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Modeling the Global Market for Crude Oil and Forecasting the Price: A Comprehensive Study

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To my loving brother, Roozbeh Bashiri Behmiri, who forever there will be a special place for him in my heart, and to my dearest parents, who beleived me, encouraged me and thaught me to be strong.

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Resumo

Antes de 1970 os preços do petróleo eram controlados por companhias petrolíferas multinacionais; de 1970 até 1986 esteve em vigor o sistema de preços administrativos da OPEP; e de 1986 até ao presente, são determinados pelo mecanismo conhecido como "market-linked pricing mechanism" ou rácio "demand-to-supply" assente num conjunto de diversos factores – económicos, políticos, financeiros, tecnológicos, meteorológicos e reservas de petróleo. Neste mecanismo, os principais factores determinantes da evolução do preço do petróleo bruto são a procura e a oferta; por isso, a identificação dos "drivers" do consumo de petróleo e da produção é a principal prioridade na definição dos preços futuros do petróleo.
Assim, para levar a cabo uma previsão segura dos preços do petróleo torna-se necessário seguir um processo tri-etápico em que: 1) A primeira etapa consiste na exploração do consumo de petróleo numa escala mundial. Isto significa que os factores que explicam as variações do consumo de petróleo e consequentemente que explicam as variações do preço do petróleo devem ser identificados ou reconhecidos primeiro. 2) A segunda etapa consiste em investigar o comportamento da produção de petróleo numa escala igualmente mundial. Tal significa que os factores que provocam as oscilações da produção de petróleo e que, consequentemente, fazem variar o preço do petróleo devem ser igualmente identificados. E 3) a terceira etapa consiste em estudar os factores determinantes que estão por detrás das variações do preço do petróleo tendo em atenção os resultados das primeira e segunda etapas, e finalmente, em seleccionar os modelos com menores erros previsionais.

Para cumprir as etapas acima descritas levamos a cabo três grandes investigações:
Na primeira, investigamos o nexo de causalidade ou de ligação entre o consumo de petróleo e o crescimento económico, o "crude oil consumption-economic growth nexus", recorrendo ao teste de raízes unitárias com dados em painel, ao teste de cointegração com dados em painel e aos testes de causalidade à Granger ainda com dados de painel, em cinco estudos, que incluem um painel de países da OCDE, dois painéis de países da América Latina, dois panéis para as regiões subsaarianas de África, um painel para a região do Médio Oriente e África do Norte (MENA) e um painel de mercados emergentes da Ásia do Sul e do Leste; além disso, investigamos ainda o mesmo efeito no caso individual de Portugal.
Os resultados mostram que, entre os países da OCDE, os países importadores líquidos de petróleo da África subsaariana, do MENA, da Ásia do Sul e do Leste e Portugal, tanto no curto como no longo prazo, há relações de causalidade bidireccional entre o consumo de petróleo bruto e o crescimento económico; no caso dos países da América Central, no curto prazo, há uma relação de causalidade bidireccional entre os dois tipos de séries, e no longo prazo, há uma relação de causalidade unidireccional do consumo de petróleo para o crescimento económico; e entre os países exportadores líquidos de petróleo da África subsaariana, no curto prazo, há uma relação de causalidade unidireccional do consumo de petróleo para o

crescimento económico, havendo no longo prazo, uma relação de causalidade bidireccional entre os dois tipos de séries; e na região das Caraíbas e da América do Sul, no curto prazo, há uma relação de causalidade bidireccional entre as séries do consumo e do crescimento económico, enquanto no longo prazo, há uma relação de causalidade unidireccional no sentido crescimento económico para consumo de petróleo.

Tendo em atenção os resultados acima descritos, recomendamos que o crescimento económico seja usado como variável explicativa das variações futuras do consumo de petróleo e consequentemente dos preços internacionais futuros do preço do petróleo. Além disso, entre as regiões em que o consumo de petróleo é causa à Granger do crescimento económico, recomendamos que os "policymakers" implementem cuidadosas políticas de conservação de energia e que tenham em consideração que a redução do consumo de petróleo tem impactos negativos nos seus crescimentos económicos.

No segundo estudo investigamos os comportamentos dos produtores de petróleo dos membros e não membros da OCDE usando o teste de raiz unitária, o teste de cointegração conhecido como abordagem "ARDL bounds testing" e o teste de causalidade à Granger. A importância da identificação dos factores determinantes da produção petrolífera numa escala mundial advém do facto de num mecanismo de preço "market-linked", a produção de petróleo bruto ser um factor explicativo dos preços de petróleo; além disso, a determinação das variáveis com impacto na produção de petróleo é essencial para a análise do mercado futuro do petróleo e para aumentar a capacidade previsional dos preços futuros do petróleo bruto.

Os resultados do segundo estudo mostram que cada país produtor de petróleo bruto tem um comportamento diferenciado assente nas suas condições internas, e que não há um só conjunto de variáveis explicativas que se possa sugerir como factores determinantes; esta ilação aplica-se tanto aos países produtores da OPEP como aos países não-OPEP. Recomendamos a adopção por parte da OPEP de medidas punitivas e de incentivos que obriguem os seus membros a prosseguirem um comportamento produtivo adequado de forma a estabilizar os preços do petróleo. Além disso, a quota dos membros da OPEP como critério oficial é a única variável útil para controlar e explicar as flutuações futuras dos preços internacionais do petróleo.

E no terceiro estudo levamos a cabo a modelação e previsão do preço do petróleo. Nesse sentido analisamos os factores determinantes com impacto no preço do petróleo desenvolvendo nove modelos estruturais com vista a explicar os 'drivers' por detrás dos movimentos ou oscilações do preço do petróleo. Calculamos também as previsões mensais (de curto prazo) para o preço nominal spot do petróleo Brent para os anos de 2008 a 2012.

Os resultados mostram que, o choque no preço de 2008 pode ser explicado pelo aumento na produção industrial da OCDE, e que os movimentos de preços de petróleo de 2012 são melhor clarificados ou explicados pela especulação nos mercados do petróleo. Nesse sentido

recomendamos a adopção de algumas medidas restritivas no financiamento dos mercados petrolíferos.

Palavras-Chave:

Consumo de petróleo, produção de petróleo bruto, previsão dos preços do petróleo, causalidade à Granger de painel, testes de cointegração de painel, teste de cointegração ARDL.

Abstract

Crude oil prices before 1970 were under control by multinational monopolist oil companies; from 1970 to 1986 OPEC administered pricing system determined crude oil prices; and from 1986 to the present, crude oil prices are determined by a market-linked pricing mechanism or demand-to-supply ratio, taking in account a set of many other factors, such as economic, political, financial, technological, meteorological and oil reserves. As in a market-linked pricing mechanism, the main determinant factors behind crude oil prices are demand and supply; hence, identifying crude oil consumption and production and the drivers behind them are the main priority to define future crude oil prices.

Therefore, to achieve an accurate crude oil price forecasting, a three stages study is required: 1) the first stage is to explore crude oil consumption in a worldwide scale. This means that the factors that explain crude oil consumption changes and consequently they are involved in crude oil price changes should be firstly recognized. 2) The second stage is to investigate crude oil production behaviors in a worldwide scale. This means that the factors that cause changes in crude oil production and consequently are involved in crude oil price changes should be identified. And 3) the third stage is to study the determinant factors behind crude oil price variations based on the results from stages one and two, and finally to choose the best models those with less forecasting errors.

To perform the above-described stages, we develop three major researches:

In the first study, we investigate crude oil consumption-economic growth nexus, applying the panel unit root, the panel cointegration and the panel Granger causality tests, under five panel framework studies, including a panel of OECD countries, panels of Latin American regions, panels of Sub-Saharan African countries, a panel of MENA countries and a panel of Southern and Eastern Asian emerging markets; moreover, we investigate the same effect in the case of an individual country-Portugal-as well.

The results show that, among OECD, net oil importing Sub-Saharan African, MENA, Southern and Eastern Asian countries and Portugal, both in the short-run and in the long-run, there are bidirectional causality relationships between crude oil consumption and economic growth; in Central America region, in the short-run, there is a bidirectional causality relationship between the series, and in the long-run, there is a unidirectional causality relationship running from crude oil consumption to economic growth; and among net oil exporting Sub-Saharan African countries, in the short-run, there is a unidirectional causality relationship running from crude oil consumption to economic growth, and in the long-run, there is a bidirectional causality relationship among the series; and in Caribbean and South America regions, in the short-run, there are bidirectional causality relationships between the series, while in the long-run, there is a unidirectional causality relationship running from economic growth to crude oil consumption.

According to the above-described results, we recommend that economic growth can be used as an explanatory variable to explain future changes in crude oil consumption and consequently future international crude oil prices. Moreover, among the regions that crude oil consumption Granger causes economic growth, we recommend that policymakers implement oil conservation policies more carefully and consider that reduction of crude oil consumption has negative impacts on their economic growth.

In the second study, we investigate crude oil production behaviors by OPEC members and non-OPEC producers, using the unit root test, the ARDL bounds testing approach for cointegration and the Granger causality test. The importance behind identifying the determinant factors of crude oil production in a worldwide scale is that, in a market-linked pricing mechanism, crude oil production is an explanatory factor of crude oil prices; therefore, determining the variables that impact on crude oil production is essential in order to analyze future crude oil market and to increase the forecasting accuracy of future crude oil prices.
The results of the second study show that, each crude oil producer country has a different production behavior based on its domestic conditions, and there is not a unique set of explanatory variables that can be suggested as the determinant factors; this applies to OPEC and non-OPEC producers. We recommend the adoption of punitive and incentive tools by OPEC as an international organization to oblige its member to follow the appropriate production behavior in order to stabilize crude oil prices. Moreover, OPEC members' quota as an official criterion is the only helpful variable to control and explain future fluctuations of international crude oil prices.

And in the third study, we perform crude oil price modeling and forecasting. We analyze the determinant factors that impact on crude oil price by developing nine structural models to explain the drivers behind crude oil price movements. We provide the short term monthly forecasts for the nominal spot price of Brent crude oil for the years 2008 and 2012.
The results show that, the 2008 price shock mainly can be explained by the surge in the OECD industrial production, and that the 2012 price movement mainly can be clarified better by the level of speculation in crude oil markets. Thus, we recommend the adoption of some restrictions on the financialization of crude oil markets.

Keywords

Crude oil consumption, crude oil production, forecasting crude oil prices, panel Granger causality, panel cointegration tests, ARDL cointegration test.

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List of Acronyms

ADF: Augmented Dickey -Fuller

AIC: Akaike Information Criterion

APEC: Asia-Pacific Economic Cooperation

AR: Auto-Regressive

ARCH: Auto-Regressive Conditional Heteroskedasticity

ARDL: Auto-Regressive Distributed Lag

ARIMA: Auto-Regressive Integrated Moving Average

ASEAN: Association of Southeast Asian Nations

BP: British Petroleum

BRIC: Brazil, Russia, India, China

CFTC: US Commodity Futures Trading Commission

CO2: Carbon dioxide

D-L: Dolado-Lütkepohl

ECM: Error Correction Model

ECT: Error Correction Term

EIA: Energy Information Administration

E-G: Engle-Granger

FMOLS: Fully Modified Ordinary Least Square

GC: Granger Causality

GARCH: Generalized Auto-Regressive Conditional Heteroskedasticity

GDP: Gross Domestic Product

GIR: Generalized Impulse Response

GMM: Generalized Method of Moments

H-P: Hodrick–Prescott

IEA: International Energy Agency

IP: Industrial Production

IPE: International Petroleum Exchange

IRF: Impulse Response Function

J-J: Johansen-Juselius

MENA: Middle East and North Africa

NYMEX: New York Mercantile Exchange

OECD: Organization for Economic Cooperation and Development

OPEC: Organization of Petroleum Exporting Countries

PDVSA: Petróleos de Venezuela, SA, is the Venezuelan state-owned petroleum company

PMG: Pooled Mean Group

PP: Phillips-Perron

RIN: Relative Inventory

SBC: Schwartz Bayesian Criterion

SIMEX: Singapore International Monetary Exchange

SPU: Speculation

T-Y: Toda-Yamamoto

US: United States

UK: United Kingdom

VAR: Vector Auto-Regressive

VD: Variance Decomposition

VECM: Vector Error Correction Model

WDI: World Development Indicators

WTI: West Texas Intermediate

Chapter 1

1. General introduction

1.1. Description of crude oil market

Crude oil is a product that occurs naturally and can be found in certain rock formations around the world. This special substance is a dark and sticky liquid, which scientifically is classified as a compound of hydrocarbons; this means that the components are carbon and hydrogen, with or without oxygen and sulfur. Crude oil is extremely flammable and is using to generate energy; therefore, derivatives from crude oil produce excellent fuels.

