Bernanke *et al.* (1997), showing that under neutral monetary policy, the entire output reduction associated with oil prices is due only to the oil price changes, and none of the declines is attributable to monetary policy. Finally, Abderrezak (2006) found no evidence of causation between oil price shocks and the money supply in Algeria. What we can conclude based on this rather mixed evidence is that further study is of great importance, especially as multicountry studies including both oil importers and oil exporters.

In this paper, we consider this question from several different perspectives. First, we use the notion of net oil consumption and net oil production instead of oil importing and oil exporting to identify countries. We believe this is a more nuanced way to identify the monetary effects of oil price shocks. For instance, based on International Energy Agency (IEA) figures, Canada produces more oil than Mexico and Mexico produces more oil than Norway. However, in terms of the oil production share of GDP, these

countries would be ordered Norway, Mexico and Canada, while Norway exports more oil than Mexico and Mexico exports more oil than Canada. Likewise, the order of net oil consuming countries is not necessarily the same as their oil-importing ranking. We consider that such indices separate major net oil importers and exporters better as is based on both their exporting and importing behaviour and domestic consumption and production.

Second, we conduct both linear and nonlinear causality tests to identify any possible causal relationships between our sample variables. Although we start with traditional linear causality tests, the restrictive assumptions of linearity make these models inefficient in uncovering certain nonlinear causal relations, and hence, we are unable to detect all possible causal relations. Furthermore, a significant part of the literature allows for nonlinear causal relationships between the macroeconomic variables (e.g. Baek and Brock, 1992; Bell *et al.*, 1996; Chen *et al.*, 2004; Hiemstra and Jones, 1994; Hiemstra and Kramer, 1997; Li, 2006; Skalin and Teräsvirta, 1999).

Finally, as the direction of oil price change in the studied series has a significant effect on any causal relationships, we test this using the asymmetric version of the modified Mackey and Glass (1977) model. The results suggest that monetary aggregates respond to oil price changes asymmetrically, in both net oil consuming and net oil producing countries. That is, only positive changes in oil prices induce a significant nonlinear influence on monetary aggregates.

The remainder of the paper is organised as follows: Section 2 describes the data. Section 3 provides the initial empirical results for conventional country-specific causality tests. Section 4 outlines the methodology of our modified parametric and nonparametric nonlinear causality models and presents the results. Section 5 presents the concluding remarks.

6.2.Data

Our sample data consist of oil prices and monetary aggregates in selected net oil consuming and net oil producing countries for the period January 1986–August 2013. Our sample selection criterion is the net oil production (consumption) share of GDP. Calculating this index for a wide range of oil-exporter and oil-importer countries and considering the availability of data, we identify the US, Brazil, Denmark, Italy,

Germany, the Netherlands, and Sweden as major net oil consuming countries and Canada, Mexico and Norway as major net oil producing countries.

As a proxy for monetary aggregates (*MA*), following Jiménez-Rodríguez (2011), we use seasonally adjusted narrow money (M1), collected from the Organization for Economic Co-operation and Development (OECD) for Canada, Denmark, Mexico, Norway, Sweden, Brazil and the US. For Germany and Italy, we use statistics from the Deutsche Bundesbank and Banca d'Italia websites, respectively. We also collect M3 (as a proxy for M1) for Netherlands from the De Nederlandsche Bank. The monetary aggregate series for the last three countries are seasonally adjusted using X12-ARIMA method of the US Census Bureau. We deflate our data using domestic consumer price indices (CPI) from the OECD, and then index this series using the monthly-averaged 2010 series as the base year. The available data periods are shorter for Brazil, Italy, Sweden and Norway, with the sample period for Brazil commencing in August 1994, September 1997 for Italy, February 1998 for Sweden and December 1992 for Norway.

As a proxy for the world oil price index (*OP*), we use monthly oil prices of West Texas Intermediate (WTI) crude oil, a very widely used oil pricing benchmark, not least given its strong correlation with the major other crude oil prices (Brent and Dubai) (Wang *et al.*, 2013). We collect WTI price data from the World Bank website. Then, using the monthly US CPI index, collected from the OECD website, we calculate inflation-adjusted real oil prices. Finally, we index the oil prices using the monthly-averaged 2010 prices.

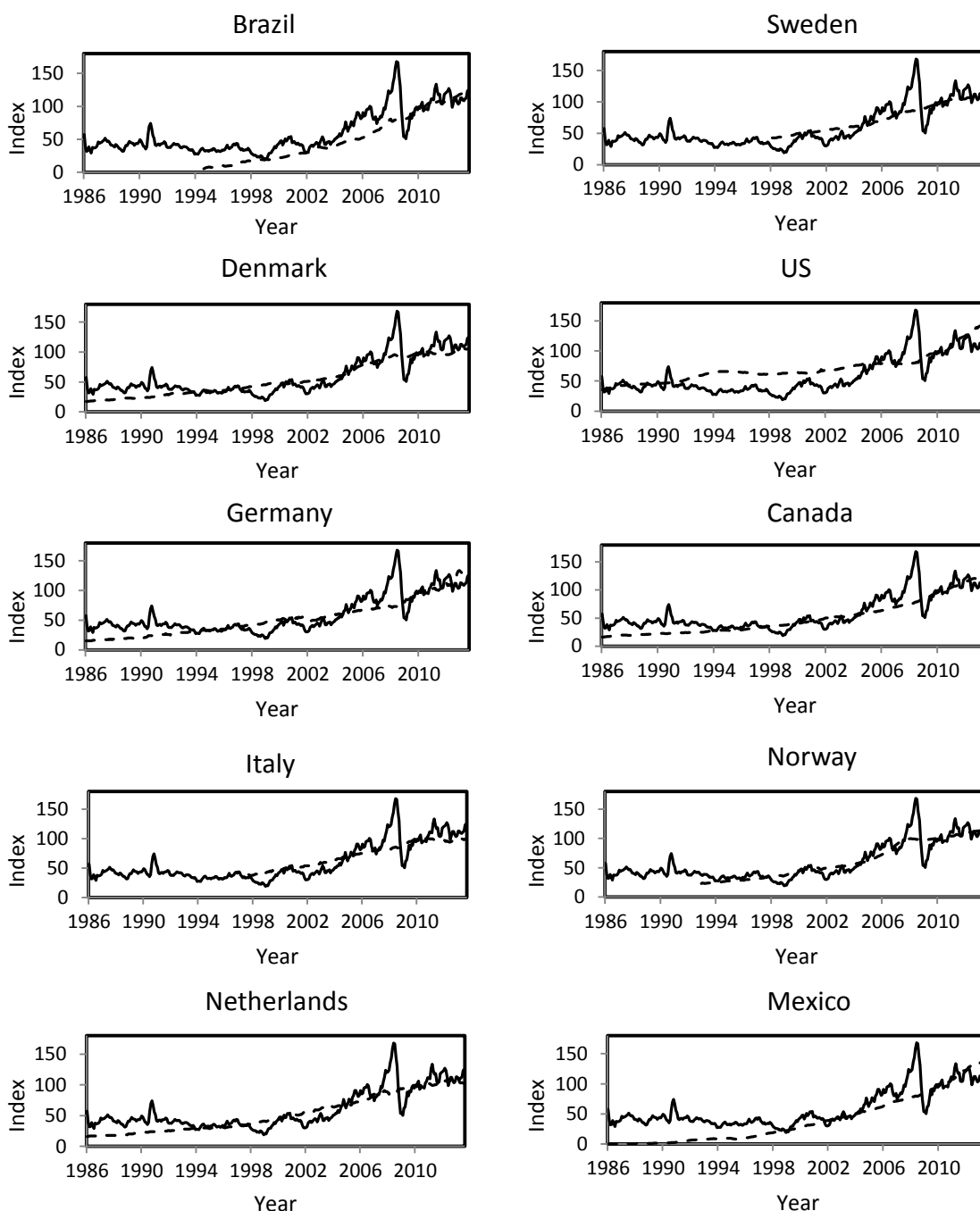
Table 6.1. Selected statistics

Country	Mean		SD	
	Level	Difference	Level	Difference
<i>MA</i>				
Brazil	51.6039	0.5342	36.0061	0.7271
Denmark	36.9659	0.1969	32.1917	0.4409
Germany	45.6237	0.2853	30.9992	1.2279
Italy	72.3281	0.3193	20.8163	1.0144
Netherlands	49.4390	0.2418	30.9713	1.0433
Sweden	74.4005	0.3978	22.2382	0.4821
US	52.6246	0.2575	31.4098	0.6453
Canada	34.9059	0.2414	32.3588	0.3685
Norway	63.3409	0.3766	30.5047	0.5909
Mexico	36.7579	0.3937	40.5727	0.5700
<i>OP</i>	59.2783	0.2042	31.7885	5.5322

Note: This table provides statistics for the sample data. WTI real oil price deflated by US CPI. Country-specific monetary aggregate (*MA*) series are seasonally adjusted and deflated using domestic CPIs. Data are monthly and indexed to constant inflation-adjusted 2010 year.

Table 6.1 presents statistics for the above data. As shown, the average monetary aggregate index ranges from 34.9 equivalents for Canada to 74.4 equivalents for Sweden. We also plot the time variations of the global oil price and monetary aggregate indices in Figure 6.1. We find that the chosen monetary aggregate and the global oil

Figure 6.1. Oil prices and monetary aggregates by country



Note: This figure depicts WTI real oil price (solid lines) deflated by US CPI. Country-specific monetary aggregate (dashed lines) are seasonally adjusted and deflated using domestic CPIs. The time dimension is shorter for Brazil, Italy, Sweden and Norway; it starts from August 1994, September 1997, February 1998 and December 1992, respectively.

price exhibit similar trends over time for all of the sample countries. This suggests potential causal relationships between the two variables.

6.3. Traditional linear causality test

To conduct the country-specific traditional linear causality test, we first need to consider our sample data order of integration. As a prerequisite, all data should be $I(0)$. Table 6.2 provides the results of the Augmented Dicky–Fuller (ADF) and Philips–Perron (PP) unit root tests. The ADF and PP tests indicate that the oil prices and monetary aggregates are integrated of order one, but their first differences are stationary. However, as the ADF and PP unit root tests are known to suffer potentially severe finite sample power and size problems (e.g., DeJong, 1992; Schwert, 1989), we employ additional unit root tests to check the robustness of the ADF and PP results, namely, the generalised least squares Dicky–Fuller (DF-GLS) test. Other than Italy, we find evidence of nonstationary oil prices and monetary aggregates in levels while their first difference values are stationary. The test results show that our data series for all of sample countries, excepting Italy, are stationary in first differences.

Table 6.2. Unit root tests

Country	ADF		DF-GLS		PP	
	Level	Fist difference	Level	Fist difference	Level	First difference
<i>Unit root test for MA</i>						
Brazil	4.564	-9.139***	-0.357	-2.551*	3.370	-9.036***
Denmark	5.447	-13.912***	-0.360	-4.460***	3.446	-14.176***
Germany	3.114	-18.687***	-0.057	-3.372 **	2.719	-18.939***
Italy	-0.933	-18.974***	-2.853*	-1.408	-1.013	-18.730***
Netherlands	0.841	-19.351 ***	-1.165	-2.231*	0.860	-19.350***
Sweden	2.615	-9.296***	-0.596	-3.251*	2.258	-9.013***
US	7.995	-18.974***	-1.268	-3.406**	6.068	-20.179***
Canada	18.813	-13.019***	-0.634	-2.555*	16.917	-13.628***
Norway	2.040	-8.994***	-1.654	-2.554*	1.230	-8.971***
Mexico	15.072	-8.590***	-0.188	-3.108**	11.543	-8.618***
<i>Unit root test for OP</i>	-0.905	-12.852***	-1.172	-2.571*	-1.563	-12.833***

Note: This table provides the results of the unit root tests for the monetary aggregate (MA) and global oil price (OP) for each country. The test statistics report rejection or acceptance of the null hypothesis of no Granger causality. T-test statistic used for ADF and PP tests and tau-test statistic used for DF-GLS test with proper lag order selected by Schwarz criterion. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

Table 6.3 reports the results of country-specific traditional Granger causality tests for the oil price and monetary aggregate relationship. The results indicate that global oil prices influence monetary aggregate of both net oil consuming and producing countries linearly in the same direction. The test statistics are significant, mainly at the 1 percent level. However, there is no evidence to confirm the causal effects of global oil price changes on the monetary aggregate in Brazil. The only difference could be found in

causal relations between two panels of countries is that such relations are reported to be unidirectional within net oil producing countries while they are mostly bidirectional across net oil consuming countries. It seems that monetary changes in net oil consuming countries exhibit statistically significant causation over global oil price changes. One possible answer is the differences in the role of monetary change in the market. Given that consumers in net oil consuming countries consider oil price changes transitory, monetary reactions to oil price changes motivates aggregate demand. If such variations induce changes in productions of oil-intensive industries, there would be the possibility of exerting pressure on oil prices due to high demand for oil. Concerning above assumptions, the monetary causal effects on global oil price movements in net oil producing countries, however, seems to be less. The findings are consistent with Bernanke *et al.* (1997), Leduc and Sill (2004), Lee *et al.* (2001) and Wu and Ni (2011) in both net oil consuming and net oil producing countries. However, given our evidence implying the significant effects of global oil price changes on monetary aggregates in the US and other net oil consuming countries, our results do not align with those in Abderrezak (2006), Carlstrom and Fuerst (2006) and Hamilton and Herrera (2004).

Table 6.3. Traditional country-specific linear causality tests

Causality	$\Delta OP \rightarrow \Delta MA$			$\Delta MA \rightarrow \Delta OP$		
	Test statistic (chi-square)	p-value	Result	Test statistic (chi-square)	p-value	Result
Brazil	5.3993	0.494	Noncausality	21.91***	0.001	Causality
Denmark	19.143**	0.038	Causality	19.631**	0.033	Causality
Germany	37.831***	0.000	Causality	18.671***	0.005	Causality
Italy	7.260*	0.064	Causality	4.095	0.663	Noncausality
Netherlands	31.011***	0.000	Causality	9.759	0.135	Noncausality
Sweden	10.935**	0.050	Causality	10.331**	0.066	Causality
US	25.495***	0.000	Causality	6.1447	0.407	Noncausality
Canada	45.381***	0.000	Causality	17.707	0.125	Noncausality
Norway	12.929**	0.044	causality	7.4016	0.285	Non-causality
Mexico	17.821**	0.037	causality	4.3872	0.884	Non-causality

Note: This table presents the results for traditional linear Granger causality tests. The null hypothesis is non-causality. ** and *** indicate significance at the 5% and 1% level, respectively.

Although our findings modify the existence of linear causation between global oil price changes and domestic monetary aggregates, there is still the possibility of nonlinear causation among these variables. Because of linearity assumptions in traditional Granger causality test, this model would not reveal certain nonlinear causations among variables. As Baek and Brock (1992), Bell *et al.* (1996), Chen *et al.* (2004), Hiemstra and Jones (1994), Hiemstra and Kramer (1997), Li (2006) and Skalin and Teräsvirta (1999) recommend, further nonlinear causality tests may reveal more detailed

information about the nature of causation among the macroeconomic variables. In the following section, we consider nonlinear causality between our variables using two different models.

6.4. Nonlinear causality tests

The traditional Granger causality approach previously used compares the prediction errors obtained by a model that relates oil price changes to past and current values of both the monetary aggregate and the oil price. The advantage of this approach is its simplicity. However, two disadvantages are common. First, parametric tests require an important assumption regarding the linearity of the regression structure even though there is considerable evidence for nonlinearity among macroeconomic variables (see e.g., Chiou-Wei *et al.*, 2008; Lee and Chang, 2007; Seifritz and Hodgkin, 1991). Second, because of the sensitivity of the prediction errors from linear Granger causality tests to causality in the mean, higher order structures, such as conditional heteroscedasticity, are usually precluded (Ajmi *et al.*, 2013). Thus, nonlinear causality tests can better clarify the nature of the causal relationships between the variables. We employ two nonlinear Granger causality approaches. The first is a nonparametric model, introduced by Baek and Brock (1992) and modified by Hiemstra and Jones (1994). The second is a parametric model following Mackey and Glass (1977), modified by Kyrtsov and Labys (2006).