In general the unit of measure for crude oil is barrel; however, in some cases it is also measured in ton. The reason why barrel is chosen as the measure unit is that, in the 19th century in the US[1], when crude oil came into the large scale commercial use for the first time, it was stored in wooden barrels. One barrel is equal to 42 US gallons or 159 liters (Etzel, 2008). Moreover, the number of barrels that is contained in each ton varies depending on the type and gravity of crude oil; nonetheless, the average number is around 7.33 barrels per ton.

In January 1, 2013, the proven world crude oil reserves were estimated at 1.638 billion barrels that is almost 7 percent higher than the estimated amount for 2012 (Oil and Gas Journal, 2012). According to the estimation for January 2013, around one-half of the proven world crude oil reserves were located in the Middle East, and more than 80 percent of that was located in eight countries, that among them only Canada and Russia are not OPEC members (Oil and Gas Journal, 2012).There are various types of crude oil around the world with different qualities and characteristics, they are classified based on the geographical location where it is formed, its gravity (it is light if it has low density and is heavy if density is high) and its sulfur content (it is sweet if it contains little sulfur and is sour if the amount of sulfur is higher) (EIA, 2012). There are almost 161 identified crude oil benchmarks (EIA, 2006); however, only few of them are well known, such as West Texas Intermediate (WTI), North Sea Brent and Dubai crude oil. Moreover, some other primary benchmarks are OPEC reference basket, Indonesian Minas, Malaysian Tapis, Nigerian Forcados, etc. All classifications have different prices.

[1] US, United States

Crude oil pricing mechanism has changed during past decades. Before the mid 1950s, the global crude oil market was under control by a panel of multinational oil companies recognized as the Seven Sisters or the Majors, as during that period the host governments did not have any role in production or crude oil price formation; they were acting only as competing sellers of oil licenses (Fattouh, 2006). The Seven Sisters or the Majors were controlling approximately 85% of the world's crude oil production outside the US, Canada, Soviet Russia and China (Danielsen, 1982). In the same period several events impacted on crude oil prices; the Second World War that started in 1939 declined crude oil price sharply, but after the war in 1945 crude oil became a predominant source of energy, during the period 1945-1947, the world's economy and specially the US was activated and crude oil consumption increased and led to an about 80% rising in crude oil prices; however, the US recession in 1948 again decreased crude oil prices; furthermore, the Korean war between 1951-1953, the Iranian oil industry nationalization in 1951, the strike in the US oil refinery industries in 1952, the nationalization of the Suez Canal in 1956 and the new US recession in 1957 had significant impacts on crude oil prices.

On the other hand, new oil reserves were discovered mainly in the Middle East by the late 1950s; consequently, new countries became producers and entered to the international crude oil market. Moreover, in the mid 1950s, Venezuela granted independence mainly from the US and by 1965 the non-majors were responsible for 15% of the Venezuela's oil production (Parra, 2004). As another examples for growing the Majors' competitors we can mention to the cases of Libya, Iran and Saudi Arabia: after oil discovery in Libya, Libyan decided to attract various oil companies and not only the Majors, another example is the signing of two oil exploration and development agreements in Persian Gulf offshore with the non-majors by Iran; and last example is the Saudi Arabian and Japanese trading companies' agreement to explore and develop a Saudi Arabia's field (Parra, 2004). Consequently, controlling crude oil production and crude oil prices became more complex and control of the Majors on crude oil pricing was challenged.

In 1960, the Middle Eastern oil producing countries established OPEC[2] cartel in order to prevent crude oil price decline (Skeet, 1988); however, it took more than one decade that OPEC obtained enough power to influence the world crude oil market. Despite all changes that occurred in the structure of crude oil industry, until the late 1960s the total volume of crude oil from the US independents and other companies operating in Venezuela, Libya and Persian Gulf offshore still remained very small and the Seven Sisters or the Majors were the dominant power of the crude oil industry (Penrose, 1968).

During the period 1965-1973, global crude oil demand increased at a fast rate with an average annual growth of more than 3 million barrels per day (BP statistical yearbook, 2010). Most of this increase was provided by OPEC cartel, with an increase in production from around 14 million

[2] OPEC, Organization of Petroleum Exporting Countries.

barrels per day in 1965 to around 30 million barrels per day in 1973, and as a consequence the world's production share of OPEC jumped from 44% in 1965 to 51% in 1973 (Fattouh, 2011); as a result, OPEC members' power increased considerably in comparison to the Majors. On the other hand, in 1971 for the first time the Texas Railroad Commission produced at 100 percent of its capacity and there was no spare production capacity in the US, this means that the US dominant producers had no tool to control crude oil prices; hence, for the first time the power to control crude oil prices shifted from the US corporations to OPEC cartel (Texas State Library and Archives Commissions, 2013).

During the period from 1974 to the mid-1980s OPEC was pricing crude oil by administered pricing system when the balance of power was in favor of OPEC (Mabro, 2005). The success for OPEC boosted since 1970 when world crude oil demand exceeded world supply; however, the shortage consequence became more visible after the Yom Kippur War in October 1973, when the Arab OPEC crude oil exporting members reacted with an oil embargo to countries that were supporting Israel during the war (Texas State Library and Archives Commissions, 2013). At this time OPEC reduced production by five million barrels per day while non-OPEC producers increased their production only by one million barrels per day (Williams, 2011); as a result, during the next six months prices raised by 400 percent, from 3 US$ per barrel to 12 US$ per barrel at the end of 1974 (BP statistics yearbook, 2012). These numbers showed the vulnerability of crude oil price to supply.

The second crude oil crisis happened in 1979-1980. The combination of Iranian revolution in 1978-79 and the Iran-Iraq war, which started in 1980 led to a reduction in crude oil production of both countries by 6.5 million barrels per day in 1980; consequently, prices increased to more than double from 14 US$ per barrel in 1978 to 35 US$ per barrel in 1981(Williams, 2011). However, higher crude oil prices caused several reactions from countries and individual consumers, such as implementing energy efficiency programs in industries, automobiles and households; and energy substitution programs among others, reactions that together with a global recession led to a falling in crude oil prices in the first half of the 1980s.

On the other hand, higher crude oil prices encouraged non-OPEC producers to increase their production by 6 million barrels per day in order to obtain more benefits. Furthermore, new resources that were discovered during the 1970s were coming available and OPEC faced an oversupply (Fattouh, 2011), and after 1980 crude oil prices began a six years decline.

At this time, a disagreement among OPEC members caused the implementation of a two-tiered price reference structure (Fattouh, 2011). In 1980 Saudi Arabia used 32 US$ per barrel as the reference price, while the other OPEC members used 36 US$ per barrel; thus, two new concepts were introduced: the actual market price that was fixed by Saudi Arabia and the deemed market price that was fixed by the rest of OPEC (Amuzegar, 1999).

During the period from 1982 to 1985 OPEC attempted to set a production quotas policy to stabilize crude oil prices; however, this strategy failed several times as some OPEC members kept on producing beyond their quotas. During this period, Saudi Arabia acted as a swing producer, cutting its production in order to adjust demand and prevent price falls (Williams, 2011). During the same period, price dropped from 35 US$ per barrel to 15 US$ per barrel (BP statistics yearbook, 2012), and it became obvious that OPEC administered pricing system was not able to defend price for the long term and the only result of the Saudi Arabia's attempt to defend crude oil price was its country's market share loss. Therefore, in 1986, Saudi Arabia left the role of swing producer and increased production from 2 million to 5 million barrels per day to recover the country's market share. This new strategy led to a falling in crude oil price to less that 10 US$ per barrel in July 1986 (Monthly Energy Review, 2013).

Failing the OPEC administered pricing system in 1986-1988 led to a new pricing mechanism; the power to set crude oil prices shifted from OPEC to market (Fattouh, 2011). The market-related pricing mechanism started in 1986, being widely accepted by most of the crude oil exporting countries, and from 1988 to the current it is the main crude oil pricing mechanism in the international crude oil markets (Fattouh, 2011).

After starting crude oil pricing through market-related mechanism, price stayed in the average rate of 20 US$ per barrel until the 1990's Gulf War. In this year, the third crude oil price crisis happened. The invasion of Kuwait by Iraq led to a sudden decrease in production and consequently caused a price shock. This crude oil price shock was milder than previous crises, had only a nine months' duration and contributed to the 1990s' recession. In the same year, prices rose from 15 US$ per barrel at the end of July 1990 to 21 US$ per barrel by August and 30 US$ per barrel by October (Monthly Energy Review, 2013).

After the Gulf War, crude oil prices entered a period of steady reduction until 1994 when price reached an average of 13 US$ per barrel (Monthly Energy Review, 2013). Following 1994, the US economy was growing well and the Asian Pacific region was active; consequently, world's crude oil consumption increased by 6 million barrels per day; on the other hand, Russia declined its production in order to keep price stability (Williams, 2011). During this period, crude oil prices moved from 13 US$ per barrel in 1994 to 17 US$ per barrel in 1997 (Monthly Energy Review, 2013). In 1997, OPEC increased its quota for 10 percent, Iraq came back into crude oil production market, the Asian financial crisis happened and the rapid growth in Asian economies came to half and oil consumption declined; moreover, during this period demand slowed due to warm winters in the northern hemisphere. The combination of lower consumption and higher production led to a downward price trend and prices shifted from 17 US$ per barrel in 1997 to 8 US$ per barrel at the end of 1998 (Monthly Energy Review, 2013). During early 1998 to the mid 1999, OPEC declined its production quota about 3 million barrels per day and prices moved to 22 US$ per barrel at the end of 1999, and continued to rise up to 30 US$ per barrel in 2000 (Monthly Energy Review, 2013).

In 2000, in the first step, OPEC increased its quota by 3.2 million barrels per day, and in the second step, made a second increase of 500,000 barrels per day; furthermore, non-OPEC producers especially Russia increased their production (Williams, 2011) and prices decreased from 30 US$ per barrel in 2000 to 20 US$ per barrel in 2001 (Monthly Energy Review, 2013).

After the terrorist attack of September 11, 2001, prices continued to fall until 2002, and decreased to 15 US$ per barrel in January 2002 (Monthly Energy Review, 2013), when OPEC decreased its quota by 1.5 million barrels per day and non-OPEC countries decreased their production by 426.500 barrels per day (Williams, 2011) and prices moved to 20 US$ per barrel in March 2002 (Monthly Energy Review, 2013). Moreover, in this year Venezuela strike at PDVSA[3] caused a reduction in Venezuela production. As a result, prices increased to 25 US$ per barrel at the end of 2002 and reached to 30 US$ per barrel at the beginning of 2003 (Monthly Energy Review, 2013). In January and February 2003, again OPEC increased its quota by 2.8 million barrels per day and crude oil price declined to 28 US$ per barrel at the end of 2003.

In March 2003, military action of the Western world in Iraq has occurred. In this period, oil inventories either in the US or in OECD[4] countries remained low (EIA, 2012); simultaneously the US and the Asian Economies oil demand again were growing fast. Therefore, OPEC increased its quota and used the spare capacity to meet the world crude oil requirements and compensate production's reduction of Iraq and Venezuela, this policy led to the spare production capacity erosion; hence, spare capacity was not sufficient to compensate the production loss by some OPEC members (Williams, 2011). As a result, crude oil price rose to 40 US$ per barrel and then to 50 US$ per barrel by 2004, to 60 US$ per barrel by August 2005, and finally picked up to 147 US$ per barrel by 2008 (Monthly Energy Review, 2013), the highest price ever seen.