6.4.1. Nonparametric model

Our nonparametric nonlinear approach draws on Baek and Brock (1992). This method assumes that the variables are mutually independent and identically distributed. As this assumption seems quite restrictive in not considering time dependence, Hiemstra and Jones (1994) modified the model to include short-term temporal dependence in variables. Denote that m -length lead vector of MA_t by MA_t^m and the Lma -length and Lop -length lag vectors of MA_t and OP_t by MA_{t-Lma}^{Lma} and OP_{t-Lop}^{Lop} . Thus:

$$\begin{aligned}
 MA_t^m &= (MA_t, MA_{t+1}, \dots, MA_{t+m-1}) \\
 MA_{t-Lma}^{Lma} &= (MA_{t-Lma}, MA_{t-Lma+1}, \dots, MA_{t-1}) \\
 OP_{t-Lop}^{Lop} &= (OP_{t-Lop}, OP_{t-Lop+1}, \dots, OP_{t-1})
 \end{aligned} \tag{6.1}$$

where $m = 1, 2, \dots$; $t = 1, 2, \dots$; $Lma = 1, 2, \dots, t$ and $Lop = 1, 2, \dots, t$. In the case of MA , $t = Lma + 1, Lma + 2, \dots$ and in case of OP , $t = Lop + 1, Lop + 2, \dots$. Based on definition delivered by Hiemstra and Jones (1994), for given values of $m, Lma, Lop \geq 0$ and for $e > 0$, OP does not strictly Granger cause MA if:

$$\begin{aligned} & \Pr(\|MA_t^m - MA_s^m\| < e \mid \|MA_{t-Lma}^{Lma} - CPI_{s-Lma}^{Lma}\| < e, \|OP_{t-Lop}^{Lop} - OP_{s-Lop}^{Lop}\| < e) \\ & = \Pr(\|MA_t^m - MA_s^m\| < e \mid \|MA_{t-Lcpi}^{Lma} - MA_{s-Lcpi}^{Lma}\| < e) \end{aligned} \quad (6.2)$$

where $\Pr(\cdot)$ denotes the probability and $\|\cdot\|$ refers to the maximum norm. The left-hand side of Equation 6.2 contains a conditional probability explaining two arbitrary m -length lead vector of MA_t within a distance e of each other when corresponding Lma -length lag vectors of MA_t and Lop -length lag vectors of OP_t are given. The right-hand side of Equation 6.2 describes the conditional probability that two arbitrary m -length lead vectors of MA_t are within a distance e of each other where their corresponding Lma -length lag vectors within a distance e of each other are given. It is worth noting that for bivariate observable series (OP_t and MA_t), $t = 1, \dots, T$, the Hiemstra–Jones test consists of choosing a value between 0.5 and 1.5 after normalizing the series to obtain unit variance. This allows us to estimate the conditional probabilities in Equation 2 as ratios of the unconditional probabilities. To test the nonlinear noncausality hypothesis presented in Equation 6.2, Hiemstra and Jones (1994) use the following statistic, which has an asymptotic normal distribution:

$$\begin{aligned} & \sqrt{n} \left(\frac{C_1(m + Lma, Lop, e, n)}{C_2(Lma, Lop, e, n)} - \frac{C_3(m + Lma, e, n)}{C_4(Lma, e, n)} \right) \\ & \sim N(0, \sigma^2(m, Lma, Lop, e)) \end{aligned} \quad (6.3)$$

where $n = T + 1 - m - \max(Lma, Lop)$, and C_1, C_2, C_3 and C_4 are correlation integral estimators of the joint probabilities in Equation 6.2 and σ^2 is estimated based on the theory of the U-statistic for weakly dependent processes as measured by Denker and Keller (1983). This test statistic is applied to the estimated residuals of the bivariate VAR model, which employs MA and OP . The test statistic, which is used to examine the null hypothesis, states that the oil price does not nonlinearly and strictly Granger-cause the monetary aggregate. As Hiemstra and Jones (1994) and Kanas and Ma (2000) show, this model has a very good power in estimating nonlinear Granger causal and noncausal relationships.

To implement the nonparametric nonlinear causality test for the monetary aggregate and oil price, we first need to determine the values of the lead lengths, the lag lengths and the common scale e . Following Hiemstra and Jones (1994) and relying on the results of their Monte Carlo simulation, we set the values as $m = 1$, lag length = 1, ..., 8 and e

Table 6.4. Nonparametric (Hiemstra–Jones) nonlinear causality tests

Lags	OP → MA		MA → OP		Lags	OP → MA		MA → OP	
	CS	TVAL	CS	TVAL		CS	TVAL	CS	TVAL
Brazil					Sweden				
1	0.0068	0.1009	0.0085	0.1257	1	0.0181	0.2383	-0.0094	-0.1244
2	0.0117	0.1724	0.0103	0.1520	2	0.0344	0.4514	-0.0122	-0.1607
3	0.0127	0.1853	0.0136	0.1989	3	0.0364	0.4766	0.0016	0.0210
4	0.0127	0.1853	0.0226	0.3293	4	0.0554	0.7236	0.0137	0.1786
5	0.0126	0.1832	0.0294	0.4282	5	0.0618	0.8036	0.0220	0.2872
6	0.0163	0.2374	0.0361	0.5240	6	0.0564	0.7318	0.0486	0.6309
7	0.0215	0.3115	0.0450	0.6518	7	0.0594	0.7677	0.0841	1.0872
8	0.0251	0.3626	0.0528	0.7615	8	0.0563	0.7255	0.1208	1.5567*
Denmark					US				
1	0.0196	0.3503	0.0226	0.4031	1	0.0632	1.1376	0.0561	1.0107
2	0.0949	1.6913**	0.0377	0.6713	2	0.1071	1.9265**	0.0956	1.7184**
3	0.1333	2.3701***	0.0501	0.8921	3	0.1355	2.4315***	0.1003	1.7998**
4	0.1525	2.7074***	0.0350	0.6215	4	0.1510	2.7059***	0.0972	1.7425**
5	0.1504	2.6661***	0.0172	0.3048	5	0.1471	2.6318***	0.0833	1.4914*
6	0.1482	2.6222***	-0.0056	-0.0990	6	0.1344	2.4006***	0.0708	1.2651
7	0.1624	2.8697***	-0.0293	-0.5190	7	0.1223	2.1826**	0.0561	1.0007
8	0.1757	3.0999***	-0.0504	-0.8895	8	0.1143	2.0354**	0.0433	0.7722
Germany					Canada				
1	0.0437	0.7805	0.0412	0.7350	1	0.0552	0.9891	0.0265	0.4742
2	0.0839	1.4943*	0.0560	0.9981	2	0.0912	1.6289*	0.0505	0.9021
3	0.1359	2.4173***	0.0826	1.4686*	3	0.1003	1.7901**	0.0478	0.8532
4	0.1558	2.7656***	0.1001	1.7767**	4	0.0822	1.4647*	0.0450	0.8017
5	0.1541	2.7315***	0.1012	1.7950*	5	0.0688	1.2234	0.0421	0.7498
6	0.1386	2.4525***	0.0935	1.6555**	6	0.0516	0.9174	0.0285	0.5059
7	0.1261	2.2276**	0.0827	1.4615*	7	0.0404	0.7167	0.0444	0.7882
8	0.1124	1.9824**	0.0696	1.2290	8	0.0338	0.5986	0.0646	1.1444
Italy					Norway				
1	0.0063	0.0865	-0.0036	-0.0500	1	0.0234	0.3648	0.0148	0.2304
2	0.0074	0.1005	0.0154	0.2086	2	0.0728	1.1285	0.0165	0.2562
3	0.0048	0.0647	0.0165	0.2235	3	0.0997	1.5413*	0.0216	0.3353
4	0.0041	0.0559	0.0131	0.1764	4	0.1282	1.9781**	0.0523	0.8081
5	-0.0288	-0.3869	0.0108	0.1460	5	0.1490	2.2948**	0.0758	1.1669
6	-0.0494	-0.6615	0.0229	0.3074	6	0.1467	2.2543**	0.0882	1.3550*
7	-0.0796	-1.0620	0.0263	0.3514	7	0.1331	2.0413**	0.1105	1.6943**
8	-0.1055	-1.4042	0.0038	0.0514	8	0.1089	1.6664	0.1294	1.9799**
Netherlands					Mexico				
1	0.0482	0.8686	0.0614	1.1062	1	0.0550	0.9857	0.0690	1.2372
2	0.1095	1.9683**	0.1161	2.0872**	2	0.1023	1.8305**	0.1069	1.9123**
3	0.1371	2.4613***	0.1368	2.4561***	3	0.1136	2.0296**	0.1060	1.8934**
4	0.1437	2.5758***	0.1330	2.3839***	4	0.1086	1.9376**	0.0952	1.6988**
5	0.1398	2.5020***	0.1015	1.8168**	5	0.1039	1.8508**	0.0698	1.2445
6	0.1393	2.4882***	0.0766	1.3690*	6	0.0900	1.6008	0.0430	0.7661
7	0.1366	2.4368***	0.0458	0.8174	7	0.0791	1.4045	-0.0036	-0.0654
8	0.1260	2.2441**	0.0264	0.4705	8	0.0738	1.3084	-0.0325	-0.5773

Note: This table reports the results of the nonparametric nonlinear Baek and Brock (1992) test, as modified by Hiemstra and Jones (1994). CS and TVAL are the differences between the conditional probabilities and the standardized test statistics, respectively. Canada, Norway and Mexico are net oil producer countries and the remainder are net oil consumer countries. *, ** and *** indicate significance at the 10%, 5% and 1% level, respectively.

$=1.5\sigma$. Then, we apply the model again by employing the residuals of a bivariate VAR model including the monetary aggregate and the oil price. Table 6.4 presents the results.

The results indicate that in both panels, there is evidence demonstrating the nonlinear causal effects of oil price changes on the monetary aggregates. This is evident in all of the net oil producing countries and nearly half of the sample net oil consuming countries. Consequently, it appears more likely that the causal effects of global oil price changes on monetary aggregates are nonlinear in net oil producing countries as against net oil consuming countries. Table 6.4 shows that the nonlinear causal effects of the oil price changes on monetary aggregates are evident in Germany, the Netherlands, and the US. The relevant test statistics are highly significant and demonstrate that the causal effects of the oil price changes on the monetary aggregates are persistent for 7 months with a 2-month lag. In the net oil producing countries, bilateral causation is evident in Norway and Mexico. In this case, the causation of global oil price changes on the monetary aggregate is persistent for 5 months with a 3-month lag in Norway and 4 months with a 2-month lags in Mexico.

There is also strong evidence demonstrating unilateral nonlinear causality among net oil consuming countries for Denmark and among net oil producing countries for Canada. The nonlinear causal effects of the oil price changes in Denmark, which are mostly significant at the 1 percent level, persist for 7 months. Such evidence is also evident, although weaker, at the 10 percent level in Canada with a 2-month lag and persistent for 3 months.

Altogether, the nonparametric nonlinear causality tests reveal that there is stronger evidence in net oil producing countries concerning nonlinear causal relationships between global oil price changes and monetary aggregates. Furthermore, the nonlinear effects of global oil price changes on monetary aggregates are persistent over the longer term in net oil consuming countries. It thus seems that contrary to Carlstrom and Fuerst (2006) and Hamilton and Herrera (2004), monetary policy has widely been used in both most net oil consuming and net oil producing economies in response to oil price movements.

6.4.2. Parametric model

The nonparametric nonlinear causality test implemented provides strong evidence of the unilateral and bilateral causal relationships between oil prices and monetary aggregates

within some net oil consuming and producing countries. The results are strong enough in themselves to confirm the existence of such direct causation. However, to capture asymmetry among the causal relationships and to confirm the nonparametric nonlinear test results, we also use a parametric model. The test is similar to the linear Granger causality test. However, it contains the Mackey–Glass model process with special parameters estimated using ordinary least squares method. In order to examine the existence of nonlinear causality between oil price changes and consumer price index, we start with the following models:

$$DOP_t = \alpha_{11} \frac{DOP_{t-\tau_1}}{1 + DOP_{t-\tau_1}^{c_1}} - \delta_{11} DOP_{t-1} + \alpha_{12} \frac{DMA_{t-\tau_2}}{1 + DMA_{t-\tau_2}^{c_2}} - \delta_{12} DMA_{t-1} + \varepsilon_t \quad (6.4)$$

$$DMA_t = \alpha_{21} \frac{DOP_{t-\tau_1}}{1 + DOP_{t-\tau_1}^{c_1}} - \delta_{21} DOP_{t-1} + \alpha_{22} \frac{DMA_{t-\tau_2}}{1 + DMA_{t-\tau_2}^{c_2}} - \delta_{22} DMA_{t-1} + u_t \quad (6.5)$$

where DMA_t and DOP_t are the first differences of the monetary aggregate and the oil price, respectively. Also, $\tau = \max(\tau_1, \tau_2)$ is the calculated integer delays, c is the constant and $t = \tau, \tau + 1, \dots, N$. The parameters α and δ , indicate the linear and nonlinear effects of the causal variable on dependent variable, respectively. Finally, the two error terms u_t and ε_t are assumed to be $N(0, I)$. We select the integer delays τ_i and constants c_i prior to the model estimation using the Schwarz criterion and likelihood ratio. If the oil price is defined to nonlinear Granger cause the monetary aggregate, α_{11} should be significantly different from zero (the null hypothesis). Thus, we need to estimate each equation once with no constraint and once with the constraint of a zero value for α_{11} (and α_{22}). Assuming $\hat{\vartheta}$ and $\hat{\mu}$ are the residuals of the unconstrained and constrained Mackey–Glass models, respectively we calculate a Fisher-distributed statistic as below:

$$S_F = \frac{(S_c - S_u)/n_c}{S_u/(T - n_u - 1)} \sim F(n_c, T - n_u - 1) \quad (6.6)$$

where $S_u = \sum_{t=1}^T \hat{\vartheta}^2$, $S_c = \sum_{t=1}^T \hat{\mu}^2$, $n_u=4$ due to existence of four parameters in the Mackey–Glass model and $n_c = 1$ because there is one parameter needed to be zero when estimating constrained model. To conduct the parametric nonlinear Mackey–Glass

test, we first need to select the models' parameters using Schwarz criterion and likelihood ratio. Table 6.5 details the results.

The first and the second columns in Table 6.5 indicate the lag orders employed in Equations 6.4 and 6.5. The third and fourth columns in this same table provide the powers used in Equations 6.4 and 6.5. The lag lengths in terms of the effects of the oil price changes on the monetary aggregates range from 3 months in Sweden and Italy to 9 months in Canada and Mexico. These lags have important implications for policy decision makers when considering the time needed for the monetary aggregate to respond to the oil price change. This delay in the net oil producing countries seems to be slightly longer than in the net oil consuming countries, from an average of nearly 8 months in the former compared with nearly 5 months on average in the latter. We use the estimated lag orders as preestimates when estimating Equations 6.4 and 6.5.

Table 6.5. Parameter-prior selection in the M–G model

Country	τ_1	τ_2	c_1	c_2
Brazil	5	1	4	7
Denmark	5	1	1	1
Germany	5	1	10	10
Italy	3	1	5	1
Netherlands	6	1	10	2
Sweden	3	1	3	8
US	6	1	1	2
Canada	9	1	2	1
Norway	5	1	10	1
Mexico	9	1	3	1

Note: In this table, τ_1 and τ_2 are the optimal integer delay variables for the causality from OP to MA, and for the causality from MA to OP, respectively. c_1 and c_2 are the power of the lagged values of OP and MA, respectively.

The results of our nonlinear parametric causality test presented in Table 6.6 indicate strong unilateral nonlinear causality running from oil price changes to the monetary aggregates. The first point is that the results confirm the outcomes of the nonparametric model, except in the case of Norway. Similar to the nonparametric model, oil price changes Granger cause the monetary aggregate in Denmark, Germany, the Netherlands, and the US. Similar causation in net oil producing countries is significant only for Canada and Mexico. The statistics for net oil producing countries are generally more statistically significant than for the net oil consuming countries. This confirms the nonparametric model results, which indicated that the monetary aggregates in net oil producing countries have great opportunity to respond nonlinearly to global oil price movements. Finally, as opposed to the nonparametric model, reverse nonlinear causation is not evident except in Italy.

Table 6.6. Symmetric nonlinear causality test

Country	H0: OP does not cause MA		H0: MA does not cause OP	
	F-statistic	Probability	F-statistic	Probability
Brazil	0.2212	0.6385	1.5636	0.2124
Denmark	5.4768	0.0198	2.2669	0.1331
Germany	4.6151	0.0012	0.1880	0.9445
Italy	1.0987	0.3585	37.3992	0.0000
Netherlands	4.7036	0.0010	0.4401	0.7796
Sweden	1.3081	0.2542	0.5691	0.4515
US	5.7841	0.0167	0.0371	0.8473
Canada	7.5949	0.0061	2.4086	0.1216
Norway	0.3670	0.5451	1.1678	0.2809
Mexico	9.9967	0.0017	2.2226	0.1369

Considering both parametric and nonparametric models, we now know that global oil price changes nonlinearly affect monetary aggregates in both net oil consuming and producing countries. In the next subsection, we use nonlinear asymmetric tests the effective direction of these changes.