In addition to the above-mentioned factors, many other factors contributed to the recent crude oil prices' increase; among them there were the decline in petroleum reserves, worries about the peak oil, the level of inventories in the US and other consumers and speculations in the crude oil markets. Furthermore, some geo-political events and natural disasters had strong short term effects on crude oil price shocks, such as the US and the Gulf of Mexico hurricanes in 2005, North Korean missile tests in 2006, turmoil in Nigeria during the years 2006 to 2008, Israel and Lebanon conflicts in 2006, ongoing conflict in Iraq and worries about Iranian nuclear plans. Besides the mentioned factors, from 2002 to 2005 the majority of OPEC crude oil producers continued their low production quota policy combined with insufficient non-OPEC countries production. At the same time, although crude oil supply declined, demand was growing strongly, this situation led to boost prices in 2007 and 2008, when global recession appeared in 2008.

These severe global recessions caused crude oil demand to decline in the late 2008 and consequently crude oil prices to fall from 147 US$ per barrel in July 2008 to 32 US$ per barrel by December 2008 and reached 75 US$ per barrel by November 2009 and 84 US$ per barrel by

[3] PVSA, Petróleos de Venezuela, SA, is the Venezuelan state-owned petroleum company.

[4] OECD, Organisation for Economic Cooperation and Development

November 2010; however, it rose to 105 US$ per barrel by November 2011 and to 113 US$ per barrel by April 2012 (Monthly Energy Review, 2013). The most important factors that contributed to the recent crude oil price boost of 2011-2012 were disruption of crude oil production in Libya due to this country's revolution, the global concern on Iranian nuclear program and speculation in crude oil markets.

In a market-linked pricing mechanism, the main determinant factors of crude oil price are demand and supply; hence, identifying crude oil consumption and production and the drivers behind them are the main priority to define future crude oil prices. Below we provide a short description on crude on consumption and production:

World crude oil consumption regions can be divided in two groups: OECD and non-OECD regions. OECD area is the largest crude oil consumer in the world; in 2011 responsible for a share of 51.1% of the total world crude oil consumption. In the same year, among OECD countries, the US with a share of 20.5%, was the largest world crude oil consumer, followed by Japan with a share of 5%, which was the third biggest consumer (after China). At the same time, non-OECD countries reached a share of 48.5% of the total world crude oil consumption. Among them, China with a share of 11.4% of the world crude oil consumption was the second largest crude oil consumer in the world (after the US), India with a share of 4%, was the fourth one (after Japan); moreover, the Russian Federation and Saudi Arabia with 3.4% and 3.1%, respectively, were the fifth and sixth largest world crude oil consumers, followed by Brazil with 3%, Germany with 2.7%, South Korea with 2.6% and Canada with 2.5%, the seventh, eighth, ninth and tenth largest world crude oil consumers (BP statistics yearbook, 2012).

In production side, world crude oil producers are grouped in OPEC and non-OPEC producers. OPEC is a permanent intergovernmental organization created in 1960 by Iran, Iraq, Kuwait, Saudi Arabia and Venezuela that later was joined by nine other members: Qatar, Indonesia (suspended its membership in 2009), Libya, the United Arab Emirate, Algeria, Nigeria, Ecuador (suspended its membership during the period 1992-2007), Angola and Gabon (ended its membership in 1995) (OPEC world oil outlook, 2011). The objective of OPEC is organizing petroleum policies among member countries in order to secure and stable prices for petroleum producers; to guarantee an efficient, economic and regular supply of petroleum for consuming countries; and to assurance a fair return on capital to those investing in the industry (OPEC world oil outlook, 2011).

OPEC member countries contained 72.5% of the world crude oil proven reserves in 2011 that are mostly located in the Middle East with a share of 65% of the total OPEC proven reserves. Moreover, five countries with the largest world crude oil proven reserves are OPEC members. Among them, Venezuela with a share of 17.9% contained the largest crude oil proven reserves in the world, Saudi Arabia with 16.1% was the second, Iran with 9.1% (after Canada) was the fourth, Iraq with 8.7% was the fifth, Kuwait with 6.1% was the sixth, the United Arab Emirates with 5.9% was the seventh, Libya with 2.9% was the ninth (after the Russian Federation), Nigeria with 2.3% was the tenth, Qatar with 1.5% was the thirteenth (after the US and Kazakhstan) and Angola with 0.8% was the fifteenth country with the largest crude oil proven reserves (after China and Brazil), in 2011 (BP statistics yearbook, 2012).

On the other hand, during the same year the OPEC's world crude oil production share was 42.5%. Saudi Arabia with a share of 13.2% was the largest crude oil producer in the world, Iran with 5.2% was the fourth largest (after the Russian Federation and the US), the United Arab Emirates with 3.8% was the seventh (after China and Canada), Venezuela and Kuwait with 3.5% were the ninth (after Mexico), Iraq with 3.4% was the tenth, Nigeria with 2.9% was the eleventh, Angola with 2.1% was the thirteenth (after Norway) and Qatar with 1.8% was the fourteenth largest crude oil producer in the world (BP statistics yearbook, 2012). These significant shares in crude oil reserves and productions give an enormous power to OPEC in order to influence global crude oil prices.

Crude oil proven reserves outside OPEC represent almost 27.5% of the world crude oil proven reserves. Among the fifteen countries that have the largest world crude oil proven reserves, seven of them are non-OPEC countries. Among them, in 2011, Canada with a share of 10.6% was the third country with the largest crude oil proven reserves (after Venezuela and Saudi Arabia), the Russian Federation with 5.3% was the eighth (after the United Arab Emirate), the US with 1.9% was the eleventh (after Nigeria), Kazakhstan with 1.8% was the twelfth, and China and Brazil with 0.9% (after Qatar) both were the fourteenth countries with the largest crude oil proven reserves (BP statistics yearbook, 2012).

Moreover, non-OPEC producers contain 41% of the world crude oil production. Among them, in 2011, there is the Russian Federation with a share of 12.8% that was the second largest crude oil producer (after Saudi Arabia), the US with 8.8% was the third, China with 5.1% (after Iran) was the fifth, Canada with 4.3% was the sixth, Mexico with 3.6% was the eight (after the United Arab Emirates) and then Brazil and Nigeria with 2.9% both were the eleventh (after Venezuela, Kuwait and Iraq), Norway with 2.3% was the twelfth, Kazakhstan (jointly with Angola as an OPEC member) with a share of 2.1% were the thirteenth and the UK[5] with 1.3% (after Qatar) was the fifteenth largest crude oil producer in the world (BP statistics yearbook, 2012).

Non-OPEC producers are mostly considered as price takers and profit maximizers; however, they have significant impact on OPEC share of the world's crude oil production and consequently on OPEC's ability to influence on prices (Kaufmann, 1995). Historically, most of non-OPEC producers have increased their production in order to increase their revenue; it means that these producers have taken advantage of OPEC's role as the swing producer that restricts its production to stabilize the market prices. As a result, for some years, the non-OPEC producers' market share rose. However, there is a general consensus that crude oil market stability is achievable only through cooperation between OPEC and non-OPEC producers, for this reason, during the recent years several non-OPEC producers, including Mexico, Norway, Oman and the Russian Federation, started

[5] UK, United Kingdom

to cooperate with OPEC and cut their production in order to stabilize the market and recover crude oil prices (OPEC[6], 2012).

In summary, before 1970 crude oil prices were under control and determined by the multinational monopolist oil companies; from 1970 to 1986 the OPEC administered pricing system determined crude oil prices; and from 1986 to the present, crude oil prices are determined through a market-linked pricing mechanism or demand-to-supply ratio. Currently, the market-linked mechanism determines crude oil price taking in account a set of many other factors, such as economic, political, financial, technological, meteorological, oil reserves and etc, based on three mentioned crude oil classifications (location, gravity and sulfur) at exchange merchandise centers such as NYMEX[7], IPE[8], and SIMEX[9], mainly using spot contracts, future and option contracts, short-term forward contract and swap bargain.

1.2. Research questions and motivations

As we mentioned earlier, from 1986 to present, crude oil prices were determined by a market-linked mechanism. This means that price increases and decreases to reflect scarcities and surpluses; a high consumption or a low production lead to a higher market price, and a low consumption or a high production lead to a lower market price. Hence, in order to forecast price of this strategic product, an inclusive investigation on consumption and production is essential.

Therefore, to achieve crude oil price forecasting, a three stages study is required: 1) the first stage is to study crude oil consumption in a worldwide scale. This means that the factors that explain crude oil consumption changes and consequently they are involved in crude oil prices changes should be firstly recognized. 2) The second stage is to investigate crude oil production behaviors in a worldwide scale. This means that the factors, which cause crude oil production changes and consequently are involved in crude oil price changes should be identified. And 3) the third stage is to study the determinant factors behind crude oil price variations based on the results from stages one and two, and finally to choose the best models those with less forecasting errors.

To perform the above-described stages, we develop three major research questions:

1. *What is the direction of Granger causality relationships between crude oil consumption and economic growth?*

The main determinant factors behind consumption for commodities are income and their prices; we suppose that crude oil is not an exception from this rule. Therefore, the first question is whether

[6] Do non-OPEC oil producers support market stability?, OPEC, 2012.
[7] NYMEX, New York Mercantile Exchange.
[8] IPE, International Petroleum Exchange, based in London.
[9] SIMEX, Singapore International Monetary Exchange.

the countries' economic growth and real crude oil prices Granger cause crude oil consumption. In other words, we determine if the mentioned variables are useful to analyze future crude oil consumption and consequently to analyze its future prices. Moreover, we examine the Granger causality relationship from crude oil consumption and crude oil price to the countries' economic growth.

In summary, our motivations to investigate these relationships and the causality nexus are based on two main purposes. Firstly, our motivation for investigating the Granger causality relationship from economic growth to crude oil consumption is to specify the explanatory variables behind crude oil consumption and consequently behind its price, and then build the appropriate econometric models to analyze crude oil price and finally to forecast it. Secondly, the reason for investigating the opposite direction of the relationship; the Granger causality relationship from crude oil consumption to economic growth, is to specify the vulnerability of economic growth to crude oil consumption for each of the regions of the world and consequently recommend the appropriate energy efficiency policies.

2. *What are the major determinant factors behind crude oil production?*

The second research question is to identify which are the drivers behind the production behavior of crude oil producer countries, including either OPEC member producers or non-OPEC producers.

The motivation to perform an inclusive investigation in order to identify the determinant factors of crude oil production in a worldwide scale is that, in a market-linked mechanism situation for crude oil price formation, crude oil production is an explanatory factor for its price. Therefore, identifying the variables that impact on crude oil production is essential for analyzing crude oil market characteristics and to enable us to increase crude oil price forecasting accuracy.

3. *What are the main drivers behind crude oil prices?*

The last research question is related to the main explicative and determinant factors behind crude oil price movements during the year 2008 and the year 2012, in order to generate the best forecasting models.

Crude oil is the largest demanded energy in the world and plays a crucial role on the world's economy. Therefore, forecasting crude oil price through innovative and comparative models, which increase forecasting accuracy of the benchmark methods and the previous models seems to be an essential issue. The motivation to perform the last study is to generate the best forecasting models for crude oil prices.

1.3. Methodology

In the first study we examine the Granger causality relationship among crude oil consumption and economic growth, using crude oil price as the control variable of the model, in a regional scale. We investigate this relationship under five panel framework studies, including OECD countries' panel, Latin America one, Sub-Saharan Africa one, MENA[10] countries one and Southern and Eastern Asian emerging markets one; moreover, we investigate an individual country-Portugal-as well.
To achieve this goal, in first step, we perform the Im et al. (2003) and the Breitung (2000) panel unit root tests in order to examine the stationary properties of the series. In second step, we implement the Pedroni (1999) and the Kao (1999) panel cointegration tests and the Pedroni (2000) panel Fully Modified OLS (FMOLS) test to investigate the existence of long-run relationships between the series under study. And in third step, we apply a dynamic panel Vector Error Correction Model (VECM) in order to clarify the direction of the causality relationships between the same series.

Moreover, in order to examine this relationship for Portugal as a single country study, we examine the stationary properties of the series, using the Augmented Dickey and Fuller (1979), the Phillips and Perron (1988) and the Zivot and Andrews (1992) unit root tests. We use the Johansen cointegration test (Johansen, 1988, 1991; and Johansen and Juselius, 1990) in order to investigate the existence of long-run relationships among the series. And we examine the causality relationship between the series, using a Vector Error Correction Model (VECM) and a Toda-Yamamoto (1995) approach.