6.4.3. Asymmetric model

Using the parametric nonlinear causality model presented in the last subsection, we now test the asymmetry in the causal effects of global oil price changes on monetary aggregates. To do this, we first separate the positive and negative values in the oil price data. That is, (OP_t, MA_t) is used as an observation in the Mackey–Glass process if $OP_{t-\tau} \geq 0$. We then estimate Equations 6.4 and 6.5 using the separate data. Tables 6.7 and 8 provide the symmetric test results.

Table 6.7. Asymmetric nonlinear causality test for negative changes in the causal variable.

Country	H0: OP does not cause MA		H0: MA does not cause OP	
	F-statistic	Probability	F-statistic	Probability
Brazil	0.1813	0.6712	0.1838	0.6763
Denmark	0.6620	0.4232	0.1069	0.7461
Germany	0.7355	0.5732	0.0189	0.9992
Italy	N/A	...	N/A	...
Netherlands	0.5090	0.7292	0.2323	0.9148
Sweden	0.0510	0.8288	0.6904	0.4089
US	0.3474	0.5606	0.0462	0.8314
Canada	0.3409	0.5601	0.0272	0.8702
Norway	0.9796	0.3246	0.7232	0.4076
Mexico	0.8528	0.3645	0.0349	0.8519

Table 6.7 displays nonlinear monetary responses to the negative global oil price changes. The results show that negative oil price changes have no effect on the monetary aggregates, neither in net oil producing nor in net oil consuming countries. In the case of Italy, there is insufficient data to run Equations 6.4 and 6.5. The results in Table 6.8 signify that the nonlinear causal effect of global oil price changes on monetary aggregates is strongly asymmetric in that only positive oil price changes have

an effect. Such asymmetric responses of monetary aggregates to global oil price changes have important implications for policy decision makers. For instance, as the monetary aggregates respond only to positive oil price changes, the same applies for other monetary variables, such as interest rates. This concurs with the results in Sotoudeh and Worthington (2014) such that the effect of the oil price on the short-term real interest rate is asymmetric and only for positive oil price changes.

Table 6.8. Asymmetric nonlinear causality test for positive changes in the causal variable

Country	H0: OP does not cause MA		H0: MA does not cause OP	
	F-statistic	Probability	F-statistic	Probability
Brazil	0.1292	0.7198	1.5832	0.2097
Denmark	5.2063	0.0232	2.2076	0.1384
Germany	4.2114	0.0061	0.81093	0.5256
Italy	1.2005	0.3256	2.3803	0.000
Netherlands	4.8160	0.0028	0.3655	0.8317
Sweden	1.2150	0.2718	0.0899	0.7647
US	5.7854	0.0167	0.1385	0.7102
Canada	7.9267	0.0054	2.3393	0.1272
Norway	0.1706	0.6801	1.0604	0.3042
Mexico	9.5426	0.0022	2.0201	0.1563

6.5. Conclusion

In this paper, we compared the causal effects of global oil price movements on monetary aggregates in net oil consuming and net oil producing countries. Our results indicated significant linear causality running from global oil price changes to monetary aggregates within both panels of net oil consuming and net oil producing countries. At least some of these, mostly net oil consuming countries, exhibited bilateral causal relationships. However, because of the linearity assumptions in traditional Granger causality tests and given evidence elsewhere of nonlinear causality among macroeconomic variables, these linear causality test results may not be reliable. Consequently, we employed two types of nonlinear causality tests. The interesting point is that while the results of both nonlinear models generally concurred, there are mostly bilateral and rarely unilateral causal relationships between oil price changes and monetary aggregates among both net oil consuming and net oil producing countries. Lastly, using an asymmetric version of the nonlinear parametric model we found that the causal effects of global oil price changes on monetary aggregates are strongly asymmetric, with monetary aggregates responding only to positive oil price changes.

Our findings have important implications as follows. Firstly, although a large body of research focuses on the indirect monetary responses to the inflationary effects of oil price changes, our findings provide strong evidence of the direct causal effects of oil

price changes on monetary aggregates. We confirm that in both net oil producing and net oil consuming countries, oil price changes are directly responsible for changes in monetary aggregates. This is important for policymakers when implementing monetary policy. Secondly, our results show that monetary aggregates respond to oil price changes with a lag of two months or more. This period seems longer in net oil producing countries.

Finally, although we find significant nonlinear causation, mainly from oil price changes to the monetary aggregate in both the net oil consuming and net oil producing countries, we note two important points. To start with, the nonlinear models we applied in this paper provide no guidance on the source of nonlinearities. This may require specifically parameterized structural models. Further, it is not possible to determine whether significant nonlinear predictive power is evidence of positive or negative nonlinear causality. Beside the evidence that nonlinear models presented, it is worth noting that linear causality tests may provide an incorrect assessment of the true relationship between oil price movements and monetary aggregate, which are of nonlinear nature with respect to our results, and may suggest misleading policy actions. For further study, we recommend an even more powerful statistical test, which accounts for not only nonlinearity, asymmetry and time-variations, but also the conditional heteroscedasticity of the VAR model variances.

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Part II

What follows is the submitted article to the Journal of Review of Economic Analysis. At the time of the thesis submission, the article was under editorial review. My contribution to this paper involves initial concept and empirical design, collection and analysis of data and preparation of the manuscript.

In this paper we implement a number of causality tests including linear models and nonlinear nonparametric Hiemstra-Jones and parametric Mackey–Glass to compare the causal relationship between global oil price changes and consumers' cost of living among large net oil consuming and producing countries. Our findings indicate that despite the inconclusive relationships drawn from the extant literature, global oil price affects consumers' cost of living mostly linearly across net oil consuming countries through the country-specific mechanisms. Such effects are reported to be nonlinear in net oil producing countries. Finally, possible nonlinear causations are asymmetric.

6.6.Introduction

Studying the effects of oil price movements on economies date back at least to the 1970's, when global oil price shocks–recessions grounded serious discussions. Through the first generation of studies, researchers analysed macroeconomic aspects of the oil price shocks. Thus, reaction of major macroeconomic variables such as GDP, inflation and interest rates were considered in detail. The inflationary effects of global oil price shocks on recessions have been yet a major subject to discuss. The preface to the subject is studying the recession of 1973 and its possible relation to the first OPEC embargo. Some proven hypotheses suggest that if consumers expect that oil price increases are transitory, they save less and borrow more. Thus, increasing demand lead further upgrade in price level (real balance effect). Monetary tightening following such inflation will contract GDP and recession happens afterwards (Cologni and Manera, 2008). However, others argue that there is not enough evidence to support the inflationary effects of the oil price shocks (see Bohi, 1989; Bohi, 1991; Keane and Prasad, 1996 and Rotemberg and Woodford, 1996). Such diverse outcomes within the literature motivate us to study the behaviour of consumer price index as an indicator showing consumer cost of living against global oil price movements.

A great part of heterogeneous research outcomes is arisen from various methods in estimation, identification of the oil price shocks and sample selection. Additionally, possible distinctions in reaction of oil consuming and oil producing countries to global oil price shocks can be contributed to such heterogeneity. Theoretically, while growth of oil price may be considered costly in oil importing countries, oil exporting countries benefit from income effects of such event. In most of the cases, diverse effects of global oil price changes on economic variables are still vague. One question arisen in mind is that whether changes in oil price affect consumer cost of living in oil consuming and oil producing countries identically.

In this paper, we aim to answer addressed question through applying most powerful nonlinear parametric and nonparametric models by employing large net oil consuming and producing countries. We denote net oil consumption and net oil production instead of oil importing and oil exporting. That is, any reason affecting net oil production or net oil consumption may influence the ability to export or import oil. Additionally, by definition of net oil consuming and net oil producing countries, we should be able to collect the highest frequently available monthly data, although we still have to ignore some of major net oil producing countries due to a shortage of data. Through this paper we expect to extend our findings over other oil consuming and producing countries which are not involved in studies due to data limitation. Implementing both linear and nonlinear estimation methods using panel data and time series enhances our findings and assures us to approach any possible causation between global oil price movements and consumer price index. The outcome of this paper may contribute to the current academic studies, macroeconomic policy decision makers, market activists and everyone who approach consumers' cost of living.

Our study differs in some aspects from other studies. Firstly, we use net oil consumption and net oil production concept. This enables us to classify our sample beyond oil exporting and oil importing. Secondly, we collect the highest frequently data which enables us to obtain accurate outcomes. Finally, we run several econometric methods, which is supposed to reveal any possible causality between global oil price and consumer price index. While majority of similar studies employ linear causality tests using time series, we estimate panel linear causality models with the least bias in estimated results. Additionally, employing two different nonlinear models following the linear tests enables us approach any nonlinear relationship between the variables. The remainder of this paper is as follows: after reviewing the literature in Section 2, we

describe our data set in Section 3. Sections 4 and 5 demonstrate the econometrics approaches and the estimation results, respectively. Finally, we provide concluding remarks and policy advices in Section 6.

6.7. Background

Where major studies consider influences of oil price changes on price indices through direct mechanisms, some believe that such effects are indirect. Reviewing the current literature shows that other than direct and indirect mechanisms of effect, oil price shocks affect economies through aggregate and disaggregate channels. In a seminal study, Jones and Kaul (1996) note that the aggregate channel includes those, which investigate the traditional supply shocks and demand adjustments theoretically or generally regressing GDP on the oil price and several more variables empirically. One of the main findings of aggregate level studies is the significant effects of the oil price shocks on economic activity (see Hamilton, 1983, 1996, 2003; Gisser and Goodwin, 1986; Mork, 1989; Hooker, 1999; Burbidge and Harrison, 1984; Mork *et al.*, 1994; Jiménez-Rodríguez and Sánchez, 2005, 2009 and Kilian, 2008). In contrast, disaggregate level studies are mainly focused on the influences of the oil price shocks on markets, sectors and industries.

Within aggregate level, some studies support existence of significant effects of the oil price changes on consumer price index. For instance, Burbidge and Harrison (1984) assess the dynamic relationship between oil price and six other economic variables including aggregate price level for a group of five developed countries. Applying vector auto regressive (VAR) model on a monthly data set which covers January 1961 to June 1982, they find that oil price have significant effects on the US and Canadian aggregate price levels. However, such effects are reported to be considerably weaker in Germany, Japan and the UK. Likewise, using annual data for the period of 1970 to 2006, Greenidge and DaCosta (2009) show that oil price changes have significant effects on the inflation rate of four Caribbean countries (that is, Barbados, Jamaica, Guyana and Trinidad and Tobago). Finally, Cunado and Perez de Gracia (2005) prove that oil price shocks have rather significant influences on the inflation rate. Using quarterly data covering 1975Q1 to 2002Q2 for a group of six Asian countries — Japan, Singapore, South Korea, Malaysia, Thailand and Philippines — in a bivariate VAR framework, they conclude that such influences are even stronger when the oil price is expressed in local currencies.

As opposed to supportive aggregate level studies, there is more evidence indicating that oil price changes have neutral effects or no effects on consumer price index (Hooker, 2002; LeBlanc and Chinn, 2004; Barsky and Kilian, 2004; Gregorio *et al.*, 2007; Bachmeier *et al.*, 2008 and Chen, 2009). Employing quarterly data within the Philips curve framework, Hooker (2002) shows that inflationary effects of increasing oil prices have been declined or even disappeared since 1980. Using a similar framework to Hooker (2002), LeBlanc and Chinn (2004) employ quarterly data for five developed countries covering 1980 to 2001. Their results indicate that the effects of oil price movements on inflation across all sample countries are moderate. Barsky and Kilian (2004) argue that the effects of oil price shocks on inflation are not as significant as what is claimed in the literature. Employing the US inflation rates during 1971 to 2004, they note that several spikes in the US inflation rates cannot be explained by the oil price shocks. Additionally, major oil shocks are not followed by inflation in consumer prices. Likewise, Gregario *et al.* (2007) and Chen (2009) find poor effects of the oil price shocks on the inflation rate. The majority of 39 developing and developed sample countries in the former study and 19 industrialized countries in the latter research display declining inflationary effects of the oil price increases. Finally, covering US data for the period of the late 1940's to 2004, Bachmeier *et al.* (2008) suggest that oil price changes do not have predictive power over future inflation and output.

On the other hand, disaggregate level studies present considerable information of possible channels which transfer the effects of oil price shocks to aggregate price levels. The main purpose of disaggregate level studies is commonly considering the effects of oil price shocks on various disaggregate price levels. Reviewing the literature reveals that there is no adequate evidence to specify the most effective channels transferring the influences of oil price shocks to consumer price index. For instance, Zhang *et al.* (2010) conclude that the long-term relationship between energy prices — ethanol, gasoline and oil — and a group of global commodities — corn, rice, soybeans, sugar and wheat — is not evident in China. They also find that in short-term, there is no causal relationship between energy prices and agricultural prices. In a similar study, Nazlioglu and Soytaş (2011) find that oil price have no significant effects on agricultural productions.

Conversely, disaggregate level studies present more evidence supporting the existence of causal relationship between oil price changes and disaggregate level prices. For example, Baffes (2007), Harri and Nalley (2009) and Chen *et al.* (2010) prove that oil price movements have close relationship with different tradable agricultural

commodities. Alghalith (2010) and Ibrahim and Said (2012) show that there is significant linkage between oil price movements and food price index. Most recently, Ibrahim and Chanchaoenchai (2013) find that there are long-term relationships between oil price, aggregate consumer price index and a set of disaggregate price indices. Employing Thailand's quarterly data covering 1993Q1 – 2010Q2, they note that aggregate consumer price, non-food and beverage prices and the housing and furnishing prices adjust their long-term equilibrium with oil price movements asymmetrically. They also show that oil price changes have short-term effects on the inflation rate of all kinds of commodities.

Altogether, reviewing the literature illuminates some important gaps for consideration. Recent studies mainly approach individual samples such as the US or Canada. Within the limited number of international studies, there is no comparative study between net oil consuming and net oil producing countries. Also, within disaggregate level studies, certain groups of commodities are usually selected. Finally, despite the importance of considering the effects of global oil price changes on consumer cost of living, there is no evidence to address possible nonlinear causation between these two variables. Our study tries to shed light over aforementioned issues using the most powerful nonlinear models, panel linear models and selected groups of net oil consuming and producing countries.

6.8.Data Description and Preliminary Overview

Our data set consists of oil price and consumer price index in selected net oil consuming and net oil producing countries during the period of January 1986 – August 2013. The sample selection criterion is the net oil production (consumption) share of GDP. Calculating this criterion using the extensive number of oil exporting and oil importing countries and considering data availability, we select the US, Brazil, Denmark, Italy, Germany, Netherlands and Sweden as net oil consuming and Canada, Mexico and Norway as net oil producing countries.

As a proxy for consumers' cost of living, we employ consumer price index which is collected from the Organisation for Economic Co-operation and Development (OECD). Also, as a proxy for the world oil price index (*OP*), we use monthly oil price index of West Texas Intermediate (WTI) crude oil. WTI oil price index has widely been used in the literature as the benchmark for the oil pricing. Moreover, it is highly correlated with the prices for other major categories of crude oil; Brent and Dubai (Wang et al, 2013).

We collect WTI statistics from World Bank website. Then, using the monthly US CPI, which is collected from the OECD website, we calculate inflation-adjusted real oil prices. Finally, data are indexed by monthly-averaged 2010 statistics.

Table 6.9. Main statistics

Countries	Mean		SD	
	Level	Difference	Level	Difference
<i>Data description for CPI</i>				
Brazil	65.6484	0.4723	31.1679	0.7451
Denmark	62.8376	0.1757	27.5755	0.2762
Germany	70.9101	0.14282	21.3249	0.2325
Italy	56.4595	0.19464	32.8547	0.1520
Netherlands	68.1223	0.16003	22.6615	0.3144
Sweden	64.0492	0.17284	30.2663	0.3476
US	61.2652	0.17189	26.9451	0.2439
Canada	64.0492	0.16883	27.2263	0.2583
Norway	61.0389	0.17342	28.5041	0.3112
Mexico	40.4424	0.25203	38.5547	0.3052
<i>Data description for OP</i>				
	59.2783	0.2042	31.78851	5.5322

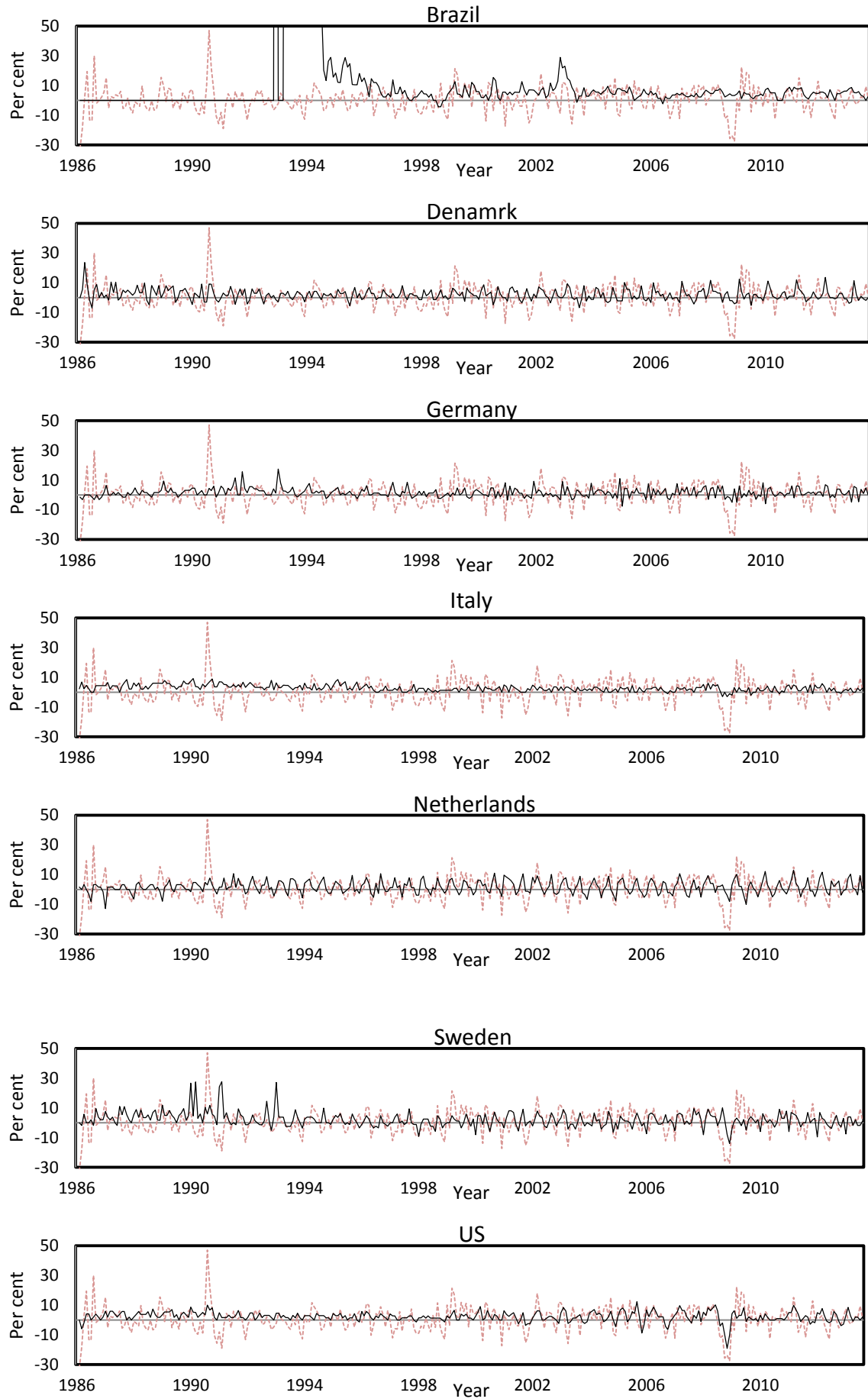
Note: This table reports main statistics of our sample data. Both consumer price index (*CPI*) and oil price (*OP*) are expressed monthly and indexed to constant inflation-adjusted year of 2010.

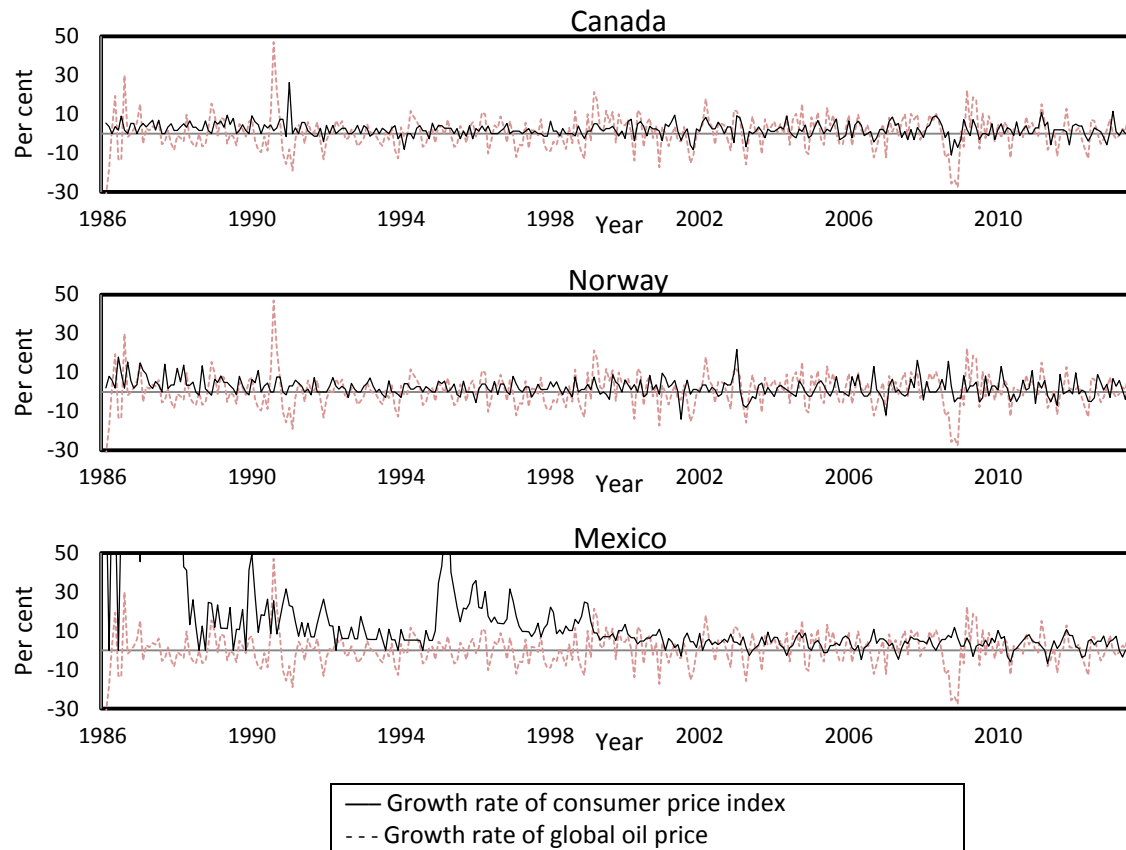
Table 6.9 presents data main statistics. The Table indicates that the average consumer price index varies between 40.4 equivalents for Mexico to 70.9 equivalents for Germany. We also plot the time variation of growth rates of global oil price and consumer price indices in Figure 6.2. Due to small fluctuations in consumer price levels compared with oil price levels, we plot the growth rates of the variables to highlight such fluctuations. By the Figure 6.2, it is almost hard to find any relationship between two time series. Whereas in the US, consumer price index follows global oil price with variant delays, no relationship between mentioned two variables is viewed across other countries. Our preliminary investigation indicates that global oil price is linearly

Table 6.10. Correlation coefficient of global oil price – consumer price index

Countries	Lag (months)			
	No lag	1	2	3
Brazil	0.8174	0.8161	0.8226	0.8255
Denmark	0.7744	0.7728	0.7705	0.7686
Germany	0.7163	0.7141	0.7114	0.7091
Italy	0.7111	0.7093	0.7072	0.7051
Netherlands	0.7656	0.7623	0.7586	0.7553
Sweden	0.6289	0.6293	0.6290	0.6287
US	0.7809	0.7796	0.7766	0.7732
Canada	0.7701	0.7694	0.7675	0.7653
Norway	0.7377	0.7374	0.7365	0.7355
Mexico	0.7409	0.7374	0.7340	0.7309

Figure 6.2. Growth rate of global oil price versus growth rate of consumer price index





Note: Cpi is multiplied by 10.

correlated with consumer price index. The correlation coefficients reported in Table 6.10 vary between 0.62 equivalents for Sweden and 0.82 equivalents for Brazil. However, such correlation does not guarantee the existence of any causation.

6.9. Empirical Methodology

6.9.1. Data Stationary Tests

There are several methods estimating data order of integration. To select a proper test, the first criterion to be considered is sharing the parameters across panel units. Some tests such as the Levin–Lin–Chu (LLC), Harris–Tsavalis (HT) and Breitung assume that all panels share the same autoregressive parameter while some other tests such as Im–Pesaran–Shin (IPS), Fisher-type and Hadri LM tests assume an autoregressive parameter to be panel-specific. In most of the cases, mentioned assumption is too restrictive in practice (Maddala and Wu, 1999).

The second criterion is considering the restrictions on the number of cross-sectional units and time dimensions. While microeconomic data usually overspread with an infinite number of cross-sections during a fixed period of time, macroeconomic data are typically restricted to limited number of cross-sections with infinite time dimension. Thus, the size of the sample and number of periods prescribes the type of unit root test

(to see further technical discussions about the size of N and T , consider Moon and Phillips, 1999 and Phillips and Moon, 2000). As our unbalanced panel includes 10 cross-sectional units with time dimension of more than 500, we select Fisher-type and (to some extent) IPS tests to measure panel data order of integration.

The Fisher unit root test addresses Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests. Using four methods proposed by Choi (2001), the Fisher unit root test combines p-values from panel-specific unit root tests. These methods apply inverse Chi-square, inverse normal, inverse logit and modified inverse chi-square transformations of p-values. Each method has different assumptions in the size of panel. While majority of mentioned test statistics are applied to infinite samples, the reverse chi-square P statistic is applicable for finite panels. The P statistic has a chi-square distribution with $2N$ degree of freedom. We test the null hypothesis of the existence of unit root across all of cross-sections against the alternative hypothesis, which demonstrates the entity of at least one stationary panel.

The second test we conduct here is IPS, which allows heterogeneity across panels with serially uncorrelated errors. This test is applicable to the unbalanced panel data and allows N to be finite or infinite and reports three statistics: t -bar, t -tiled-bar and z - t -tiled bar. Among all, t -bar statistic delivers our desired stationary test results regarding the finite N . due to assumption of finite time dimension, we assign the IPS test following Fisher-Type ADF test.

Finally, to test data order of integration for our country-specific and nonlinear models, we perform Augmented Dicky-Fuller (ADF), Elliot-Rothenberg-Stock (DF-GLS) and Philips-Perron (PP) tests using time series.

6.9.2. Panel Linear Causality Test

One of the best available econometric methods to investigate possible dynamic relationships within panel data is the panel vector autoregressive (PVAR) approach. This method has the least bias when cross-sectional units and time dimension tend to infinity. However, due to finite cross-sections in our study, PVAR estimators are biased and hence, this method is not applicable to our panel. Juessen and Linnemann (2010) compared several panel estimation models using Monte-Carlo simulation. Because of biased estimations using instrumental variables and GMM estimators in models with a restricted number of cross-sectional units, Juessen and Linnemann (2010) recommend a

bias-corrected least squares dummy variables (LSDV) model, which is easy to implement and suits samples with large time dimension. Consequently, we implement the bias-corrected LSDV model modified by Bruno (2005), which is designated for panels with a small number of cross-sectional units. Consider the following dynamic standard model:

$$y = D\eta + W\delta + \epsilon \quad (6.7)$$

where D is the matrix of individual dummies, $W = (y_{-1} : X)$ is the matrix of stacked observations, η is the vector of individual effects and δ is the vector of coefficients. To select the usable observations from within unbalanced panel data, a selection index is used as below:

$$s_{it} = \begin{cases} 1 & \text{if } (r_{it}, r_{it-1}) = (1,1) \\ 0 & \text{otherwise} \end{cases} \quad (6.8)$$

where $r_{it} = 1$ if y_{it} and x_{it} are observed and $r_{it} = 0$ otherwise, i denotes the size of time series and t indicates time dimension. We now rewrite Equation 6.7 as follows:

$$Sy = SD\eta + SW\delta + S\epsilon \quad (6.9)$$

In this equation, δ is the LSDV estimator that should be measured. Through the estimation procedure of δ , which has been explained in detail in Bun and Kiviet (2003) and Bruno (2005), one of the Anderson and Hsiao (1982), Arellano and Bond (1991) or Blundell (1998) estimators are employed to measure three types of bias approximations. Assuming B_i indicates estimated bias approximation extracted from formulations presented in Bruno (2005), the bias-corrected LSDV model (LSDVC) is estimated through the second stage of estimation as below:

$$LSDVC_i = LSDV - \hat{B}_i \quad (6.10)$$

where $i=1, 2, 3$ denotes one of the bias approximations.

The linear Granger causality tests suggest the predictability of a variable by its past values and the current and the past values of the cause variable. We use bias-corrected LSDV method to estimate the Granger linear causation between global oil price changes and consumers' cost of living. Thus, in a regression of CPI_t on lagged values of CPI_t and OP_t , OP_t would not be Granger-cause of CPI_t if the coefficients of OP_t are jointly zero:

$$CPI_t = \sum_{i=1}^m a_i CPI_{t-i} + \sum_{j=1}^n b_j OP_{t-j} + D_t + e_t \quad (6.11)$$

where a_i and b_j are coefficients, D_t is deterministic trend and e_t is the random error term. Rejection of the null hypothesis of $b_1 = b_2 = b_3 = \dots = b_n = 0$ indicates that OP_t is the Granger cause of CPI_t . This model, as Guilkey and Salemi (1982) describe, rejects false null hypothesis by 3.26 per cent and 2.64 per cent more than Sims and Modified Sims causality tests, respectively. The direct Granger causality test as a powerful tool describes both the existence and direction of causality. Finally, we run bootstrapping simulation to see whether desired coefficients are statistically significant.

6.9.3. Nonlinear Causality Tests

Where the existence of nonlinear relationship between economic variables is dramatically being proven in the current literature, the linear causality tests may cover just a portion of such existing relationships (Ajmi *et al.*, 2013). Furthermore, higher order structure, such as conditional heteroscedasticity is usually forgotten through within linear Granger causality tests. Thus, in order to extend our estimations beyond linear methods, we perform nonlinear parametric and non-parametric causality models.

In this paper, we employ Baek and Brock (1992) nonlinear non-parametric model, which has been modified by Hiemstra and Jones (1994). Denote that m -length lead vector of CPI_t by CPI_t^m and the $Lcpi$ -length and Lop -length lag vectors of CPI_t and OP_t by CPI_{t-Lcpi}^{Lcpi} and OP_{t-Lop}^{Lop} . As a result;

$$\begin{aligned} CPI_t^m &= (CPI_t, CPI_{t+1}, \dots, CPI_{t+m-1}) \\ CPI_{t-Lcpi}^{Lcpi} &= (CPI_{t-Lcpi}, CPI_{t-Lcpi+1}, \dots, CPI_{t-1}) \\ OP_{t-Lop}^{Lop} &= (OP_{t-Lop}, OP_{t-Lop+1}, \dots, OP_{t-1}) \end{aligned} \quad (6.12)$$

where $m = 1, 2, \dots$; $t = 1, 2, \dots$; $Lcpi = 1, 2, \dots, t$ and $Lop = 1, 2, \dots, t$. For CPI , $t = Lcpi + 1, Lcpi + 2, \dots$ and in case of OP , $t = Lop + 1, Lop + 2, \dots$. For given values of $m, Lcpi, Lop \geq 0$ and for $e > 0$, OP does not strictly Granger cause CPI if:

$$\begin{aligned} \Pr(\|CPI_t^m - CPI_s^m\| < e \mid \|CPI_{t-Lcpi}^{Lcpi} - CPI_{s-Lcpi}^{Lcpi}\| < e, \|OP_{t-Lop}^{Lop} - OP_{s-Lop}^{Lop}\| < e) \\ = \Pr(\|CPI_t^m - CPI_s^m\| < e \mid \|CPI_{t-Lcpi}^{Lcpi} - CPI_{s-Lcpi}^{Lcpi}\| < e) \end{aligned} \quad (6.13)$$

where $\Pr(\cdot)$ denotes the probability and $\|\cdot\|$ indicates the maximum norm. The conditional probability stated in the left side of Equation 6.13 explains two arbitrary m -length lead vector of CPI_t within a distance e of each other when corresponding $Lcpi$ -length lag vectors of CPI_t and Lop -length lag vectors of OP_t are given. Likewise, the conditional probability given in the right side of Equation 6.13 denote that two arbitrary m -length lead vectors of CPI_t are within a distance e of each other where their corresponding $Lcpi$ -length lag vectors within a distance e of each other are given. Hiemstra and Jones (1994) show that the following statistic has asymptotic normal distribution:

$$\sqrt{n} \left(\frac{C_1(m + Lcpi, Lop, e, n)}{C_2(Lcpi, Lop, e, n)} - \frac{C_3(m + Lcpi, e, n)}{C_4(Lcpi, e, n)} \right) \sim N(0, \sigma^2(m, Lcpi, Lop, e)) \quad (6.14)$$

where $n = T + 1 - m - \max(Lcpi, Lop)$, and C_1, C_2, C_3 and C_4 are correlation integral estimators of the joint probabilities in Equation 6.13. Also, σ^2 is estimated using the theory of U-statistic for weakly dependent processes and has been measured by Denker and Keller (1983). This test statistic is applied to the estimated residuals of the bivariate VAR model using CPI and OP . The test statistic is used to examine the null hypothesis of nonlinearly and strictly Granger non-causation OP to CPI . As Hiemstra and Jones (1994) and Kanas and Ma (2000) argue, this model has a very good power in estimating nonlinear Granger causal and non-causal relationships.