In the second study we investigate the determinant factors behind crude oil production by OPEC producer members and non-OPEC producer countries. This research is based on two production models and two separate studies, as below:
The first one develops a new production model for OPEC producer members in which we examine the Granger causality relationship running from several important variables, including real crude oil price, investment needs of each individual country, OPEC quotas for each individual country and production by the rest of OPEC to crude oil production of each individual OPEC member country. Moreover, we include a set of appropriate exogenous variables, such as political and natural events to the production model of each individual country. OPEC member countries under this study are Algeria, Indonesia, Iran, Libya, Nigeria, Qatar, Saudi Arabia and Venezuela.
The second one develops a new production model for non-OPEC producer countries in which examines the Granger causality relationships running from several important factors, including crude oil price, investment needs of each individual country, total production by OPEC countries and proven reserves for each individual country, to crude oil production by each individual non-OPEC producer country.

[10] MENA, Middle East and North Africa.

Non-OPEC producer countries that are considered in this study are Canada, China, Egypt, Mexico, Norway, the Russian Federation, the UK and the US.

In order to achieve the empirical examination of the above described models, we perform two unit root tests with allowing for one structural break in the time series to examine the stationary properties of the series, the Zivot and Andrews (1992) and the Perron (1997) unit root tests. Then we apply the Auto-Regressive Distributed Lag (ARDL) bounds testing approach for cointegration proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) to estimate the cointegration relationships between the variables. Furthermore, the Granger causality relationships among the variables are examined by a Vector Error Correction Model (VECM) approach.

And in the third and last study we develop several structural models to experimentally explain the drivers behind 2008 and 2012 crude oil price movements. Furthermore, we compare their forecasting power in order to understand from the econometrics point of view, which are the quantitative factors that better explains crude oil price shocks during the above-mentioned years.
For this purpose, we apply a simple autoregressive model to forecast crude oil price as benchmark, then we develop it by including different determinant factors and we build nine extended forms models.
In first step, we develop four extended forms of the autoregressive model: the first model includes the relevant inventory level factor introduced by Ye et al. (2005) to the benchmark autoregressive model, the second one includes the Kilian index for global real activity proposed by Kilian (2009), the third one includes the OECD industrial production index, and the fourth one includes long positions held by non-commercials in crude oil markets as a proxy for speculation in crude oil markets.
In second step, we build five extended forms of the relevant inventory model by including the Kilian index for global real activity, the OECD industrial production index, and speculation factors to the initial form of the relative inventory model.
Next, we compare the forecasting ability of the ten models to select which of them generates better and more accurate explanations for the 2008 and 2012 price movements. We provide short term monthly forecasts for one, three, six, nine and twelve months ahead.

1.4. The results and contributions to the literature

The thesis adds an original empirical contribution by developing a comprehensive investigation on worldwide crude oil markets. In the following we broadly discuss the results and contributions of this thesis.

The results from the first study can be categorized in three groups:
First, among OECD, net crude oil importing Sub-Saharan African, MENA and Southern and Eastern Asian countries and an individual country of Portugal, both in the short-run and in the long-run, there are evidences of bidirectional causality relationships between crude oil consumption and economic growth (thus support the feedback hypothesis).
Second, in Central American countries, in the short-run there is a bidirectional causality relationship between crude oil consumption and economic growth (thus supports the feedback hypothesis); however, in the long-run there is a unidirectional causality relationship running from crude oil consumption to economic growth (thus supports the growth hypothesis); and among net crude oil exporting Sub-Saharan African countries, in the short-run we found evidence of a unidirectional causality relationship running from crude oil consumption to economic growth (thus supports the growth hypothesis) and in the long-run we discovered evidences that there is a bidirectional causality relationship between crude oil consumption and economic growth (thus supports the feedback hypothesis).
Third, evidences found that in Caribbean and South American countries, in the short-run there are bidirectional causality relationships between crude oil consumption and economic growth (thus support the feedback hypothesis) while in the long-run there are unidirectional causality relationships running from economic growth to crude oil consumption (thus support the conservation hypothesis).

The first policy implication of the evidences found is related to the impact of economic growth on crude oil consumption in each region. If in the long-run the feedback or the conservation hypothesis are supported in a region, this means that economic growth Granger causes crude oil consumption; therefore, in this region economic growth is a useful variable to analyze the future crude oil consumption and consequently to analyze the future crude oil prices and to forecast it. According to the results of this research, among all regions covered by our investigation, except Central America, economic growth Granger causes crude oil consumption; therefore, we can use the world economic growth as an explanatory variable to explain changes in international crude oil prices and forecast it.
The second policy implication is related to the impact of crude oil consumption on economic growth in each region. In the regions where, in the long-run, the feedback or the growth hypothesis are supported, policymakers should develop and implement crude oil conservation policies more carefully, taking in account that a reduction of crude oil consumption has negative impacts on their economic growth. Nevertheless, there are still some policies that decrease crude oil consumption without significant impacts on the levels of production and growth, such as appropriate crude oil efficiency policies; rational oil use; shift the economy from heavy energy consumption industries toward light energy consumer sectors, such as information and services sectors; and there is also the possibility of substituting crude oil by renewable energies. Moreover, among the regions where in the long-run, the conservation hypothesis is supported; policymakers can pursue crude oil conservation policies without concerning about their negative effects on economic growth.

The above described results are additive to the literatures, as among the existing works, we did not find studies that examine crude oil consumption-economic growth nexus in a worldwide scale; however, most of the published studies that examined the causality relationship between energy consumption and economic growth, focused on total energy or on electricity consumptions, or they covered single countries. Thus, we found a lack of study on this critical issue.

The results from the second study show that, there are long-run cointegration relationships running from crude oil price, investment needs, OPEC quotas and production by the rest of OPEC members, to crude oil production for six of OPEC member countries, except Indonesia and Saudi Arabia. And, we found evidences to show that there are long-run cointegration relationships running from crude oil price, investment needs, total production by OPEC countries and proven reserves, to crude oil production in each of the eight non-OPEC producer countries.
Furthermore, there are evidences that support each nation follows a different production behavior; and there is evidence against the existence of a unique set of explanatory variables that can be suggested as the determinant factors that Granger cause OPEC member countries and non-OPEC producers. As a result, in order to stabilize crude oil production and prices, we recommend adoption of punitive and incentive tools by OPEC organization in order to oblige, at least OPEC member countries, to follow the appropriate production behavior.

The above described results visible on the second study add two original contributions. Firstly, the existing studies that investigate production behavior of OPEC member countries focused mainly on determining OPEC behavior as an organization and they are less concentrated on the determinant factors of the individual OPEC member countries. Therefore, in many of these studies the authors built univariate models that mostly ignored the impacts of domestic situations of the individual countries and the impacts of exogenous events on their crude oil production behaviors, such as economic, political and natural events or the variables that are specified for each individual country. In order to fill this gap, in this study, we propose a multivariate model that significantly reduces the problem of omitted variable bias specific for each country and that simultaneously increases the possibility of existing cointegration relationships among the variables. Our proposed model includes almost all important quantitative and qualitative factors that may impact on crude oil production of OPEC member producers during last years.
Secondly, all the existing studies that investigated the production behavior of non-OPEC producer countries assumed that these countries produce crude oil based on a competitive behavior and that their production is only a function of crude oil price. However, the economic production models by non-OPEC producers are mostly unreliable, as there is not a simple relation among real crude oil prices and their production (Kaufmann and Cleveland, 2001; Dées et al., 2007). For instance, from the end of World War II to 1970, crude oil price declined but crude oil production of the US increased significantly. Conversely, among 1970 to 1985, price increased greatly, but the US production decreased (Dées et al., 2007). Therefore, other factors, such as changes in crude oil reserves or economic and political situations, impact on production behavior of those countries.

In order to fill this gap, in this study, we propose a multivariate model that includes almost all important quantitative and qualitative factors that may impact on crude oil production of non-OPEC producers.

The results from the third and last study indicate that, although for both years 2008 and 2012, all the factors develop the prediction power of the benchmark autoregressive model; however, there are strong evidences to prove that the price shock in 2008 mainly can be explained by a surge in the OECD industrial production; and that price movement in 2012 can be better explained by an increase of speculation in crude oil markets. Nevertheless, for both years, the roles of the other factors are noteworthy as well. These results show the increasing role of financial markets on crude oil price fluctuations; hence, in order to stabilize the price we recommend adoption of more restrictive measures against growing financialization in crude oil markets.

The results from the third study are additive to the literature through various contributions. The first main contribution is due to the explanatory variables that we apply in order to build the structural models used to forecast crude oil prices. For instance, most of the existing studies that perform structural models to investigate and forecast crude oil prices are based on fundamentals of the market, crude oil consumption and production; however, forecasting the global crude oil consumption is a difficult task. In this study we apply two proxies for crude oil consumption, one is the Kilian index for global real activity and another is the OECD industrial production index. These indexes are provided in global scale; therefore, if we forecast them, the results are more reliable than the sum of the forecasting results for each country's crude oil consumption. Moreover, the role of speculation on crude oil price is growing along the last years, which is mostly neglected among the relevant literature; in this study we examine it broadly.
The second contribution of the third study is that it is comparative. The proposed univariate structural models that are based on the Kilian index, the OECD industrial production index, speculation and the relative inventory level can reflect the magnitude of the shares of each factor in 2008 and 2012 price movements. Moreover, the five multivariate models that we propose are innovative and never have been applied before for modeling crude oil prices.
And the third main contribution of the third study is analyzing, modeling and forecasting 2008 and 2012 crude oil prices, while both years experienced crude oil price shocks. However, as the years considered in this study are very recent, this is the first study that investigates crude oil price movements and the determinant factors of the shocks that occurred during these years through the application of econometrics models.

1.5. Structure of the thesis

The thesis comprises five chapters, including the introduction one, the rest are expressed as below:

Chapter two, under title of: ***crude oil consumption-economic growth nexus: a worldwide investigation***, is organized in eight sections: in the first one an introduction to the theme is provided; the second one is an inclusive literature review; the third one explains the structure of the model; the fourth one provides the applied methodologies; the fifth one performs data description; the sixth one provides the results; the seventh one discusses the results and the eighth one offers the conclusion.

Chapter three under title of: ***crude oil production behaviors by OPEC memeber producers and Non-OPEC producers***, begins with a general introduction and continues based on two separate studies. The first study of chapter three is based on seven sections; the first section provides an introduction of the theme; the second one presents the literature review; the third one develops the proposed model; the fourth one describes the methodology; the fifth one explains data; the sixth one provides the empirical results and the seventh and last one concludes the study.
And the second study of chapter three also is organized in seven sections; the first one provides an introduction of the theme; the second one presents the literature review; the third one develops the proposed model; the fourth one describes the methodology; the fifth one explains data; the sixth one provides the empirical results and the seventh one concludes the study.

Chapter four under title of: ***crude oil price modeling and short-term forecasting: a comparative survey***, comprises five sections. Section one provides an introduction to the theme; section two expands the literature review; section three develops the models; section four describes the forecasting results and section five concludes the chapter.

And finally chapter five contains ***summary and future works***. The first section provides a summary of the results and presents some policy recommendations and the second section gives some ideas for future works.

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Chapter 2

2. Crude oil consumption-economic growth nexus: a worldwide investigation

2.1. Introduction

The main determinant factors of consumption for commodities are income and price of the same commodity, and we suppose that crude oil is not an exception from this rule. In the first step of this study, we examine whether countries' economic growth and real crude oil price Granger cause crude oil consumption. In other word, the first motivation of this study is to specify the explanatory variables behind crude oil consumption, in order to develop the appropriate and fundamental econometrics models to analyze crude oil price, based on its consumption and production, and finally to forecast price. In summary, we determine if the mentioned variables are useful to forecast crude oil consumption and consequently to forecast crude oil price.

In the second step of this study, we examine the Granger causality relationship in an opposite direction; we examine whether crude oil consumption and its price Granger cause countries' economic growth. Therefore, the second motivation is to specify the vulnerability of economic growth to crude oil consumption for each region and consequently to recommend the appropriate energy efficiency policies.

Energy efficiency policies are important due to two main reasons. One of them is the environmental issue and the problem of global climate change caused by greenhouse gas emissions. The main greenhouse gas is carbon dioxide (CO_2) that is generated from burning fossil fuels. This problem increased the global interest on the reduction of fossil fuels' consumption and led to perform energy conservation policies and to adoption of the alternative energy sources to fossil fuels.

These policies caused the reduction in the oil intensity of production, especially after the acceptance of the Kyoto protocol by the developed and developing countries in 1997. In 2009, the levels of CO_2 emissions for the countries who have participated in the Kyoto protocol were 14.7% less than their levels in 1990. However, in this year, the emissions of developing countries continued to grow (+3.3%), as emissions of the Middle Eastern and Asian countries grew, (+3.6%) and (+5.5%), respectively, while the emissions of developed countries fell (-6.5%). Moreover, the largest five emitters in 2009 were China, the US, India, the Russian Federation and Japan, which together produced 56% of the world CO_2 emissions and 51% of the world GDP[11].

[11] Data obtained from International Energy Agency, IEA.

The second reason for the importance of energy efficiency policies is the role of the three oil price shocks in several periods -1973-1974, 1978-1979 and 2007-2008 - which led to the idea that future oil supply security is affected by random shocks, such as wars and political upheavals in oil exporting countries.

However, the main concern to implement oil conservation policies is the negative impacts that these policies can have on economic growth. Therefore, the second main goal of this study is to examine the causality relationship running from crude oil consumption to economic growth, using crude oil price as control variable of the model, in a regional scale.

In order to reach the above mentioned goals, we investigate the Granger causality relationships between crude oil consumption and economic growth under five panel framework studies, including a panel of OECD countries, panels of Latin American regions, panels of Sub-Saharan African countries, a panel of MENA countries and a panel of Southern and Eastern Asian emerging markets; moreover, we investigate the same effect in the case of an individual country-Portugal-as well. Therefore, we generate six different researches, as below:

The first study investigates the Granger causality relationship between crude oil consumption and economic growth in Portugal. To the best of our knowledge, there is not any empirical study that investigates this relationship in Portugal; however, there are a few numbers of empirical studies on investigating the causality relationship between energy consumption and economic growth in this country. Among them we have Narayan and Prasad (2008), Chontanawat et al. (2008), Shahbaz et al. (2011) and Fuinhas and Marques (2012). The first study examined the causality relationship among electricity consumption and economic growth in 30 OECD countries and found a unidirectional causality relationship running from electricity consumption to economic growth. The second study assessed the causality relationship among energy consumption and economic growth in more than 100 countries and showed that there is a unidirectional causality relationship running from energy consumption to economic growth in Portugal. The third study investigated the causality relationship among electricity consumption and economic growth in Portugal and found that there is a unidirectional causality relationship running from economic growth to electricity consumption in the short-run and there is a bidirectional causality relationship between them in the long-run. And the fourth one examined primary energy consumption and economic growth nexus in southern European countries including Portugal, Italy, Greece, Spain and Turkey and found evidences of bidirectional causality relationships among the variables in these countries.

In this context, we extend the existing literature through considering crude oil as a source of energy consumption in Portugal. As we mentioned earlier, there is no empirical study on the relationship between crude oil consumption and economic growth in Portugal, although in the case of energy-growth nexus, considering different sources of energy generates different results even when the data span and applied methodology are the same; for instance, Fatai et al. (2004), based on Johansen Juselius method, found empirical evidence in Australia in favor of a unidirectional causality running from economic growth to energy, coal, and electricity (1960 to 1990), though economic growth, natural gas and industrial energy are independent. Moreover, using the same methodology and time span, they also found that there is independency between, on one side, economic growth, and on the other, coal, gas and oil in New Zealand, that there is a unidirectional causality running from economic growth to total energy and that there is a unidirectional causality running from industrial energy to economic growth. Lee and Chang (2005), using also Johansen and Joselius technique found that in Taiwan there are bidirectional causality relationships between economic growth with total energy and coal (1954-2003), while there are unidirectional causality relationships running from oil, gas and electricity to economic growth.

In this study, we fill this gap through using annual data from 1980 to 2009 for Portugal. Our multivariate model considers per capita crude oil consumption in barrels per day, per capita real GDP in constant 2000 US$ and real Brent crude oil spot price in constant 2000 US$.

The second study investigates the Granger causality relationships between crude oil consumption and economic growth within a panel of OECD countries. Although there are some studies on the group of OECD countries that investigated the causality relationships between energy consumption and economic growth (see Dincer, 1997; Chontanawat et al., 2008; Lee et al., 2008; Constantini and Martini, 2010), or electricity consumption and economic growth (see Narayan and Prasad, 2008), or coal consumption and economic growth (see Jinke et al., 2008), and renewable energy consumption and economic growth (see Apergis and Payne, 2010a); however, to the best of our knowledge, there is no study that examines the causality relationship between crude oil consumption and economic growth among OECD countries.

To fill this gap, we apply annual data from 1976 to 2009 for a panel of twenty seven OECD countries, including Australia, Austria, Belgium and Luxemburg, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, South Korea, Spain, Sweden, Switzerland, Turkey, the UK and the US. Furthermore, our multivariate model considers per capita crude oil consumption in barrels per day, per capita real GDP in constant 2000 US$ and real Brent crude oil price in constant 2000 US$.

The third study investigates the Granger causality relationships between crude oil consumption and economic growth within three panels of Latin America regions. Among the literature,there are three panel framework studies that focused on Latin America's energy consumption-growth nexus, including Apergis and Payne (2009 and 2010c) and Zilio and Recalde (2011). In the first and the second ones, the authors focused on energy consumption-economic growth relationship for a panel of six Central American countries and a panel of nine South American countries, respectively. And in the third one, the authors focused on energy consumption-economic growth relationship for twenty one Latin American countries. Therefore, among the existing literature we could not find any study that investigates the causality relationship between crude oil consumption and economic growth in a panel of Latin American countries, which is one of the subjects of this research.

In this study we divide Latin America region into the three panels, one for Caribbean region, one for Central America, and another for South America. We apply annual data from 1980 to 2012 for

Caribbean countries, including Bahamas, Barbados, Dominica, Dominican Republic, Grenada and Trinidad and Tobago; for Central American countries, including Belize, Costa Rica, El Salvador, Guatemala, Honduras and Panama; and for South American countries, including Argentina, Bolivia, Colombia, Ecuador, Paraguay, Peru, Uruguay and Venezuela.
Our multivariate models contain per capita crude oil consumption in barrels per day, per capita real GDP-PPP in constant 2005 US$, and real West Texas Intermediate (WTI) crude oil spot price in constant 2005 US$.

The fourth study investigates the Granger causality relationship between crude oil consumption and economic growth within two panels of Sub-Saharan African countries. Among the existing literature, there are only two studies that used panel-based causality approach on energy consumption-economic growth nexus in Africa, Eggoh et al. (2011) and Al-mulali and Sab (2012).The first one examined the causality relationships between energy consumption, economic growth, consumer price index, labor and capital in twenty one African countries; the countries are divided in two groups of net oil importers and net oil exporters, and the second one investigated the impact of energy consumption and CO_2 emissions on economic growth and financial development in thirty Sub-Saharan African countries without categorizing net oil exporting and net oil importing countries. Therefore, to the best of our knowledge, there is no study that examines the causality relationship between crude oil consumption and economic growth for a panel of African countries, as the existing studies considered total energy in Africa.
In order to fill this gap, we divide Sub-Saharan African countries into the two homogenous panels: (*i*) panel of net crude oil exporting countries contains nine countries and (*ii*) panel of net crude oil importing countries contains fourteen countries. Considering heterogeneity among net oil exporting and net oil importing countries is important, as they have different economic structures and energy consumption characteristics; therefore, they respond differently to the crude oil shocks and to changes of crude oil consumption.
panel of net crude oil exporting countries applies annual data from 1985 to 2011, including Angola, Cameroon, Chad, Congo Republic, Cote d'Ivoire, Equatorial Guinea, Gabon, Nigeria and Sudan; and panel of net crude oil importing countries uses annual data from 1985 to 2011, including Cape Verde, Central Africa Republic, Ghana, Kenya, Malawi, Mauritania, Mauritius, Niger, Senegal, Seychelles, South Africa, Swaziland, Togo and Uganda. Our multivariate model for Sub-Saharan Africa comprises per capita crude oil consumption in barrels per day, per capita real GDP-PPP in constant 2005 US$ and real Brent crude oil spot price in constant 2005 US$.

The fifth study examines the Granger causality relationship between crude oil consumption and economic growth within a panel of MENA countries. Among the existing literature, the only study that assessed oil consumption-GDP nexus in a panel of MENA countries is Al-mulali (2011). In this study, the author examined the causality relationships among oil consumption, CO_2 emissions, and GDP. The contribution of this study against the one of Al-mulali (2011) is that, we apply international crude oil price as control variable of the model which have never been applied before for a panel of MENA countries.

We apply annual data from 1980 to 2008 for a panel of MENA countries including Algeria, Bahrain, Egypt, Iran, Jordan, Morocco, Saudi Arabia, Syria and Tunisia. Our multivariate model includes per capita crude oil consumption in barrels per day, per capita real GDP in constant 2000 US$ and real Dubai crude oil spot price in constant 2000 US$.

And the sixth study examines the Granger causality relationship between crude oil consumption and economic growth within a panel of Eastern and Southern Asian countries. Among the Asian studies, which applied a panel framework, Joyeux and Pipple (2007) and Chen et al. (2007) assessed the relationship between electricity consumption and economic growth and Lee and Cheng (2008) examined the relationship between energy consumption and economic growth. Therefore, to the best of our knowledge, none of the studies that used a panel framework, considered crude oil consumption as the source of energy.

To fill this gap, we apply annual data from 1986 to 2008 for a panel of Eastern and Southern Asian countries. In Southern Asia we include Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka, and in Eastern Asia we include Brunei Darussalam, China, Hong Kong, Indonesia, South Korea, Malaysia, Philippine, Singapore and Thailand. Our multivariate model includes per capita crude oil consumption in barrels per day, per capita real GDP in constant 2000 US$ and real Dubai crude oil spot price in constant 2000 US$.

Another contribution of this study to the existing literature on this issue is that, we apply international crude oil price as control variable of the models. Based on theory, there is a broad consensus that higher oil price impacts global economic growth (Brown and Yucel, 1999; Hamilton, 2009; He et al., 2010). The impacts of higher oil prices on aggregate economic activity can be explained through various channels. The most primary channel is classic supply-side effect; the second channel is through an income transformation from net oil importing to net oil exporting countries, this leads to a demand-side effect; the third channel is through the real balance effect; and the fourth channel is via monetary policy after the oil price shock. However, the consequences of oil shocks are not transparent and depend on the degree that each country is net oil importing or net oil exporting.

Generally, in net oil exporting countries crude oil price and economic growth are positively correlated (see, Rodriguez and Sanchez, 2005; Mehrara, 2008; Farzanegan and Markwadt, 2009) and in net oil importing countries they are negatively correlated (see, Jayaraman and Choong, 2009; Tang et al., 2010; Aydin and Acar, 2011; Hanabusa, 2009).Therefore, ignoring the impacts of crude oil price on crude oil consumption and economic growth leads to the omitted variable bias in the results, which is avoided in this study.

Moreover, most of the existing studies on energy consumption-economic growth nexus focused on individual countries that usually do not provide reliable results due to the short data span that reduces the power of unit root and cointegration tests (Narayan and Smyth, 2007). Thus, in this study the major part of our investigation will be performed through employing the panel frameworks, in order to overcome the mentioned problems, as panel framework tests increase their power by combining cross-section and time series data, while allowing heterogeneity across the countries (Narayan and Smyth, 2007).

The applied methodology to examine the Granger causality relationship between the mentioned series can be explained as below.
For Portugal as a single country study, we examine the stationary properties of the series through using the ADF (Dickey and Fuller, 1979), the PP (Phillips and Perron, 1988) and the Zivot and Andrews (1992) unit root tests. We use the Johansen cointegration test (Johansen, 1988, 1991; and Johansen and Juselius, 1990) in order to investigate the existence of long-run relationships between the series. And we examine the causality relationship between the series through the Granger causality approaches, a Vector Error Correction Model (VECM) and Toda-Yamamoto (1995) methods.

Furthermore, in order to empirically examine this relationship among the panel framework studies, in the first step, we perform the Im et al. (2003) and the Breitung (2000) panel unit root tests in order to examine the stationary properties of the series. In the second step, we implement the Pedroni (1999) and the Kao (1999) panel cointegration tests and the Pedroni (2000) panel Fully Modified OLS (FMOLS) approaches to investigate the existence of long-run relationships between the series. And in the third step, we apply a dynamic panel Vector Error Correction Model (VECM) in order to clarify the direction of the causality relationships between the series.