On the other hand, our parametric nonlinear model has first been applied by Mackey and Glass (1977). They employed a bivariate noisy procedure in describing physiological control system using Chaos Theory. Their model has been modified with essentials in different sciences. One of the economic modifications has been done with Kyrtsov and Labys (2006). The test is similar to the linear Granger causality test. However, it contains the Mackey–Glass model process with special parameters, which is estimated using ordinary least squares method. In order to examine the existence of nonlinear causality between oil price changes and consumer price index, we start with the following models:

$$DCPI_t = \alpha_{11}(DOP_{t-\tau_1})(1 + DOP_{t-\tau_1}^{c_1})^{-1} - \delta_{11}DOP_{t-1} + \alpha_{12}(DCPI_{t-\tau_2})(1 + DCPI_{t-\tau_2}^{c_2})^{-1} - \delta_{12}DCPI_{t-1} + u_t \quad (6.15)$$

$$\begin{aligned}
DOP_t = & \alpha_{21}(DOP_{t-\tau_1})(1 + DOP_{t-\tau_1}^{c_1})^{-1} - \delta_{21}DOP_{t-1} \\
& + \alpha_{22}(DCPI_{t-\tau_2})(1 + DCPI_{t-\tau_2}^{c_2})^{-1} - \delta_{22}DCPI_{t-1} + \varepsilon_t
\end{aligned} \tag{6.16}$$

where $DCPI_t$ and DOP_t are the first differences of consumer price index and oil price, respectively. Also, $\tau = \max(\tau_1, \tau_2)$ is the calculated integer delays, c is the constant and $t = \tau, \tau + 1, \dots, N$. The parameters α and δ present the linear and nonlinear effects of the cause variables on dependent variables, respectively. Finally, the two error terms u_t and ε_t are assumed to be $N(0, I)$. The integer delays τ_i and constants c_i are chosen prior to the model estimation using Schwarz criterion and likelihood ratio. If OP is defined to be nonlinear Granger cause of CPI , α_{11} should be significantly different from zero (the null hypothesis). Thus, we need to estimate Equation 6.15 once with no constraint and once with the constraint of zero value of α_{11} . Assuming that $\hat{\vartheta}$ and $\hat{\mu}$ are the residuals of such unconstrained and constrained Mackey–Glass models, respectively. We then calculate a Fisher-distributed statistic as below:

$$S_F = \frac{(S_c - S_u)/n_c}{S_u/(T - n_u - 1)} \sim F(n_c, T - n_u - 1) \tag{6.17}$$

where $S_u = \sum_{t=1}^T \hat{\vartheta}^2$, $S_c = \sum_{t=1}^T \hat{\mu}^2$, $n_u=4$ due to existence of four parameters in the Mackey–Glass model and $n_c=1$ as there is one parameter needed to be zero when estimating constrained model. The parametric nonlinear causality test is capable to be applied for the asymmetric cases as well. Thus, in order to investigate the asymmetric nonlinear causation of OP to CPI , one can consider positive and negative values of OP , respectively. That is, (OP_t, CPI_t) is used as observation in the Mackey–Glass process if $OP_{t-\tau} \geq 0$ in case of studying nonlinear causation of positive OP 's to CPI . Conversely, negative changes of oil price may be used in studying the nonlinear causation of negative OP 's to CPI . It is worth noting that the whole mentioned symmetric and asymmetric procedure is repeated for the Equation 6.16 to consider the nonlinear causation of CPI to OP .

6.10. Empirical Results

6.10.1. Panel Linear Causality Test

Table 6.11 demonstrates the results of Fisher-type ADF and IPS panel unit root tests. The test statistics reported in the first two rows of the Table indicate that both consumer price index and global oil price are integrated of order one. However, the IPS test

statistic delivers stationary oil price in trend while we justify Fisher-type ADF in preference to IPS. The second two rows of the Table 6.11 outline such panel unit root tests for the first difference of the variables. The results reveal that the null hypothesis of no stationary existence is rejected in all of the cases with 99 percent level of confidence. Consequently, we employ the first difference of the variables.

Table 6.11. Panel unit root test

Variable	Fisher-type ADF				IPS			
	Constant		Trend		No trend		Trend	
	P-statistic	p-value	P-statistic	p-value	t-bar	p-value	t-bar	p-value
CPI	11.6928	0.9262	21.2389	0.3832	-0.3102	1.0000	-1.4195	0.7277
OP	4.8110	0.9998	28.0935	0.1072	-0.9054	0.9898	-2.6777	0.0000
DCPI	670.6648	0.0000	667.2005	0.0000	-16.4909	0.0000	-16.6190	0.0000
DOP	720.8731	0.0000	720.8731	0.0000	-12.8518	0.0000	-12.8396	0.0000

Note: This Table denotes panel unit root test results. The null hypothesis indicates non-stationarity. The P-statistic has a chi-square distribution with 2N degree of freedom and t-bar statistic has normal distribution.

Now, we place the first difference of the variables in our bias-corrected LSDV model and simulate statistical significance of the coefficients by bootstrapping. It is worth noting that following Hamilton (2011), we primarily enter 24-month lags and choose the optimum lag order using Akaike Information Criterion (AIC). The results are displayed in Table 6.12. By the Table, it is evident that oil price movements are not Granger cause of consumer price index. Likewise, the null hypothesis of no causality running from consumer price index to the oil price cannot be rejected. This finding is consistent with Hooker (2002), LeBlanc and Chinn (2004), Barsky and Kilian (2004), Gregario *et al.* (2007), Bachmeier *et al.* (2008) and Chen (2009).

Table 6.12. Panel linear causality test

Causality	Net oil consuming countries			Net oil producing countries		
	Test statistic (Chi-square)	p-value	Result	Test statistic (Chi-square)	p-value	Result
$\Delta OP \rightarrow \Delta CPI$	0.51	0.9730	Non-causality	4.38	0.3569	Non-causality
$\Delta CPI \rightarrow \Delta OP$	0.86	0.9299	Non-causality	1.94	0.7471	Non-causality

Note: This Table reports the results of panel linear causality test. The null hypothesis indicates the non-causality. P-values extracted from bootstrapping simulation.

6.10.2. Traditional Linear Causality Test

Following our results in finding no evidence of panel linear causation between global oil price changes and consumer price index, we now test such causation using traditional country-specific causality test. As the test needs stationary data, we first consider country-specific data order of integration. Table 6.13 indicates the results of (ADF), (DF-GLS) and (PP) unit root tests. The results suggest that consumer price index and global oil price are integrated of order one. However, their first differences are stationary across all countries at 99 percent level of confidence. Thus, we enter the first difference of the variables into the test.

Table 6.13. Time series unit root test

Country	ADF		DF-GLS		PP	
	Level	Fist difference	Level	Fist difference	Level	Fist difference
<i>Unit root test for CPI</i>						
Brazil	-2.099	-6.367*	-1.823	-5.977*	-1.426	-6.378*
Denmark	-1.647	-19.358*	-0.698	-16.697*	-1.750	-19.098*
Germany	-1.556	-24.421*	-0.824	-13.203*	-1.545	-24.368*
Italy	0.341	-16.028*	-0.475	-7.635*	0.157	-17.147*
Netherlands	-1.125	-17.041*	-1.380	-17.815*	-1.376	-16.596*
Sweden	-2.232	-19.007*	-0.062	-15.154*	-2.058	-18.862*
US	0.548	-13.726*	-2.365	-13.863*	0.363	-13.206*
Canada	-1.488	-19.564*	-0.614	-12.414*	-1.309	-19.665*
Norway	-1.108	-20.943*	-0.727	-15.091*	-1.123	-20.862*
Mexico	7.265	-8.453*	-0.112	-8.322*	3.883	-8.417*
<i>Unit root test for OP</i>						
	-0.905	-12.852*	-2.550**	-4.422*	-1.563	-12.833*

Note: This Table reports country-specific unit root test results. The null hypothesis denotes non-stationarity. * and ** indicate significance at the 1% and 10% levels, respectively.

The results of country-specific Granger causality test, presented in Table 6.14, reveal that in spite of rejecting the null hypothesis of no panel linear causation in the last section, global oil price fluctuations may affect consumer price index in each country individually. Where the test statistics are reported to be statistically significant in all net oil consuming countries, such results are nil in net oil producing countries rather than Canada. Furthermore, the results reported for the US, Italy and Canada are statistically significant at 99 percent level of confidence whereas such evidence for Brazil, Germany and Sweden is reported to be inadequate. Finally, rather than Netherlands and Canada, the causation direction is unilateral across other sample countries. To conduct further investigation of the subject and due to heterogeneous outcomes within panel and country-specific linear causality tests, we then apply nonlinear causality tests at the next section.

Table 6.14. Traditional country-specific linear causality test

Causality	$\Delta OP \rightarrow \Delta CPI$	$\Delta CPI \rightarrow \Delta OP$
	Test statistic	Test statistic (chi-square)
Brazil	1.92***	0.81
Denmark	2.78**	0.88
Germany	1.95***	1.52
Italy	4.20*	1.05
Netherlands	2.38**	1.87**
Sweden	1.96***	0.99
US	3.92*	1.15
Canada	4.14*	1.85***
Norway	1.23	1.40
Mexico	1.01	0.80

Note: This table demonstrates the results of country-specific linear Granger causality test. The test statistic is F-distributed. The null hypothesis indicates the non-causality. *, ** and *** indicate significance at 1%, 5% and 10% levels, respectively.

6.10.3. Non-parametric Nonlinear Causality Test

To implement our nonparametric nonlinear test, we first need to assure that data are stationary. The results of such stationary test are reported in Table 6.13 and indicate that the first difference of the variables is integrated of order zero. Now, we should make up values of lead-lengths, lag-lengths and the common scale of e . Monte-Carlo simulations conducted by Hiemstra and Jones (1994) suggest that lead-lengths = 1, lag-lengths = 1, ..., 8 and $e = 1.5\sigma$. Estimating the model by entering such predetermined values, our nonparametric nonlinear test results are displayed in Table 6.15. The results indicate that global oil price changes have significant nonlinear causal effects on consumer price index of three out of seven net oil consuming countries and three net oil producing countries.

The reported results for net oil consuming countries are summarized as follows: first, Germany and Sweden exhibit a strong nonlinear unilateral causation running from global oil price to consumer price index. The test statistics are significant at 99 percent level of confidence. Second, the nonlinear causation in the US is reported to be bilateral and statistically significant. Finally, there is a unilateral causation running from consumer price index to global oil price, which is statistically significant at 90 percent level of confidence in Denmark.

On the other hand, our net oil producing sample countries demonstrate strong causal effects running from oil price to consumer price index. Canada exhibits a unilateral causation running from global oil price to consumer price index at 99 percent level of

Table 6.15. Hiemstra–Jones' nonlinear causality test

Lags	<i>OP</i> → <i>CPI</i>		<i>CPI</i> → <i>OP</i>		Lags	<i>OP</i> → <i>CPI</i>		<i>CPI</i> → <i>OP</i>	
	CS	TVAL	CS	TVAL		CS	TVAL	CS	TVAL
Brazil					Sweden				
1	0.0001	0.0020	-0.0113	-0.1782	1	0.0250	0.4457	-0.0023	-0.0418
2	-0.0040	-0.0625	-0.0160	-0.2509	2	0.0412	0.7337	0.00334	0.0595
3	-0.0215	-0.3361	-0.0161	-0.2518	3	0.0606	1.0765	0.0228	0.4054
4	-0.0374	-0.5830	-0.0176	-0.2752	4	0.0833	1.4777***	0.0250	0.4452
5	-0.0668	-1.0394	-0.0250	-0.3889	5	0.0957	1.6965**	0.0139	0.2478
6	-0.0675	-1.0473	-0.0297	-0.4612	6	0.1107	1.9583**	-0.0090	-0.1609
7	-0.0675	-1.0451	-0.0297	-0.4603	7	0.1231	2.1738***	-0.0276	-0.4887
8	-0.0632	-0.9768	-0.0345	-0.5341	8	0.1262	2.2251***	-0.0357	-0.6305
Denmark					US				
1	0.0274	0.4896	0.0242	0.4323	1	0.0662	1.1813	0.0409	0.7295
2	0.0485	0.8643	0.0359	0.6399	2	0.0915	1.6298*	0.0822	1.4644*
3	0.0685	1.2186	0.0485	0.8624	3	0.0997	1.7722**	0.0979	1.7418**
4	0.0631	1.1209	0.0561	0.9963	4	0.0949	1.6846**	0.1109	1.9698***
5	0.0560	0.9928	0.0593	1.0520	5	0.0791	1.4018*	0.1177	2.0873***
6	0.0531	0.9404	0.0681	1.2059	6	0.0562	0.9949	0.1184	2.0952***
7	0.0435	0.7681	0.0868	1.5334*	7	0.0365	0.6456	0.1062	1.8775***
8	0.0440	0.7754	0.0906	1.5984*	8	0.0196	0.3462	0.0991	1.7477**
Germany					Canada				
1	0.0293	0.5225	0.0124	0.2218	1	0.0424	0.7567	0.0148	0.2640
2	0.0603	1.0743	0.0220	0.3929	2	0.0605	1.0774	0.0275	0.4904
3	0.0923	1.6414*	0.0175	0.3120	3	0.0991	1.7615**	0.0524	0.9315
4	0.1144	2.0314***	-0.0051	-0.0911	4	0.1186	2.1047***	0.0652	1.1574
5	0.1409	2.4977***	-0.0422	-0.7486	5	0.1235	2.1895***	0.0484	0.8578
6	0.1632	2.8875***	-0.0734	-1.3000	6	0.1135	2.0089***	0.0310	0.5490
7	0.1675	2.9585***	-0.0882	-1.5591	7	0.0923	1.6310**	0.0233	0.4132
8	0.1528	2.6944***	-0.1034	-1.8250	8	0.0785	1.3849*	0.0264	0.4669
Italy					Norway				
1	0.0224	0.3987	0.0231	0.4120	1	0.0457	0.8155	0.0202	0.3605
2	0.0525	0.9356	0.0292	0.5202	2	0.0783	1.3937	0.0633	1.1280
3	0.0549	0.9757	0.0213	0.3802	3	0.0966	1.7182**	0.1004	1.7854**
4	0.0528	0.9364	0.0041	0.0742	4	0.0883	1.5680*	0.1121	1.9908***
5	0.0431	0.7631	-0.014	-0.2609	5	0.0759	1.3455*	0.1097	1.9441**
6	0.0480	0.8497	-0.0209	-0.3713	6	0.0564	0.9977	0.1119	1.9800***
7	0.0412	0.7277	-0.0078	-0.1378	7	0.0340	0.6006	0.1054	1.8626**
8	0.0424	0.7478	0.0062	0.1105	8	0.0309	0.5450	0.0976	1.7228**
Netherlands					Mexico				
1	0.0336	0.5999	0.0052	0.0942	1	0.0254	0.4538	0.0033	0.0602
2	0.0320	0.5701	0.0092	0.1654	2	0.0625	1.1135	0.0225	0.4010
3	0.0404	0.7178	0.0083	0.1480	3	0.0977	1.7378**	0.0361	0.6419
4	0.0385	0.6834	-0.0014	-0.0256	4	0.1102	1.9566***	0.0490	0.8709
5	0.0394	0.6981	-0.0042	-0.0745	5	0.1070	1.8970**	0.0543	0.9627
6	0.0388	0.6865	-0.0170	-0.3016	6	0.1012	1.7898**	0.0870	1.5405**
7	0.0285	0.5038	-0.0292	-0.5164	7	0.1058	1.8682**	0.1257	2.2207***
8	0.0238	0.4197	-0.0466	-0.8233	8	0.1165	2.0552***	0.1670	2.9465***

Note: CS and TVAL denote the difference between the two conditional probabilities, and the standardized test statistic, respectively. *, ** and *** indicate significance at the 1%, 5% and 10% levels, respectively. Canada, Norway and Mexico are net oil producing countries and the rest are net oil consuming countries.

confidence. Norway and Mexico display bilateral causality running from oil price to consumer price index at 95 percent and 99 percent level of confidence, respectively. In short, our nonlinear non-parametric causality test reveals that global oil price changes have statistically significant nonlinear effects on consumer price index of some of the net oil consuming and all of the net oil producing countries.