The structure of this study is based on eight sections; in section 2.1 an introduction is provided; section 2.2 is an inclusive literature review; section 2.3 explains structure of the model; section 2.4 describes the applied methodologies; section 2.5 performs the description of data; section 2.6 provides the results; section 2.7 discusses the results and section 2.8 offers the conclusion.

2.2. Literature review

In general, as Apergis and Payne (2009 and 2010a) stated, according to the literature, there are four expected types of causality relationships between energy consumption and economic growth, which can be explained as below:

(i) The first type occurs when there is a unidirectional causality relationship running from economic growth to energy consumption (supports the conservation hypothesis). In this case economic growth significantly affects energy consumption; however, energy consumption does not impact on economic growth; therefore, implementing energy conservation policies, such as increasing energy costs through higher taxes does not adversely impact on economic growth.

(*ii*) The second type occurs when energy consumption and economic growth are independent (supports the neutrality hypothesis); therefore, implementing conservation policies does not adversely impact on economic growth.

(iii) The third situation happens when there is a unidirectional causality relationship running from energy consumption to economic growth (supports the growth hypothesis). In this case, implementing energy conservation policies might widely affects on economic growth; thus, applying conservation policies (such as increasing energy costs) decreases economic growth and policymakers need to apply different types of policies to reduce the wasting of energy, such as invest on energy efficiency programs and on energy saving techniques, improve industrial technologies in order to reduce wasting energy, or allocate subsidies on clean energy alternatives.

(iv) The fourth and last situation occurs when there is a bidirectional causality relationship between energy consumption and economic growth (supports the feedback hypothesis). In this case, reduction of energy consumption still negatively impacts on economic growth; however, it is a complementarily effect, the same policies referred to the growth hypothesis should be applied to avoid negative impacts on economic growth.

Several studies have investigated the causality relationship between energy consumption and economic growth; these studies used different sources of energies, including total energy, electricity, crude oil, natural gas, coal, nuclear energy and renewable energies, within three main groups of studies: single country studies, multiple countries studies, and multiple countries studies under a panel framework. They revealed that, there is no clear consensus about the direction of causality relationship between energy consumption and economic growth for an individual country or for a panel of countries. These contradictory results are due to various reasons, such as the country heterogeneity, the varying energy consumption pattern, the degree of economic development of each country, the alternative econometric methodology, the existence of omitted variable bias, and the different time horizons employed (Yu and Choi, 1985; Ferguson et al., 2000; Toman and Jevelkova, 2003; and Apergis and Payne, 2010b).

Following, we divide the existing literature in five sub-groups: OECD, Latin America, Sub-Saharan Africa, MENA and Southern and Eastern Asia. Furthermore, each relevant sub-group is categorized into the three groups of studies: single country studies, multiple countries studies and multiple countries studies under a panel framework (tables 1 to 5).

2.2.1. Literature review for OECD countries

Table (1) presents a synthesis of the literature review and the results for OECD countries:

Table 1-Literature review for OECD countries

Authors	Countries	Methodologies	Time span	Results	Hypothesis
Single country studies					
Stern (1993)	The US	J-J[12]	1948-1994	Energy→GDP	Growth
Payne and Taylor (2008)	The US	T-Y[13]	1957-2006	Nuclear≠ GDP	Neutrality
Warr and Ayres (2010)	The US	E-G[14]	1946-2000	Energy→GDP	Growth
Jobert and Karanfil (2007)	Turkey	J-J	1960-2003	Energy≠ GDP	Neutrality
Altinay and Karagol (2005)	Turkey	D-L[15]	1950-2000	Electricity→GDP	Growth
Yoo (2006a)	Korea	J-J	1968-2002	Oil→GDP	Growth
Shahbaz et al. (2011)	Portugal	E-G	1971-2009	GDP↔ Electricity	Feedback
Multiple countries studies					
Chontanawat et al. (2008)	Austria	Hsiao	1960-2000	Energy→GDP	Growth
	Belgium		1960-2000	Energy→GDP	Growth
	Czech Republic		1971-2000	Energy→GDP	Growth
	Denmark		1960-2000	Energy→GDP	Growth
	Ireland		1960-2000	Energy→GDP	Growth
	South Korea		1971-2000	Energy→GDP	Growth
	Mexico		1971-2000	Energy→GDP	Growth
	The Netherlands		1960-2000	Energy→GDP	Growth
	Poland		1960-2000	Energy→GDP	Growth
	Switzerland		1960-2000	Energy→GDP	Growth
	Australia		1960-2000	GDP→Energy	Conservation
	Canada		1960-2000	GDP→Energy	Conservation
	Finland		1960-2000	GDP→Energy	Conservation
	Spain		1960-2000	GDP→Energy	Conservation
	Sweden		1960-2000	GDP→Energy	Conservation
	France		1960-2000	GDP↔Energy	Feedback
	Germany		1960-2000	GDP↔Energy	Feedback
	Greece		1960-2000	GDP↔Energy	Feedback
	Hungary		1965-2000	GDP↔Energy	Feedback
	Iceland		1965-2000	GDP↔Energy	Feedback
	Italy		1960-2000	GDP↔Energy	Feedback
	Japan		1960-2000	GDP↔Energy	Feedback

[12] Johansen-Juselius
[13] Toda-Yamamoto
[14] Engle-Granger
[15] Dolado-Lütkepohl

	New Zealand		1960-2000	GDP↔Energy	Feedback
	Portugal		1960-2000	GDP↔Energy	Feedback
	Slovakia		1971-2000	GDP↔Energy	Feedback
	Luxemburg		1960-2000	Energy≠ GDP	Neutrality
	Turkey		1960-2000	Energy≠ GDP	Neutrality
	UK		1960-2000	Energy≠ GDP	Neutrality
	The US		1960-2000	Energy≠ GDP	Neutrality
Narayan and Prasad (2008)	Australia	Bootstrap GC[16]	1960-2002	Electricity→GDP	Growth
	Czech Republic		1960-2002	Electricity→GDP	Growth
	Italy		1960-2002	Electricity→GDP	Growth
	Portugal		1960-2002	Electricity→GDP	Growth
	Slovak Republic		1971-2002	Electricity→GDP	Growth
	Finland		1960-2002	GDP→Electricity	Conservation
	Hungary		1965-2002	GDP→Electricity	Conservation
	The Netherlands		1960-2002	GDP→Electricity	Conservation
	Iceland		1960-2002	GDP↔Energy	Feedback
	Korea		1971-2002	GDP↔Energy	Feedback
	UK		1960-2002	GDP↔Energy	Feedback
	Austria		1960-2002	Energy≠ GDP	Neutrality
	Belgium		1960-2002	Energy≠ GDP	Neutrality
	Canada		1960-2002	Energy≠ GDP	Neutrality
	Denmark		1960-2002	Energy≠ GDP	Neutrality
	France		1960-2002	Energy≠ GDP	Neutrality
	Germany		1960-2002	Energy≠ GDP	Neutrality
	Greece		1960-2002	Energy≠ GDP	Neutrality
	Ireland		1960-2002	Energy≠ GDP	Neutrality
	Japan		1960-2002	Energy≠ GDP	Neutrality
	Luxemburg		1960-2002	Energy≠ GDP	Neutrality
	Mexico		1971-2002	Energy≠ GDP	Neutrality
	New Zealand		1960-2002	Energy≠ GDP	Neutrality
	Norway		1960-2002	Energy≠ GDP	Neutrality
	Poland		1960-2002	Energy≠ GDP	Neutrality
	Spain		1960-2002	Energy≠ GDP	Neutrality
	Sweden		1960-2002	Energy≠ GDP	Neutrality
	Switzerland		1960-2002	Energy≠ GDP	Neutrality
	Turkey		1960-2002	Energy≠ GDP	Neutrality
	The US		1970-2002	Energy≠ GDP	Neutrality
Fuinhas and Marques (2012)	Portugal	ARDL[17]	1965-2009	GDP↔Energy	Feedback
	Italy		1965-2009	GDP↔Energy	Feedback
	Greece		1965-2009	GDP↔Energy	Feedback

[16] Granger Causality
[17] Auto-Regressive Distributed Lag

	Spain		1965-2009	GDP↔Energy	Feedback
	Turkey		1965-2009	GDP↔Energy	Feedback
Panel framework studies					
Lee et al. (2008)	OECD	Panel VECM	1960-2001	GDP↔Energy	Feedback
Costantini and Martini (2010)	OECD	Panel VECM	1960-2005	GDP→Energy	Conservation
Apergis and Payne (2008a)	OECD	Panel VECM	1985-2005	GDP↔Renewable	Feedback
Nazlioglu et al. (2010)	OECD	Panel VECM	1980-2007	GDP≠ Nuclear	Neutrality

2.2.2. Literature review for Latin America region

Table (2) presents a synthesis of the literature review and the results for Latin American countries:

Table 2-Literature review for Latin America region

Authors	Countries	Methodologies	Time Span	Results	Hypothesis
Single country studies					
Pao and Tsai (2011b)	Brazil	E-G	1980-2007	GDP↔ Energy	Feedback
Multiple countries studies					
Nachane et al. (1988)	Argentina	E-G	1950-1984	Energy→GDP	Growth
	Chile		1950-1984	Energy→GDP	Growth
	Brazil		1950-1984	GDP↔ Energy	Feedback
	Colombia		1950-1984	GDP↔ Energy	Feedback
	Venezuela		1950-1984	GDP↔ Energy	Feedback
Murray and Nan (1992)	Colombia	E-G	1970-1990	GDP→Electricity	Conservation
	ElSalvador		1970-1990	GDP→Electricity	Conservation
	Mexico		1970-1990	GDP→Electricity	Conservation
Cheng (1997)	Brazil	E-G	1963-1993	Energy→GDP	Growth
	Mexico		1949-1993	GDP≠ Energy	Neutrality
	Venezuela		1952-1993	GDP≠ Energy	Neutrality
Soytas and Sari (2003)	Argentina	E-G	1950-1990	GDP↔ Energy	Feedback
Squalli (2007)	Venezuela	ARDL ,T-Y	1980-2003	Electricity→GDP	Growth
Chontanawat et al. (2008)	Chile	J-J	1971-2000	Energy→GDP	Growth

	Colombia		1971-2000	Energy→GDP	Growth
	Uruguay		1971-2000	Energy→GDP	Growth
	Bolivia		1971-2000	GDP→Energy	Conservation
	Paraguay		1971-2000	GDP→Energy	Conservation
	Peru		1971-2000	GDP→Energy	Conservation
	Venezuela		1971-2000	GDP→Energy	Conservation
	Argentina		1971-2000	GDP↔ Energy	Feedback
	Brazil		1971-2000	GDP↔ Energy	Feedback
	Ecuador		1971-2000	GDP≠ Energy	Neutrality
Panel framework studies					
Apergis and Payne (2009)	CentralAmerica	Panel VECM	1980-2004	Energy→GDP	Growth
Apergis and Payne (2010c)	South America	Panel VECM	1980-2005	Energy→GDP	Growth
Zilio and Recalde (2011)	Latin America	Pedroni panel cointegration	1970-2007	No cointegration	Neutrality

2.2.3. Literature review for Sub-Saharan Africa region

Table (3) presents a synthesis of the literature review and the results for Sub-Saharan African countries:

Table 3-Literature review for Sub-Saharan Africa region

Authors	Countries	Methodologies	Time span	Results	Hypothesis
Single country studies					
Jumbe (2004)	Malawi	E-G	1970-1999	GDP↔ Electricity	Feedback
Akinlo (2008)	Nigeria	J-J,E-G	1980-2006	Electricity→GDP	Growth
Odhiambo (2009a)	Tanzania	ARDL,E-G	1971-2006	Electricity→GDP	Growth
Odhiambo (2009b)	South Africa	J-J,E-G	1971-2006	GDP↔ Electricity	Feedback
Belloumi (2009)	Tunisia	E-G	1971-2004	GDP↔ Energy	Feedback
Ouédraogo (2010)	Burkina Faso	ARDL	1968-2003	GDP↔ Electricity	Feedback
Multiple countries studies					