6.10.4. Parametric Nonlinear Causality Test

To estimate the parametric nonlinear Mackey–Glass model, we first select the models' parameters using Schwarz criterion and likelihood ratio. The first and second columns of the results reported in Table 6.16 show that the lag-length period in effects of global oil price changes on consumer price index varies from 1 – 10 months for sample countries. However, consumer price index affects oil prices after a month across all of the countries. The lag orders presented in Table 6.16 supply guidelines to policy decision makers regarding the time needed for appearance of global oil price effects on consumer price index.

Table 6.16. Parameter-prior selection in the Mackey–Glass model

Country	τ_1	τ_2	c_1	c_2
Brazil	1	1	2	1
Denmark	10	1	1	1
Germany	1	1	1	1
Italy	2	1	1	1
Netherlands	9	1	1	3
Sweden	6	1	1	1
US	2	1	1	2
Canada	1	1	1	1
Norway	8	1	1	1
Mexico	1	1	2	2

Note: τ_1 and τ_2 are the optimal integer delay variables for the causality from *OP* to *CPI* and for the causality from *CPI* to *OP*, respectively. c_1 and c_2 are the power of the lagged values of *OP* and *CPI*, respectively.

Now, we use symmetric modified Mackey–Glass model to test whether oil price movements cause consumer price index nonlinearly. The test results presented in Table 6.17 display very weak evidence on unidirectional nonlinear causation of global oil price movements to consumer price index. The null hypothesis of non-causation of *OP* to *CPI* is rejected just in cases of Denmark as a net oil consuming and Canada as a net oil producing country. Furthermore, there is no evidence to prove that consumer price index causes global oil price changes nonlinearly. This finding is in conjunction with Hooker (2002), LeBlanc and Chinn (2004), Barsky and Kilian (2004), Gregario *et al.* (2007), Bachmeier *et al.* (2008) and Chen (2009).

To test the assumption of asymmetric nonlinear effects of global oil price changes on consumer price index, we run the asymmetric version of Mackey–Glass model. Table 6.18 and Table 6.19 display the results. The tables indicate that unidirectional causation of oil price movements to consumer price index is asymmetric in cases of Denmark and Canada. That is, only positive changes in oil price cause movements in consumer price index of these two countries. In short, the results of parametric

Table 6.17. Symmetric nonlinear causality test

Country	H0: <i>OP</i> does not cause <i>CPI</i>		H0: <i>CPI</i> does not cause <i>OP</i>	
	F-statistic	Probability	F-statistic	Probability
Brazil	0.6180	0.4325	0.2420	0.6231
Denmark	-11.9473	0.0006	-0.6238	0.9801
Germany	1.6002	0.2067	0.1330	0.7155
Italy	2.2219	0.1370	-0.7420	0.3896
Netherlands	1.9388	0.1647	0.8106	0.3685
Sweden	2.0887	0.1493	0.1125	0.7374
US	-0.0616	0.8040	-0.7957	0.3730
Canada	3.8751	0.0498	1.0860	0.2981
Norway	1.6377	0.2015	0.1022	0.7493
Mexico	0.0121	0.9123	0.2106	0.6465

Note: This Table reports the results of symmetric nonlinear Mackey–Glass causality test. The null hypothesis indicates non-causality. F-statistic is Fisher-distributed with N-4 and N-1 degree of freedom.

Table 6.18. Asymmetric nonlinear causality test for negative changes of the causing variable

Country	H0: <i>OP</i> does not cause <i>CPI</i>		H0: <i>CPI</i> does not cause <i>OP</i>	
	F-statistic	Probability	F-statistic	Probability
Brazil	0.3421	0.5599	NA	NA
Denmark	-0.9473	0.3397	-0.1335	0.7158
Germany	-0.2022	0.6564	-0.0521	0.8200
Italy	-0.5081	0.4820	0.1780	0.6947
Netherlands	0.3744	0.5457	0.0679	0.7949
Sweden	0.4780	0.4951	-1.0342	0.3122
US	-0.9760	0.3248	-0.3397	0.5637
Canada	0.8972	0.3519	-0.8839	0.3511
Norway	-1.6051	0.2159	0.3488	0.5567
Mexico	0.2038	0.6523	-0.3647	0.5593

Note: This Table denotes the results of Mackey–Glass nonlinear causation of negative changes of *OP* to *CPI*. Fisher-statistic is F-distributed with N-4 and N-1 degree of freedom.

nonlinear causality test supplies very weak evidence on global oil price causation to changes in consumer price index.

6.11. Conclusion

In this paper, we compare the causal relationships between oil price movements and consumers' cost of living in net oil consuming and net oil producing countries. Firstly, we specify net oil consuming and net oil producing countries. Thus, any reason affecting net oil production or net oil consumption may influence the ability of oil exporting or oil importing. We select seven net oil consuming countries and three net oil producing countries among all other countries because of the existence of the highest frequently data.

Secondly, we implement two types of linear Granger causality tests including panel and country-specific. Our bias-corrected panel linear causality test supplies no evidence on

Table 6.19. Asymmetric nonlinear causality test for positive changes of the causing variable

Country	H0: <i>OP</i> does not cause <i>CPI</i>		H0: <i>CPI</i> does not cause <i>OP</i>	
	F-statistic	Probability	F-statistic	Probability
Brazil	-0.5849	0.4456	0.2506	0.6171
Denmark	-11.7646	0.0006	-0.4070	0.5240
Germany	1.9928	0.1591	0.3308	0.5657
Italy	1.7840	0.1827	-0.4052	0.5249
Netherlands	0.4141	0.5203	0.9672	0.3264
Sweden	2.0311	0.1551	1.1013	0.2950
US	0.6457	0.4227	3.0407	0.0823
Canada	6.2296	0.0131	1.5443	0.2151
Norway	1.6441	0.2007	0.7199	0.3970
Mexico	-0.2130	0.6449	0.2194	0.6398

Note: This Table denotes the results of Mackey–Glass nonlinear causation of positive changes of *OP* to *CPI*. F-statistic is Fisher-distributed with N-4 and N-1 degree of freedom.

causal effects of global oil price changes on consumers' cost of living. Following the assumption of country-specific effects of global oil price changes, we conduct country-specific linear causality test. As opposed to the panel test results, we find that the evidence on country-specific linear causality running from global oil price to consumer price index in net oil consuming countries is stronger than net oil producer countries.

Finally, due to weakness of linear models in finding all possible linkages within economic and financial variables, we employ two powerful nonlinear causality tests; non-parametric and parametric. Whereas the parametric test rejects the existence of any nonlinear causal effects of global oil price changes on consumers' cost of living across the sample countries rather than Denmark and Canada, nonparametric test displays evidence on strong causality in all of the net oil producing and three out of seven net oil consuming countries. The significant test results using parametric model are reported to be asymmetric.

Consequently, the results of our comparative study show that global oil price movements affect consumers' cost of living both in net oil consuming and net oil producing countries. The nature of such effects is reported to be mostly linear in net oil consuming countries and nonlinear across net oil producing countries. The shorter lag-lengths in net oil producing countries indicate that efficient policy decisions have a shorter deadline to avert unwanted effects of increasing global oil prices.

Although we find significant nonlinear causation, mainly running from oil price changes to consumers' cost of living, two important points should be noted: firstly, the nonlinear models we applied in this paper provide no guidance on the source of nonlinearities. Such guidance is left to theory and may need specific parameterized

structural models. Secondly, by studying the nonlinear models, it is not possible to determine whether significant nonlinear predictive power is evidence of positive or negative nonlinear causality. Beside the evidence that nonlinear models supply, linear causality tests may provide an incorrect assessment of the true relationship between oil price movements and monetary aggregate, which are of nonlinear nature with respect to our results, and may suggest misleading policy actions.

For further study, we recommend an even more powerful statistical test which accounts for not only nonlinearity, asymmetry and time-variations, but also the conditional heteroscedasticity of the VAR model's variances. Additionally, considering domestic oil prices in causation analyses is highly recommended. Finally, with regards to our findings, considering the effects of oil price changes on wider disaggregate price indices than what has been done in the literature may reveal important mechanisms to control possible oil price changes on consumers' cost of living.

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Chapter 7. Nonlinear financial market effects of global oil price fluctuations

What follows is the author-manuscript (pre-print) version of the paper reproduced in accordance with the copyright policy of the publisher. The original publication is available at <http://dx.doi.org/10.1080/13504851.2014.969821>. My contribution to this paper involves initial concept and empirical design, collection and analysis of data and preparation of the manuscript.

In this article, we test nonlinear causality between global oil price (OP) changes and short-term real interest rate (IR) in large net oil-consuming and net oil-producing countries. Applying nonlinear nonparametric Hiemstra–Jones model and nonlinear parametric Mackey–Glass model, we find no evidence to suggest that potential direct effects of global OP changes on short-term IR are nonlinear in net oil-consuming countries. In contrast, we find such effects to be nonlinear and asymmetric in net oil producing countries.

7.1. Introduction

Real interest rate is supposed to be a separate channel in transferring oil price shocks to economies (Ferderer, 1996; Hooker, 1999; Balke *et al.*, 2002). However, there is not enough evidence comparing differences in such mechanisms of effects among large net oil producing and net oil consuming countries. Theoretically, increases in oil price shift purchasing power from oil importing nations to oil exporting nations. This movement reduces consumer demand in oil importing countries and raises consumer demand in oil exporting countries. Thus, world demand for productions of oil importing countries is reduced and supply of savings is increased. Finally, real interest rate is reduced due to increasing supply of savings.

The literature addresses significant effects of the oil price changes on real interest rate. Studying the US economy, Wu (2010) and Arora and Tanner (2013) show that oil price

is consistently responsive to real interest rate. Evidences show that such effects are reported to be asymmetric (Balke *et al.*, 2002; Sadorsky, 1999). For instance, using a financial accelerator model, Balke *et al.* (2002) note that interest rate is the most important channel in transferring asymmetry from the oil price movements to the GDP.

On the other hand, some studies find that interest rate effects of oil price changes might be conditional. For example, Lowinger *et al.* (1985) reveal that only very high increases in oil price induce significant impacts on real interest rate. Dotsey *et al.* (2003) show that only high level of interest rate responds significantly to the oil price changes. Finally, Cologni and Manera (2008) prove that unexpected changes in oil price can affect real interest rates significantly.

A question that motivates us to consider the subject is that whether oil price movements affect real interest rate nonlinearly. Also, are the results identical across countries? To answer these questions, we implement the most powerful nonlinear models, monthly data for a long period and the possible largest panels of net oil consuming and net oil producing countries. The contribution of this paper would be of great interest of investors, policy decision makers and researchers.

7.2.Data and Methodology

Our sample includes the US, Brazil, Denmark, Italy, Sweden, Germany and Netherlands as the net oil consuming and Canada, Mexico and Norway as the net oil producing. Data which cover 1986m1–2013m8 include short-term real interest rate (IR) collected from Organisation for Economic Co-operation and Development (OECD) website as well as Portal de Financas website in case of Brazil. Also, we use West Texas Intermediate (WTI) crude oil price (OP) which is collected from the World Bank website and is inflation adjusted. Data are indexed to monthly-averaged 2010. Figure 7.1 illustrates the growth rate of global oil price versus growth rate of short-term real interest rate within sample countries. By the Figure, it is evident that IR is mostly moving after OP .

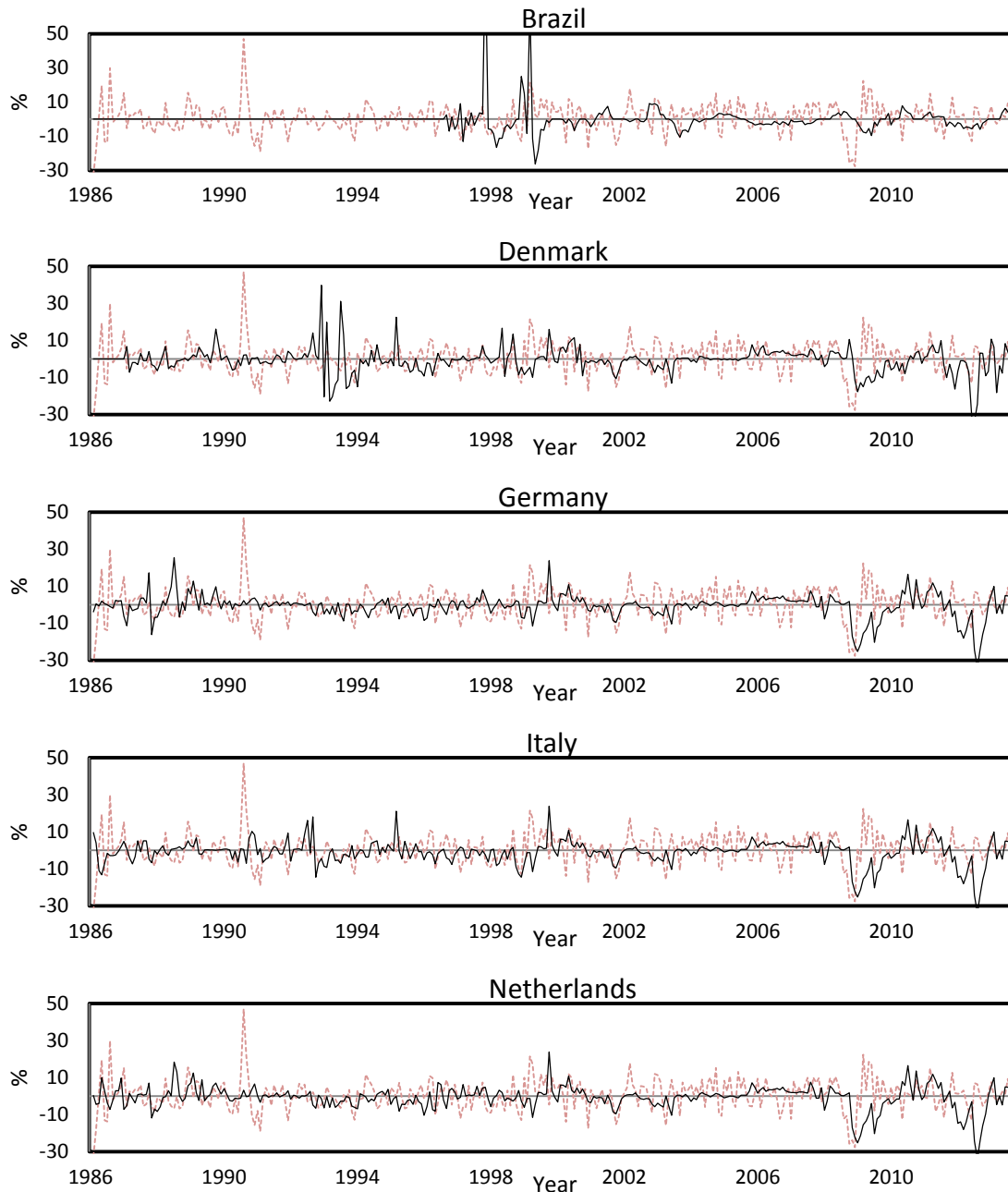
7.2.1. Nonparametric nonlinear model

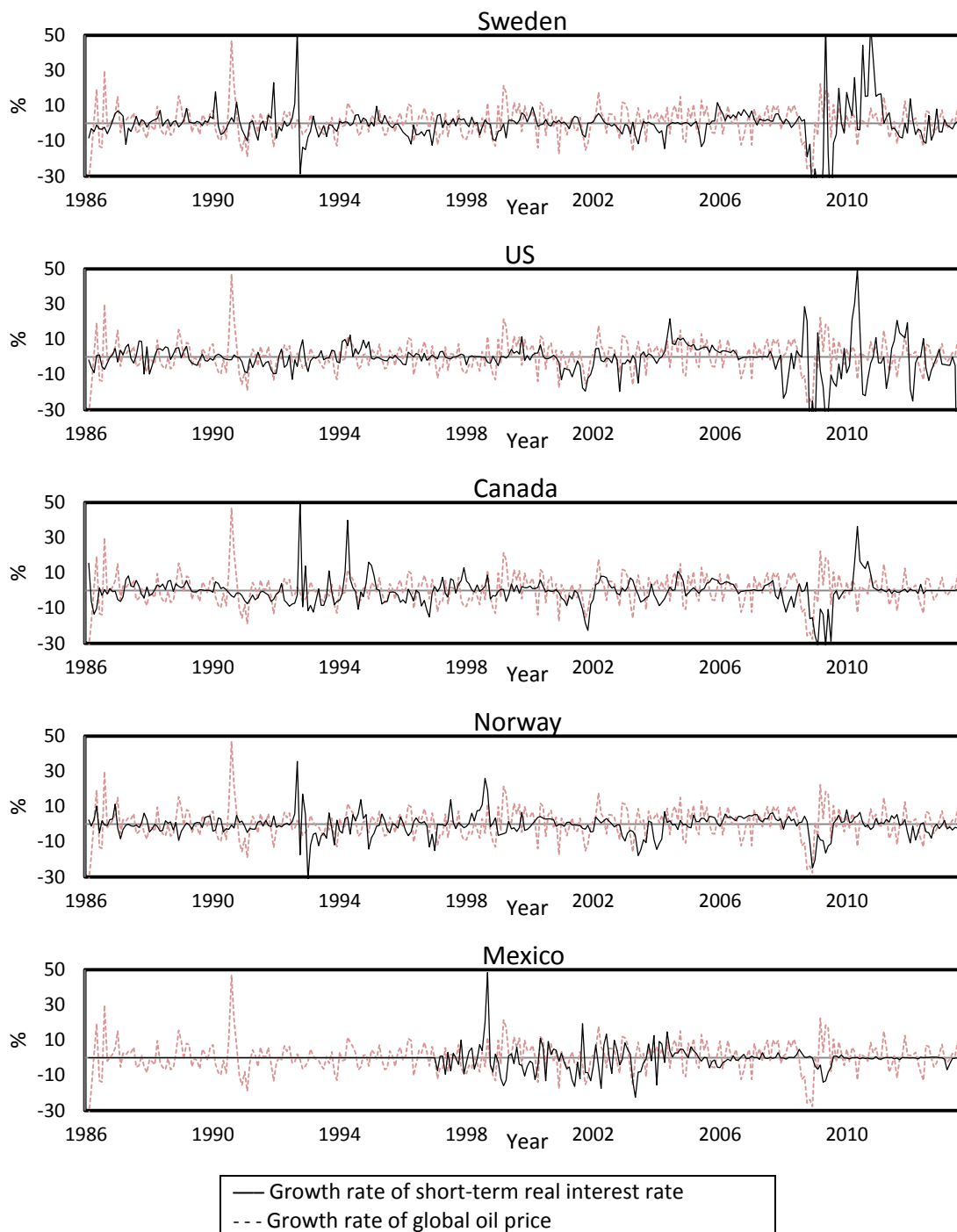
We employ Baek and Brock (1992) nonparametric nonlinear causality model, which has been modified by Hiemstra and Jones (1994). Denote m -length lead vector of IR_t by IR_t^m and Lir -length and Lop -length lag vectors of IR_t and OP_t by IR_{t-Lir}^{Lir} and OP_{t-Lop}^{Lop} . For given values of $m, Lir, Lop \geq 0$ and for $e > 0$, OP does not strictly Granger cause IR if:

$$\begin{aligned} & \Pr(\|IR_t^m - IR_s^m\| < e \mid \|IR_{t-Lir}^{Lir} - IR_{s-Lir}^{Lir}\| < e, \|OP_{t-Lop}^{Lop} - OP_{s-Lop}^{Lop}\| < e) \\ & = \Pr(\|IR_t^m - IR_s^m\| < e \mid \|IR_{t-Lir}^{Lir} - IR_{s-Lir}^{Lir}\| < e) \end{aligned} \quad (7.1)$$

where $\Pr(\cdot)$ is the probability and $\|\cdot\|$ is the maximum norm. As Hiemstra and Jones (1994) and Kanas and Ma (2000) explain, this model has a very good power in estimating non-linear Granger causal and non-causal relationships.

Figure7.1. Growth rate of global oil price versus growth rate of short-term real interest rate





7.2.2. Parametric nonlinear model

The Mackey and Glass (1977) parametric model — which has been modified by Kyrtsov and Labys (2006) — employs a bivariate noisy procedure in estimating nonlinear causality. To examine the existence of nonlinear causality, we estimate the following models:

$$\begin{aligned}
 DIR_t = & \alpha_{21}(DOP_{t-\tau_1})(1 + DOP_{t-\tau_1}^{c_1})^{-1} - \delta_{21}DOP_{t-1} \\
 & + \alpha_{22}(DIR_{t-\tau_2})(1 + DIR_{t-\tau_2}^{c_2})^{-1} - \delta_{22}DIR_{t-1} + u_t
 \end{aligned} \tag{7.2}$$

$$\begin{aligned}
 DOP_t = & \alpha_{11}(DOP_{t-\tau_1})(1 + DOP_{t-\tau_1}^{c_1})^{-1} - \delta_{11}DOP_{t-1} \\
 & + \alpha_{12}(DIR_{t-\tau_2})(1 + DIR_{t-\tau_2}^{c_2})^{-1} - \delta_{12}DIR_{t-1} + \varepsilon_t
 \end{aligned}
 \tag{7.3}$$

where DIR_t and DOP_t are the first differences of IR and OP , respectively. Also, $\tau = \max(\tau_1, \tau_2)$ is the calculated integer delays, c is the constant and $t = \tau, \tau + 1, \dots, N$. The parameters α and δ denote linear and non-linear effects of the cause variable on dependent variable, respectively. Finally, the two error terms u_t and ε_t are assumed to be $N(0,1)$. The integer delays τ_i and constants c_i are chosen prior to the model estimation using Schwarz criterion and likelihood ratio.

7.3. Empirical Results

7.3.1. Data stationary tests

Our nonlinear models are sensitive to the data order of integration. To assure whether data are stationary, we conduct Augmented Dicky-Fuller (ADF), Dicky-Fuller generalized least squares (DF-GLS) and Philips-Perron (PP) tests. The results of unit root tests presented in Table 7.1 indicate that IR is integrated of order one in all of the countries while its first difference is reported to be stationary. Likewise, the first difference of OP is reported to be stationary.

Table 7.1. Unit root tests

Country	ADF		DF-GLS		PP	
	Level	Fist difference	Level	Fist difference	Level	First difference
<i>Unit root test for IR</i>						
Brazil	-2.532	-13.526*	0.380	-7.048*	-1.391	-13.529*
Denmark	-1.589	-20.213*	-0.042	-1.259***	-1.681	-20.051*
Germany	-1.246	-14.009*	-0.824	-3.543*	-1.630	-14.221*
Italy	-0.232	-15.364*	-0.376	-2.293**	-1.140	-15.397*
Netherlands	-0.123	-11.281*	-0.810	-4.211*	-1.203	-11.413*
Sweden	-1.369	-18.646*	0.049	-1.474***	-1.488	-18.621*
US	-1.662	-16.013*	-1.091	-1.965**	-1.504	-15.518*
Canada	-1.200	-16.000*	-1.511	-1.620***	-1.315	-15.952*
Norway	-1.092	-18.827*	-0.886	-2.723*	-1.032	-18.782*
Mexico	-1.817	-10.945*	0.325	-1.984***	-1.676	-10.924*
<i>Unit root tests for OP</i>						
	-0.905	-12.852*	-0.402	-1.694***	-0.276	-12.835*

Note: *, ** and *** indicate significance at the 1%, 5% and 10% levels, respectively.

7.3.2. Results for nonparametric model

Table 7.2 demonstrates the results of Hiemstra-Jones model. Concerning mostly negative statistics and their respected t-values, it is worth noting that only positive values of OP helps predict IR , whereas a significant negative value suggests that knowledge of the lagged values of OP confounds the prediction of IR (Hiemstra and

Table 7.2. Hiemstra-Jones' nonlinear causality test

Lags	OP → IR		IR → OP		Lags	OP → IR		IR → OP	
	CS	TVAL	CS	TVAL		CS	TVAL	CS	TVAL
Brazil					Sweden				
1	0.0131	0.1816	0.0074	0.1032	1	-0.0060	-0.1092	-0.0148	-0.2655
2	0.0203	0.2809	0.0050	0.0695	2	-0.0228	-0.4080	-0.0303	-0.5434
3	0.0217	0.2997	0.0020	0.0284	3	-0.0562	-1.0041	-0.0310	-0.5545
4	0.0241	0.3313	0.0022	0.0313	4	-0.0777	-1.3873	-0.0221	-0.3947
5	0.0226	0.3111	0.0007	0.0103	5	-0.0851	-1.5159	-0.0146	-0.2608
6	0.0242	0.3316	-0.0009	-0.0126	6	-0.0829	-1.4741	-0.0194	-0.3456
7	0.0300	0.4103	-0.0029	-0.0408	7	-0.0980	-1.7399	-0.0276	-0.4899
8	0.0296	0.4027	-0.0049	-0.0679	8	-0.1115	-1.9769	-0.0312	-0.5531
Denmark					US				
1	-0.0105	-0.1863	-0.0237	-0.4198	1	0.0114	0.2053	-0.0111	-0.1997
2	-0.0330	-0.5821	-0.0442	-0.7804	2	-0.0073	-0.1310	-0.0345	-0.6197
3	-0.0668	-1.1777	-0.0644	-1.1351	3	-0.0153	-0.2746	-0.0353	-0.6330
4	-0.1016	-1.7866	-0.0750	-1.3192	4	-0.0074	-0.1335	-0.0449	-0.8026
5	-0.1227	-2.1537	-0.0792	-1.3901	5	0.0036	0.0643	-0.0617	-1.1005
6	-0.1444	-2.5309	-0.0832	-1.4586	6	0.0045	0.0810	-0.0804	-1.4322
7	-0.1741	-3.0466	-0.0843	-1.4755	7	-0.0095	-0.1703	-0.0958	-1.7038
8	-0.1900	-3.3185	-0.0871	-1.5214	8	-0.0242	-0.4308	-0.0926	-1.6448
Germany					Canada				
1	-0.0123	-0.2199	-0.0260	-0.4658	1	-0.0180	-0.3243	-0.0215	-0.3874
2	-0.0361	-0.6452	-0.0574	-1.0250	2	-0.0535	-0.9611	-0.0460	-0.8254
3	-0.0857	-1.5260	-0.0773	-1.3779	3	-0.0962	-1.7240	-0.0613	-1.0985
4	-0.1177	-2.0938	-0.0888	-1.5798	4	-0.1386	-2.4799	-0.0800	-1.4312
5	-0.1243	-2.2063	-0.0985	-1.7486	5	-0.1673	-2.9895	-0.0938	-1.6766
6	-0.1361	-2.4128	-0.1131	-2.0041	6	-0.1766	-3.1505	-0.1081	-1.9278
7	-0.1538	-2.7220	-0.1055	-1.8674	7	-0.1995	-3.5530	-0.1190	-2.1204
8	-0.1579	-2.7897	-0.0925	-1.6353	8	-0.2241	-3.9847	-0.1193	-2.1207
Italy					Norway				
1	-0.0131	-0.2360	-0.0145	-0.2612	1	-0.0086	-0.1559	-0.0221	-0.3981
2	-0.0430	-0.7733	-0.0386	-0.6952	2	-0.0309	-0.5553	-0.0443	-0.7963
3	-0.0898	-1.6122	-0.0661	-1.1878	3	-0.0708	-1.2690	-0.0592	-1.0622
4	-0.1203	-2.1556	-0.0940	-1.6844	4	-0.1150	-2.0587	-0.0702	-1.2565
5	-0.1392	-2.4907	-0.1183	-2.1171	5	-0.1486	-2.6545	-0.0788	-1.4090
6	-0.1511	-2.7004	-0.1335	-2.3860	6	-0.1806	-3.2212	-0.0918	-1.6375
7	-0.1710	-3.0497	-0.1462	-2.6074	7	-0.2082	-3.7080	-0.1073	-1.9118
8	-0.1865	-3.3214	-0.1526	-2.7181	8	-0.2240	-3.9835	-0.1112	-1.9775
Netherlands					Mexico				
1	-0.0073	-0.1321	-0.0253	-0.4564	1	-0.0229	-0.3041	-0.0247	-0.3425
2	-0.0228	-0.4110	-0.0524	-0.9424	2	-0.0539	-0.7432	-0.0656	-0.9046
3	-0.0643	-1.1553	-0.0636	-1.1416	3	-0.0973	-1.3380	-0.0966	-1.3285
4	-0.1121	-2.0098	-0.0635	-1.1385	4	-0.1340	-1.8378	-0.1323	-1.8147
5	-0.1388	-2.4830	-0.0552	-0.9886	5	-0.1527	-2.0888	-0.1713	-2.3429
6	-0.1521	-2.7178	-0.0520	-0.9303	6	-0.1473	-2.0089	-0.2061	-2.8117
7	-0.1662	-2.9647	-0.0512	-0.9138	7	-0.1522	-2.0713	-0.2336	-3.1774
8	-0.1681	-2.9936	-0.0533	-0.9493	8	-0.1384	-1.8776	-0.2388	-3.2392

Note: OP and IR indicate oil price and short-term interest rate, respectively. CS and TVAL are the difference between the two conditional probabilities, and the standardized test statistic, respectively.

Jones, 1994). Thus, the negative statistics are unacceptable and hence, this model shows no evidence on nonlinear linkages between *OP* and *IR*.

7.3.3. Results for parametric model

The outcomes displayed in Table 7.3 differ slightly from those resulted from Hiemstra-Jones model. The responses of *IR* to changes in *OP* are statistically significant. Furthermore, the statistics for Canada, Norway and Mexico are significant at 1 per cent,

10 per cent and 10 per cent levels, respectively. On the other hand, there is still no evidence indicating nonlinear causal relationship between *OP* and *IR* in net oil consuming countries rather than Sweden. In short, the linkages between oil price and short-term real interest rate addressed in the literature do not seem to be nonlinear in net oil consuming countries whereas such relationship is unilaterally nonlinear in net oil consuming countries.

Table 7.3. Symmetric nonlinear Kyrtsou-Labys causality test

Country	H0: OP does not cause IR	H0: IR does not cause OP
	Statistic	Statistic
Brazil	0.9503	0.1704
Denmark	1.4574	0.0601
Germany	2.4045	0.3673
Italy	0.5679	0.0404
Netherlands	2.6504	0.6061
Sweden	3.2196**	2.1159
US	0.4398	0.1800
Canada	26.4716*	2.2214
Norway	3.7750**	0.0213
Mexico	2.7191**	0.1855

Note: the statistic is F-distributed. * and ** denote significance at 1% and 10% levels, respectively.

7.3.4. Results for asymmetric model

The literature supports the assumption of asymmetric responses of *IR* to *OP*. To test such asymmetry, we implement asymmetric test using Kyrtsou-Labys parametric model. Thus, we run the model once using positive and then using negative values of *OP*.

Table 7.4. Asymmetric test for negative changes of the causing variable

Country	H0: OP does not cause IR	H0: IR does not cause OP
	F-statistic	F-statistic
Brazil	1.2227	0.3800
Denmark	NA	0.2836
Germany	0.7296	0.6061
Italy	0.3633	0.5121
Netherlands	0.0531	0.7068
Sweden	0.2722	0.0607
US	0.1240	0.3357
Canada	0.2182	0.3542
Norway	0.1743	0.2814
Mexico	1.7004	0.5827

Note: the statistic is F-distributed.

The asymmetric test results displayed in Table 7.4 and Table 7.5 reveal that nonlinear responses of *IR* to *OP* in net oil producing countries are asymmetric. That is, only positive changes in *OP* cause nonlinear changes in *IR*. This finding is consistent with Balke *et al.* (2002) and Sadorsky (1999).

Table 7.5. Asymmetric test for positive changes of the causing variable

Country	H0: OP does not cause IR	H0: IR does not cause OP
	F-statistic	F-statistic
Brazil	0.0388	0.2570
Denmark	1.4892	0.0248
Germany	2.1783	0.2236
Italy	0.1103	0.2758
Netherlands	2.6225	0.2991
Sweden	1.8811	2.0817
US	1.9538	0.1124
Canada	39.075*	2.1543
Norway	5.4648**	0.0160
Mexico	3.8224***	0.1488

Note: the statistic is F-distributed. *, ** and *** indicate significance at 1%, 5% and 10% levels, respectively.

7.4. Conclusions

A number of past studies have investigated oil price-interest rate relationship, mostly in the US economy. But, there is less evidence on the existence of nonlinear linkages explaining possible heterogeneities across large net oil consuming and net oil producing countries. In this paper, we used the most powerful nonlinear tests to address the above issues. Our finding for the net oil consuming countries reveals that the causal effects of global oil price changes on short-term interest rate reported in the literature is not nonlinear. Conversely, such linkages are reported to be statistically significant and also asymmetric in net oil producing countries. The differences between the results of parametric and nonparametric nonlinear tests can be explained by the ways in which they are constructed. Although the nonparametric model is free of any distribution assumption, the parametric model lets us conduct asymmetry test. For further research, it is recommended to consider such nonlinearities by using domestic oil price changes.

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Chapter 8. Conclusion

8.1. Summary of the thesis

We commenced this thesis with a general overview and explained the research background, objectives, and questions in Chapter 1. *Introduction*. The first empirical studies engaged with exploration of linear negative relationship between oil price and real activity in major oil-importer countries. Subsequently, a large body of research studied the role of oil price shocks on recessions. Finally, nonlinear effects of oil price shocks and their market level, sector level and firm level effects became interesting topics for researchers. However, fewer efforts devoted to comparison of responses between net oil-consumer and producer countries. The unclear aspects of such responses motivated us to study the issue in detail. Consequently, we approached answering the main questions indicating differences in effects of oil price fluctuations on these two panels of countries.

In Chapter 2. *Overview of the Oil Industry* we looked at oil industry and oil market. In this chapter, we understood that the history of crude oil dates back to 2000 BC. Crude oil had primarily been used for heating and lighting while it gradually found its strategic value during the time. Oil industry, which was generally known as petroleum industry, included a wide range of oil-relevant activities such as exploration, extraction, refining, transporting and marketing. These activities could be divided into the three major sectors including upstream, midstream and downstream activities. Reviewing the statistics revealed that briefly, despite increasingly daily usage of crude oil, it still can serve humankind as the main source of energy at least for the next few decades.

In this chapter, we also noticed that the most important sector in oil industry was the oil market. At the international oil market, oil-producer countries took the supply side and oil-consumer countries took the demand side. Any reason affecting oil supply or demand caused oil price to fluctuate. Where oil spot price was extracted from global oil supply and demand, investors' hedge on oil price formed future oil prices and hence, high volume of oil speculations could influence new oil price trends as well. The most important subject in oil market was the analysis of oil price shocks, factors driving these shocks and possible effects of these shocks on other variables. Studying up to date oil price chronology revealed that oil price had widely fluctuated historically due to several

supply-side and demand-side reasons. Most of the important events driving oil price fluctuations were considered as political instabilities within the major net oil-producer countries. Furthermore, relevant national policies and expansions in infrastructures and technologies were nominated as other factors caused fluctuation in oil price.

In Chapter 3, *Literature Review* we studied the current literature about oil price changes and their linkages with macroeconomics and financial market. The current literature about oil price shocks and their effects on economy was deviated into theoretical and empirical. The empirical literature was classified into these three major subjects: symmetry and asymmetry; linearity and nonlinearity; and aggregation and disaggregation. There were different definitions for asymmetry in the current literature. Some had considered this issue as the reaction speed of target variables to the oil price increase or decrease. Some others measured asymmetry through changes in magnitude of target variables due to positive and negative oil price changes. Finally, some believed that asymmetry is the diverse reaction of the target variable to the oil price movements directionally.

The reduction in contributions of oil price shocks to economic variables by the mid-1980s strengthened the possibility of nonlinearity in such effects. The current literature indicated these three widely applied leading nonlinear models: asymmetric specification, scaled specification, and net specification. However, the nonlinearity had not been studied consistently by using only these nonlinear models; some had used nonlinear causality tests with no need to nonlinear modelling. Finally, we understood that the theoretical aggregate level studies covered the traditional supply shocks and demand adjustments while the empirical aggregate level studies generally regressed GDP on the oil price and several more variables. In contrast, disaggregate level studies were mainly focused on the effects of oil price shocks on disaggregated variables in markets, sectors and industries. Our investigation of the empirical literature showed that there are still non-answered questions in aggregate level studies which needed more research to be answered. For example, the difference in responding mechanism between oil-producer and oil-consumer economies to oil price fluctuations was not clear yet.

Chapter 4. *Causal Effects of Global Oil Price Fluctuations* considered the effects of oil price changes on the economies of large net oil-producer and consumer countries using a bias-corrected least squares dummy variables approach, Granger causality tests and monthly data from May 1986 to January 2013. We found some similarities and

diversities in responses of each panel. In the both panels, there was a bi-directional relationship between global oil price movements and industrial production as well as real exchange rate. However, there was no evidence confirming panel Granger causation between global oil price changes and consumer price index. Finally, short-term interest rate did not Granger cause oil price movements in either set of countries. Our country-specific results showed that changes in real exchange rate and share prices were elastic in both panels, such that 10% increase in oil price reduced real exchange rate by 0.3% and 0.4% in net oil-consumer and net oil-producer countries, respectively. We also found that a 10% increase in oil price raised share prices by only 0.3% in net oil-consumer countries and 1.3% in net oil-producer countries.

On the other hand, we found diversities in reactions of the variables to global oil price changes: first, monetary aggregate and oil price movements exhibited bi-directional causality among net oil-producer countries, whereas we only observed one-way causation running from monetary aggregate to oil price changes in net oil-consumer countries. A 10% increase in oil price caused monetary aggregates to drop by -0.1% whereas such causal effects were not statistically significant in net oil-producer countries. Second, there was no causation reported between oil price changes and short-term real interest rate in net oil-producer countries, however, oil price changes affected short-term real interest rate in net oil-consumer countries significantly. A 10% increase in oil price raised short-term real interest rate by 0.4% in net oil-consumer countries. Finally, while oil price movements and share prices exhibited a bi-directional relationship in net oil-consumer countries, such causation was only running from oil prices to share prices in net oil-producers.

In Chapter 5. *Long-term Effects of Global Oil Price Fluctuations* we studied the long-term linkages between global oil price changes and our selected variables. Using the panel co-integration Westerlund method for our data set which was covering January 1970–August 2013, we found that first, where there was no evidence confirming the existence of panel co-integrating relationship between oil price and macroeconomy of net oil-producer countries, such linkages were significant across net oil-consumer countries. Second, the financial markets of both groups of countries were in long-term co-integrating relationship with global oil price movements. The results demonstrated that the financial markets responded to oil price shocks very similarly. Short-term real interest rate and industrial production responded to oil price shocks with the highest similarity; on average, 94% of the industrial production responses and 90% of real

interest rate responses to oil price shocks were the same across all countries. Conversely, there was no similarity in responses of consumer price index to oil price shocks across countries and hence, such behaviour was country-specific.

Finally, macroeconomic disequilibrium induced by an oil price shock was adjusted quite differently across the panels while financial markets were adjusted very similarly in both of the panels. In net oil-consumer countries, consumer price index was adjusted toward long-term equilibrium during 3.5 years on average. Such adjustment speed varied from 4.8 percent in Denmark to 1.1 percent in Italy. Furthermore, industrial production was adjusted toward long-term equilibrium by less than a year which indicated monthly adjustment speed of 8.5 percent on average. Such equilibrium, however, seemed unstable. On the other hand, where 3–10 percent of disequilibrium in share prices in net oil-consumer countries was adjusted during a month, 3–6 percent of such disequilibrium was adjusted each month in net oil-producer countries. In addition, real interest rate was adjusted toward long-term equilibrium in less than 1.5 years on average within both panels.

The unclear responses of monetary aggregate, consumer price index and short-term real interest rate resulted from Chapters 4 and 5 motivated us to perform further research through nonlinear causality tests. Consequently, in Chapter 6. *Nonlinear Macroeconomic Effects of Global Oil Price Fluctuations* we first studied the nonlinear causation of oil price changes over the relevant macroeconomic variables including monetary aggregates and consumer price index. Employing January 1986 – August 2013 data, we run nonlinear causality tests using two powerful nonlinear models named nonlinear nonparametric Hiemstra–Jones and parametric Mackey–Glass models. Both models were already modified with other researchers.

About nonlinear causation of global oil price changes over monetary aggregate, we found that oil price movements directly affected monetary aggregates in both net oil-consumer and net oil-producer countries. The strong nonlinear causation of oil price changes over monetary aggregate was mostly evident in Denmark, Germany, the Netherlands, and the US among net oil-consumer countries and in Norway and Mexico among net oil-producer countries. The relevant test statistics were highly significant in the net oil-consumer countries and demonstrated that the causal effects of the oil price changes on the monetary aggregates were persistent for 7 months with a 2-month lag. In the net oil-producer countries, the causation of global oil price changes over the

monetary aggregate was persistent for 5 months with a 3-month lag in Norway and 4 months with a 2-month lags in Mexico. It was also worth noting that such responses to global oil price changes were asymmetric; that is, only positive oil price movements caused significant changes in monetary aggregate.

Chapter 6 also included nonlinear causality tests between global oil price changes and consumer price index. We performed the same nonlinear tests applied for monetary aggregate – oil price relationship. The results of parametric and nonparametric tests were considerably different. Based on the parametric test, we found no evidence indicating nonlinear causation of global oil prices over consumer price index unless in Denmark and Canada. The results showed that the lag-length period for the effects of global oil price changes on consumer price index varied from 1 – 10 months on average.

Conversely, nonparametric test results indicated strong causality within all net oil-producer and three out of seven net oil-consumer countries running from oil price changes to consumer price index. Germany and Sweden exhibited a strong nonlinear unilateral causation running from global oil price to consumer price index. The test statistics were significant at 99 percent level of confidence. The nonlinear causation in the US was bilateral and statistically significant. There was also a unilateral causation running from consumer price index to global oil price in Denmark, which was statistically significant at 90 percent level of confidence. On the other hand, Canada exhibited a unilateral causation running from global oil price to consumer price index at 99 percent level of confidence. Norway and Mexico displayed bilateral causality at the 95 and 99 percent level of confidence, respectively.

Similar nonlinear approaches were employed in testing nonlinearity between oil price and short-term real interest rate in Chapter 7. *Nonlinear Financial Market Effects of Global Oil Price Fluctuations*. Again, parametric and nonparametric nonlinear models delivered different results; the nonparametric Hiemstra–Jones model rejected the existence of any nonlinear linkages between global oil prices and short-term real interest rate. On the other hand, the parametric Mackey–Glass test showed that as opposed to net oil-consumer countries, oil price fluctuations in net oil-producer countries caused nonlinear variations in short-term real interest rate nonlinearly. The statistics for Canada, Norway and Mexico are significant at 1 per cent, 10 per cent and 10 per cent levels, respectively. Additionally, the nonlinear responses to oil price fluctuations were reported to be asymmetric.

8.2. Contribution of the thesis

The existing theoretical literature mainly concludes that oil price changes influence the economies of both oil-exporters and importers, but in opposite directions. In this sense, lower oil prices are similar to a tax cut, which increase consumer disposable income. This allows central banks to expand money aggregate. Due to upgrading cash flows, lower interest rates and lower inflation rates cause higher economic activity and higher share prices. Jumping industrial production finally leads economic growth. In contrast, higher oil prices are common reasons for appearing recessions in net oil-consumer countries. On the other hand, while higher oil prices may cause recession in net oil-consumer countries, economic growth may appear in net oil-producers. These theoretical arguments finally conclude that significant reduction in oil price may benefit oil-importer and harm oil-exporter countries and vice versa.

The current empirical studies do not fully support the above-mentioned theoretical achievements; they usually suffer from the lack of relevant data to cover large net oil-consumer and producer countries properly. In this thesis, we concern about the mentioned gap within empirical studies. Thus, we selected the broadest sample including net oil-consumer and net oil-producer countries with the highest frequently available data set. Our criteria to select the sample was the crude oil share of GDP, such that a higher oil share of GDP for a country indicates greater oil dependency.

The contribution of this thesis is summarized into the three following achievements. First, we now have evidence indicating that in the short-term, the responses of macroeconomic and financial market variables to global oil price shocks are very similar across net oil-consumer and producer countries. This rejects the discussed diverse responses of economic variables to oil price fluctuations among net oil-consumer and producer countries. In the long-term, the macroeconomies of net oil-consumer countries are co-integrated with oil price fluctuations. This finding was not confirmed for the net oil-producer countries. In financial markets, on the other hand, both panels are in long-term co-integrating relationships with oil prices.

More specifically, these findings indicate that the macroeconomies of net oil-producer countries are more dependent onto oil price movements than those of net oil-consumers. This is due to the significant causal effects of global oil price changes on industrial production, real exchange rate, monetary aggregates and the consumer price index in net

oil-producer countries. Conversely, the strong effects of global oil price changes on share prices and short-term real interest rates in net oil-consumer countries reveal that global oil price movements exert stronger effects on the financial markets in these countries.

Second, oil price has no effect on consumer price index in the short-term while it exerts significant influences in the long-term. The nature of such effects is considered mostly linear across net oil-consumer countries and nonlinear within net oil-producer countries. These responses are country-specific; that is, we could not find any similarity between them. A shock in consumer price index induced by an oil price shock is adjusted during 3.5 years on average. Real exchange rate is our other macroeconomic variable. This variable responds to global oil price changes only in the short-term.

Monetary aggregate is our third macroeconomic variable, which responds to global oil price variations only in the short-term. The calculated responses are reported to be mostly nonlinear and country-specific. These responses are asymmetric; only positive oil price changes cause variations in monetary aggregate. Finally, industrial production is our last macroeconomic variable. Oil price influences this variable very significantly. We found that the industrial production responses to global oil price changes are very similar across net oil-consumer and producer countries. It is also in long-term co-integrating relationship with oil price; any shock in industrial production induced by an oil price shock is adjusted by less than a year.

Finally, oil price affects short-term real interest rate, as one of our financial market variables, very significantly. These effects are not similar across net oil-consumer and producer countries. Where oil price causes variations in short-term real interest rate linearly across net oil-consumer countries, such causation is nonlinear and asymmetric within net oil-producer countries. The short-term real interest rate is also in long-term co-integrating relationship with global oil prices. A disequilibrium in short-term real interest rate induced by an oil price shock is adjusted by 1.5 years on average. Share price is the other financial market variable in this thesis. We found that oil price significantly influences share prices in both panels of countries. They also perform stable long-term co-integrating relationship. Although the responses to oil price shocks are very similar across net oil-consumer and producer countries, any disequilibrium in share prices driven by oil price shocks are adjusted in net oil-producer countries slightly

slower than in net oil-consumers. However, the adjustment speed varies significantly across sample countries.

8.3.Thesis limitations

This thesis includes a number of limitations as follows. First, although we selected the broadest possible sample of net oil-consumer and net oil-producer countries, the lack of proper monthly data limited our access to the biggest oil-producer and oil-consumer countries. For instance, the biggest oil-producers are among OPEC countries where we could not add them to our sample countries.

Second, although we found significant nonlinear causation, mainly running from oil price changes to some studied variables, the nonlinear models basically provide no guidance on the source of nonlinearities. Such guidance is left to theory and may need specific parameterized structural models. Furthermore, by studying the nonlinear models, it is not possible to determine whether significant nonlinear predictive power is evidence of positive or negative nonlinear causality. Beside the evidence that nonlinear models supply, linear causality tests may provide an incorrect assessment of the true relationship between oil price movements and other variables, which might be of nonlinear nature and hence, may suggest misleading policy actions.

Finally, where a broad set of variables make up the macroeconomics and financial markets of each country, we were strictly limited in selecting the sample variables. We could not select the job market variables or sectoral variables such as investment, expenditures and international sector variables. More importantly, we could not select industrial price index to be used with industrial production which is supposed to be a proxy for economic activity in the literature. The main reasons for these limitations are the heterogeneous data sources, the lack of monthly data and strengthening the length of the thesis.

8.4.Direction for future research

There are three suggestions for future research. First, we used oil price fluctuations in this thesis, which measure simple price movements. This variation involves both expected and unexpected changes. Reviewing the current literature indicates that the economic responses to expected changes in oil price may differ from those to unexpected movements in oil price. There are econometric methods such as vector autoregressive simulation techniques to separate these two types of fluctuations in oil price.

Perhaps, studying the macroeconomic and financial market responses to expected and unexpected changes in oil price reveals more facts about oil price influences on economic variables.

Second, it is highly recommended to re-estimate our models, at least partially, by using the variables expressed in domestic currency units. Although this approach has less comparative value than what we followed in this thesis, it maintains several benefits. For instance, the country-specific reaction of some variables could be precisely monitored. Moreover, the role of the exchange rate as an intermediate between domestic and international values of the variables is considerably reduced. This thickens the influences of all other variables which could indirectly affect the variables through the exchange rate.

Finally, concerning the outcomes of this thesis, we now recommend to focus on disaggregate level which indicates sector and industry levels. Estimating the causal effects of oil prices using sectoral variables and subsequent estimations at industrial level have several benefits. At least the contribution of each economic sector and the relevant industries in total effects of oil price fluctuations on economy could be explored. This supports policy decision makers to monitor the most effective channels transmitting oil price influences. In addition, such disaggregate level studies supply detailed information for the comparison between oil-producer and consumer countries.

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