Ebohon (1996)	Tanzania	GC	1960-1981	GDP↔ Energy	Feedback
	Nigeria		1960-1984	GDP↔ Energy	Feedback
Murray and Nan (1992)	Kenya	GC	1970-1990	GDP→Electricity	Conservation
	Zambia		1970-1990	GDP≠ Electricity	Neutrality
Wolde-Rufael (2005)	Algeria	ARDL,T-Y	1971-2001	GDP →Energy	Conservation
	Congo Democratic		1971-2001	GDP →Energy	Conservation
	Republic		1971-2001	GDP →Energy	Conservation
	Egypt		1971-2001	GDP →Energy	Conservation
	Ghana		1971-2001	GDP →Energy	Conservation
	Ivory Coast		1971-2001	GDP →Energy	Conservation
	Cameroon		1971-2001	Energy→GDP	Growth
	Morocco		1971-2001	GDP →Energy	Conservation
	Nigeria		1971-2001	GDP →Energy	Conservation
	Gabon		1971-2001	GDP↔ Energy	Feedback
	Zambia		1971-2001	GDP↔ Energy	Feedback
	Benin		1971-2001	GDP≠ Energy	Neutrality
	Congo Republic		1971-2001	GDP≠ Energy	Neutrality
	Kenya		1971-2001	GDP≠ Energy	Neutrality
	Senegal		1971-2001	GDP≠ Energy	Neutrality
	South Africa		1971-2001	GDP≠ Energy	Neutrality
	Sudan		1971-2001	GDP≠ Energy	Neutrality
	Togo		1971-2001	GDP≠ Energy	Neutrality
	Tunisia		1971-2001	GDP≠ Energy	Neutrality
	Zimbabwe		1971-2001	GDP≠ Energy	Neutrality
Wolde-Rufael (2006)	Benin	T-Y	1971-2001	Electricity→GDP	Growth
	Congo Democratic		1971-2001	Electricity→GDP	Growth
	Republic				
	Tunisia		1971-2001	Electricity→GDP	Growth
	Gabon		1971-2001	GDP →Electricity	Conservation
	Nigeria		1971-2001	GDP →Electricity	Conservation
	Senegal		1971-2001	GDP →Electricity	Conservation
	Zambia		1971-2001	GDP →Electricity	Conservation
	Zimbabwe		1971-2001	GDP →Electricity	Conservation
	Egypt		1971-2001	GDP↔ Electricity	Feedback
	Morocco		1971-2001	GDP↔ Electricity	Feedback
	Algeria		1971-2001	GDP≠ Electricity	Neutrality
	Congo Republic		1971-2001	GDP≠ Electricity	Neutrality
	Kenya		1971-2001	GDP≠ Electricity	Neutrality
	South Africa		1971-2001	GDP≠ Electricity	Neutrality
	Sudan		1971-2001	GDP≠ Electricity	Neutrality

Chontanawat et al. (2006, 2008)	Congo Republic	J-J	1971-2000	Energy→GDP	Growth
	Egypt		1971-2000	Energy→GDP	Growth
	Kenya		1971-2000	Energy→GDP	Growth
	Algeria		1971-2000	GDP→Energy	Conservation
	Ethiopia		1971-2000	GDP→Energy	Conservation
	Zimbabwe		1971-2000	GDP→Energy	Conservation
	Angola		1971-2000	GDP↔ Energy	Feedback
	Ghana		1971-2000	GDP↔ Energy	Feedback
	Morocco		1971-2000	GDP↔ Energy	Feedback
	Mozambique		1971-2000	GDP↔ Energy	Feedback
	Sudan		1971-2000	GDP↔ Energy	Feedback
	Tunisia		1971-2000	GDP↔ Energy	Feedback
	Benin		1971-2000	GDP≠ Energy	Neutrality
	Cameroon		1971-2000	GDP≠ Energy	Neutrality
	Congo Democratic		1971-2000	GDP≠ Energy	Neutrality
	Republic		1971-2000	GDP≠ Energy	Neutrality
	Cote d`Ivoire		1971-2000	GDP≠ Energy	Neutrality
	Gabon		1971-2000	GDP≠ Energy	Neutrality
	Libya		1971-2000	GDP≠ Energy	Neutrality
	Nigeria		1971-2000	GDP≠ Energy	Neutrality
	Senegal		1971-2000	GDP≠ Energy	Neutrality
	Tanzania		1971-2000	GDP≠ Energy	Neutrality
	Togo		1971-2000	GDP≠ Energy	Neutrality
	Zambia		1971-2000	GDP≠ Energy	Neutrality
Squalli (2007)	Algeria	ARDL,T-Y	1980-2003	GDP→Electricity(ARDL)	Conservation
	Libya		1980-2003	GDP→Electricity(ARDL)	Conservation
	Nigeria		1980-2003	GDP↔Electricity(ARDL)	Feedback
	Algeria		1980-2003	GDP→Electricity(TY)	Conservation
	Libya		1980-2003	GDP→Electricity(TY)	Conservation
	Nigeria		1980-2003	Electricity→GDP(TY)	Growth
Akinlo (2008)	Cameroon	ARDL	1980-2003	GDP→Energy	Conservation
	Congo		1980-2003	Energy→GDP	Growth
	Gambia		1980-2003	GDP↔ Energy	Feedback
	Ghana		1980-2003	GDP↔ Energy	Feedback
	Senegal		1980-2003	GDP↔ Energy	Feedback
	Sudan		1980-2003	GDP↔ Energy	Feedback
	Zimbabwe		1980-2003	GDP↔ Energy	Feedback
	Cote d´Ivoire		1980-2003	GDP≠ Energy	Neutrality
	Kenya		1980-2003	GDP≠ Energy	Neutrality
	Nigeria		1980-2003	GDP≠ Energy	Neutrality

	Togo		1980-2003	GDP≠ Energy	Neutrality
Wolde-Rufael (2009)	Algeria	VD[18],GIR[19],	1971-2004	Energy→GDP	Growth
	Benin	T-Y	1971-2004	Energy→GDP	Growth
	South Africa		1971-2004	Energy→GDP	Growth
	Cote d´Ivoire		1971-2004	GDP→Energy	Conservation
	Egypt		1971-2004	GDP→Energy	Conservation
	Morocco		1971-2004	GDP→Energy	Conservation
	Nigeria		1971-2004	GDP→Energy	Conservation
	Senegal		1971-2004	GDP→Energy	Conservation
	Sudan		1971-2004	GDP→Energy	Conservation
	Tunisia		1971-2004	GDP→Energy	Conservation
	Zambia		1971-2004	GDP→Energy	Conservation
	Gabon		1971-2004	GDP↔ Energy	Feedback
	Ghana		1971-2004	GDP↔ Energy	Feedback
	Togo		1971-2004	GDP↔ Energy	Feedback
	Zimbabwe		1971-2004	GDP↔ Energy	Feedback
	Cameroon		1971-2004	GDP≠ Energy	Neutrality
	Kenya		1971-2004	GDP≠ Energy	Neutrality
Odhiambo (2010)	South Africa	ARDL	1972-2006	Energy→GDP	Growth
	Kenya		1972-2006	Energy→GDP	Growth
	Congo Democratic Republic		1972-2006	GDP→Energy	Conservation
Panel framework studies					
Ozturk et al. (2010)	Low income	Panel VECM	1971-2005	GDP→Energy	Conservation
	Middle income		1971-2005	GDP↔ Energy	Feedback
Eggoh et al. (2011)	Twenty one African Countries	PMG[20]	1970-2006	GDP↔ Energy	Feedback
Al-mulali and Sab (2012)	Thirty Sub-Saharan African African	Panel VECM	1980-2008	GDP↔ Energy	Feedback

[18] Variance Decomposition
[19] Generalized Impulse Response
[20] Pooled Mean Group

2.2.4. Literature review for MENA countries

Table (4) presents a synthesis of the literature review and the results for MENA countries:

Table 4-Literature review for MENA countries

Authors	Countries	Methodologies	Time span	Results	Hypothesis
Single country studies					
Zamani (2007)	Iran	E-G	1967-2003	GDP→Energy	Conservation
			1967-2003	GDP↔Gas	Feedback
			1967-2003	GDP↔Petroleum	Feedback
Belloumi (2009)	Tunisia	E-G,T-Y	1971-2004	GDP↔Energy	Feedback
Lotfalipour et al. (2011)	Iran	T-Y	1967-2007	GDP→Fosil Fuels	Conservation
			1967-2007	GDP→Petroleum	Conservation
			1967-2007	GDP≠Gas	Neutrality
Multiple countries studies					
Wolde-Rafael (2005)	Algeria	ARDL,T-Y	1971-2001	GDP→Energy	Conservation
	Egypt		1971-2001	GDP→Energy	Conservation
	Morocco		1971-2001	Energy→GDP	Growth
	Tunisia		1971-2001	Energy≠ GDP	Neutrality
Wolde-Rafael (2006)	Tunisia	T-Y	1971-2001	Electricity→GDP	Growth
	Egypt		1971-2001	Electricity↔GDP	Feedback
	Morocco		1971-2001	Electricity↔GDP	Feedback
	Algeria		1971-2001	Electricity≠GDP	Neutrality
Mehrara (2007a)	Iran	J-J,T-Y	1971-2001	GDP→Energy	Conservation
	Kuwait		1971-2001	GDP→Energy	Conservation
	Saudi Arabia		1971-2001	Energy→GDP	Growth
Squalli (2007)	Algeria	ARDL,T-Y	1980-2003	GDP→Electricity	Conservation
	Iraq		1980-2003	GDP→Electricity	Conservation
	Libya		1980-2003	GDP→Electricity	Conservation
	Kuwait		1980-2003	Electricity→GDP	Growth
	Iran		1980-2003	Electricity→GDP	Growth
	Qatar		1980-2003	Electricity↔GDP	Growth
	Saudi Arabia		1980-2003	Electricity↔GDP(ARDL)	Feedback
	Saudi Arabia		1980-2003	Electricity→GDP(T-Y)	Growth
	The UAE		1980-2003	Electricity↔GDP(ARDL)	Feedback
	The UAE		1980-2003	Electricity→GDP(T-Y)	Growth

Chontanawat et al. (2006, 2008)	Algeria	J-J	1971-2000	GDP→Energy	Conservation
	Saudi Arabia		1971-2000	GDP→Energy	Conservation
	Egypt		1971-2000	Energy→GDP	Growth
	Oman		1971-2000	Energy→GDP	Growth
	Iran		1971-2000	Energy↔GDP	Feedback
	Jordan		1971-2000	Energy↔GDP	Feedback
	Kuwait		1971-2000	Energy↔GDP	Feedback
	Lebanon		1971-2000	Energy↔GDP	Feedback
	Morocco		1971-2000	Energy↔GDP	Feedback
	Qatar		1971-2000	Energy↔GDP	Feedback
	Tunisia		1971-2000	Energy↔GDP	Feedback
	The UAE		1971-2000	Energy↔GDP	Feedback
	Yemen		1971-2000	Energy↔GDP	Feedback
	Iraq		1971-2000	Energy≠GDP	Neutrality
	Libya		1971-2000	Energy≠GDP	Neutrality
Ozturk and Acaravci (2011)	Egypt	ARDL,E-G	1971-2006	Electricity→GDP	Growth
	Oman		1971-2006	GDP→Electricity	Conservation
	Saudi Arabia		1971-2006	GDP→Electricity	Conservation
	Iran		1971-2006	Electricity≠GDP	Neutrality
	Syria		1971-2006	Electricity≠GDP	Neutrality
	Morocco		1971-2006	Electricity≠GDP	Neutrality
Panel framework studies					
Mehrara (2007b)	Oil exporting	Panel VECM	1979-2002	GDP→Energy	Conservation
Narayan and Smyth (2009)	Middle East	Panel VECM	1974-2002	Electricity↔GDP	Feedback
Al-mulali (2011)	MENA	Panel VECM	1980-2009	Crude oil↔GDP	Feedback
Sadorsky (2011)	Middle East	Panel VECM	1980-2007	Energy↔GDP	Feedback

2.2.5. Literature review for Eastern and Southern Asia region

Table (5) presents a synthesis of the literature review and the results for Eastern and Southern Asian countries:

Table 5-Literature review for Eastern and Southern Asia region

Authors	Countries	Time span	Methodologies	Results	Hypothesis
Single country studies					
Yang (2000a)	Taiwan	1954-1997	GC	Energy↔GNP	Feedback
				Electricity↔GNP	Feedback
				GNP→Oil	Conservation
				Gas→GNP	Growth
				Coal↔GN	Feedback
Yang (2000b)	Taiwan	1954-1997	GC	GDP→Coal	Conservation
Aqeel and Butt (2001)	Pakistan	1955-1996	GC	GDP→Energy	Conservation
		1955-1996		GDP→Oil	Conservation
		1955-1996		GDP≠Gas	Neutrality
		1955-1996		Eectricity→GDP	Growth
Ghosh (2002)	India	1950-1997	J-J	GDP→Energy	Conservation
Morimoto and Hope (2004)	Sri Lanka	1960-1998		Energy→GDP	Growth
Wolde-Rufael (2004)	Shanghai	1952-1999	T-Y	GDP≠ Oil	Neutrality
		1952-1999		Coal →GDP	Growth
		1952-1999		Electricity→GDP	Growth
		1952-1999		Energy→GDP	Growth
		1952-1999		Coke →GDP	Growth
Shiu and Lam (2004)	China	1971-2000	J-J	Electricity→GDP	Growth
Lee and Chang (2005)	Taiwan	1954-2003	J-J	Energy↔GDP	Feedback
		1954-2003		Coal↔GDP	Feedback
		1954-2003		Oil→GDD	Growth
		1954-2003		Gas→GDP	Growth
		1954-2003		Electricity→GDP	Growth
Yoo (2005)	Korea	1970-2002	J-J	Electricity↔GDP	Feedback
Yoo (2006a)	Korea	1968-2002	E-G	Coal↔GDP	Feedback
Zou and Chau (2006)	China	1953-2002	J-J	Oil→GDP	Growth
Yoo and Kim (2006)	Indonesia	1971-2002	Hsiao GC	GDP→Electricity	Conservation

Yoo (2006c)	Korea	1968-2002	J-J	GDP↔Oil	Feedback
Yuan et al. (2007)	China	1978-2004	J-J, H-P[21]	Electricity→GDP	Growth
Ho and Siu (2007)	Hong Kong	1966-2002	J-J	Electricity↔GDP	Feedback
Mozumder and Marathe (2007)	Bangladesh	1971-1999	J-J	GDP→Electricity	Conservation
Squalli (2007)	Indonesia	1980-2003	ARDL,T-Y	GDP→Electricity(ARDL)	Conservation
		1980-2003		Electricity→GDP(T-Y)	Growth
Yuan et al. (2008)	China	1963-2005	J-J, IRF[22]	Energy↔GDP	Feedback
		1963-2005		Oil↔GDP	Feedback
		1963-2005		Coal↔GDP	Feedback
Tang (2008)	Malaysia	1972-2003	ARDL,T-Y	Electricity→GNP	Growth
Chang (2010)	China	1981-2006	E-G	GDP→Oil	Conservation
				GDP→Coal	Conservation
				Electricity→GDP	Growth
Ghosh (2010)	India	1970-2006	J-J	GDP→HSD	Conservation
Wolde-Rufael (2010a)	India	1969-2006	T-Y,VD	NE→GDP	Growth
Lean and Smyth (2010b)	Malaysia	1971-2006	T-Y,D-L	Electricity↔GDP	Feedback
Lai et al. (2011)	Macao SAR	1999-2008	GC	GDP→Electricity	Conservation
Multiple countries studies					
Masih and Masih (1996)	India	1955-1990	J-J,VD	Energy→GDP	Growth
	Pakistan	1955-1990		Energy↔GDP	Feedback
	Malaysia	1955-1990		Energy≠GDP	Neutrality
	Indonesia	1955-1990		GDP→Energy	Conservation
	Singapore	1955-1990		Energy≠GDP	Neutrality
	Philippine	1955-1991		Energy≠GDP	Neutrality

[21] Hodrick-Prescott

[22] Impulse Response Function

Fatai et al. (2004)	India	1960-1999	GC,ARDL,	Energy→GDP	Growth
	Indonesia	1960-1999	J-J, T-Y	Energy→GDP	Growth
	Thailand	1960-1999		Energy↔GDP	Feedback
	Philippine	1960-1999		Energy↔GDP	Feedback
Yoo (2006c)	Indonesia	1971-2002	J-J	GDP→Electricity	Conservation
	Malaysia	1971-2002		GDP↔Electricity	Feedback
	Singapore	1971-2002		GDP↔Electricity	Feedback
	Thailand	1971-2002		GDP→Electricity	Conservation
Chontanawat et al. (2006, 2008)	Japan	1971-2000	J-J	GDP↔Energy	Feedback
	Korea	1971-2000		Energy→GDP	Growth
	Bangladesh	1971-2000		Energy→GDP	Growth
	Brunei	1971-2000		GDP↔Energy	Feedback
	China	1971-2000		Energy≠GDP	Neutrality
	Honduras	1971-2000		Energy≠GDP	Neutrality
	Hong Kong	1971-2000		Energy≠GDP	Neutrality
	India	1971-2000		Energy≠GDP	Neutrality
	Malaysia	1971-2000		Energy≠GDP	Neutrality
	Myanmar	1971-2000		GDP↔Energy	Feedback
	Nepal	1971-2000		Energy→GDP	Growth
	Pakistan	1971-2000		Energy≠GDP	Neutrality
	Philippine	1971-2000		Energy→GDP	Growth
	Singapore	1971-2000		Energy≠GDP	Neutrality
	Sri Lanka	1971-2000		Energy≠GDP	Neutrality
	Taiwan	1971-2000		GDP↔Energy	Feedback
	Thailand	1971-2000		GDP→Energy	Conservation
	Vietnam	1971-2000		Energy→GDP	Growth
Chiou-Wei et al. (2008)	Taiwan	1971-2003	J-J,	Energy→GDP	Growth
	Hong Kong	1971-2003	Baek and Brock	Energy→GDP	Growth
	Singapore	1971-2003	non-linear GC	GDP→Energy	Conservation
	Korea	1971-2003		Energy≠GDP	Neutrality
	Malaysia	1971-2003		Energy≠GDP	Neutrality
	Indonesia	1971-2003		Energy↔GDP	Feedback
	Philippine	1971-2003		GDP→Energy	Conservation
	Thailand	1971-2003		Energy≠GDP	
Narayan and Prasad (2008)	Japan	1960-2002	Bootstrapped GC	Electricity≠GDP	Neutrality
	Korea	1971-2002		Electricity↔GDP	Feedback
Jinke et al. (2008)	China	1980-2005	E-G	GDP→Coal	Conservation
	India	1980-2005		GDP≠Coal	Conservation
	Japan	1980-2005		GDP→Coal	Conservation

	Korea	1980-2005		GDP≠Coal	Conservation
Wodle-Rufael (2010b)	India	1965-2005	VAR, T-Y	Coal→GDP	Growth
	Japan	1965-2005		Coal→GDP	Growth
	China	1965-2005		GDP→Coal	Conservation
	South Korea	1965-2005		GDP→Coal	Conservation
Panel framework studies					
Joyeux and Ripple (2007)	Eight Asian countries	1971-2001	Pedroni panel cintegration, E-G	Electricity≠GDP	Neutrality
Chen et al. (2007)	Ten Asian countries	1971-2001	Panel VECM	Electricity↔GDP	Feedback
Lee and Chang (2008)	Asia	1971-2002	Panel VECM	Energy→GDP	Growth
	APEC	1971-2002		Energy→GDP	Growth
	ASEAN	1971-2002		Energy→GDP	Growth
Lean and Smyth (2010a)	ASEAN	1980-2006	Panel VECM	Electricity→GDP	Growth
Pao and Tsai (2011a)	BRIC	1980-2007	Panel VECM	Energy↔GDP	Feedback
Shuyun and Donghua (2011)	China provinces	1985-2007	Panel VECM	Energy↔GDP	Feedback
Akkemik et al. (2012)	China provinces	1986-2008	Heterogeneous panel causality	(19)GDP→Energy (14)Energy→GDP	Conservation Growth

2.3. Structure of the model for crude oil consumption

Crude oil is a normal commodity that its consumption depends on its price and on income of the countries. In this study, we suppose that crude oil consumption is a function of real crude oil price and economic activity, equation (2.3):

$$\ln CO = f\,(\ln PO, \ln GDP) \tag{2.3}$$

We consider per capita crude oil consumption as a function of real crude oil price and per capita real GDP. lnCO indicates the logarithm of per capita crude oil consumption in barrels/per day for each country, lnGDP represents the logarithm of per capita real GDP in US$ for each country and lnPO shows the logarithm of real crude oil spot price in US$ for each country.

2.4. Methodologies

To examine the existence of Granger (1969, 1988) causality relationship among the variables, numerous approaches have been proposed, which can be categorized as old and modern. Old approaches such as Granger (1969) and Sims (1972) did not consider the time series stationary properties. Among the studies of the old generation energy-growth nexus, we can mention Kraft and Kraft (1978), Akraka and Long (1980) and Erol and Yu (1987).

As it was proved later, the use of non stationary data in causality tests can yield spurious causality results (Park and Philips, 1989; Stock and Watson, 1989). A modern approach that requires the stationary properties and time series cointegration to be pretested by applying one of the unit root tests and the Johansen (1988, 1991) and Johansen and Juselius (1990) cointegration test is Error Correction Model (ECM) proposed by Engle and Granger (1987), which became popular since late 1980s. For instance; Mozumder and Marathe (2007), Zamani (2007), Shahbaz et al. (2011) and Ozturk and Acaravci (2010) applied VECM framework to examine energy-growth nexus.

However, the unit root and the cointegration tests are known to have low power and size properties in small samples (Cheung and Lai, 1993; Haris and Sollis, 2003); therefore, other modern approaches such as Autoregressive Distributed Lag (ARDL) bounds testing cointegration approach proposed by Pesaran et al. (2001), Toda-Yamamoto approach proposed by Toda and Yamamoto (1995) and Dolado-Lütkepohl approach proposed by Dolado and Lütkepohl (1996) became popular to examine the causality among the variables irrespective to the stationary properties of the time series and regardless of the existence of cointegration relationship among the variables. Some examples that applied recent methods in order to analyze the energy-growth nexus are Fatei et al. (2004), Narayan and Smyth (2005), Ouédraogo (2010) and Wolde-Rafael (2010).

Moreover, very recently it was argued that individual studies usually do not provide reliable results due to the short data span that reduces the power of the unit root and the cointegration tests (Narayan and Smyth, 2007). Thus, panel frameworks studies are proposed by Pedroni (1999) and Kao (1999) and later by Pesaran et al. (1997) in order to overcome the mentioned problems, as the panel framework tests increase their power by combining the cross-section and time series data, while allowing heterogeneity across the countries (Narayan and Smyth, 2007). Some examples that applied panel framework methods in order to analyze the energy-growth nexus are Mehrara (2007b), Sadorsky (2011), Al-mulali (2012) and Apergis and Payne (2010 a, b, c, d, e).

2.4.1. Methodology for the individual country of Portugal

In order to examine the Granger causality relationship between crude oil consumption and economic growth in Portugal, we apply two modern Granger causality approaches, the first one is the Johansen (1988, 1991) cointegration test and the Vector Error Correction Model (VECM) and the second one is the Toda-Yamamoto (1995) approach. However, it is considered that the Toda-Yamamoto causality approach has lower power than the Johansen based VECM approach in the bivariate and trivariate models with sample size less than 50 (Zapata and Rambaldi, 1997), the case of our sample whose size is 30.

2.4.1.1. The unit root tests

The VECM approach requires that the stationary of the time series and the existence of cointegration among the variables to be pretested. A time series is said to be non stationary if it has non constant mean, variance and auto-covariance over time. If a non stationary time series has to be differenced *d* times to become stationary, then it is integrated of order *d,* i.e., it is *I(d)*. the causality tests are very sensitive to the stationary properties of the time series (Stock and Watson, 1989); however, the majority of macroeconomic time series contain unit roots in their linear stochastic processes; in other words, they follow a non stationary process with one unit root, i.e., they are *I*(1) (Nelson and Plosser, 1982).

The first step of our study is to test the existence of unit roots in time series' data to investigate if all the series have the same order of integration, i.e., are *I*(1). To answer this challenge we apply two unit root tests that do not consider structural breaks, the Augmented Dickey Fuller (ADF) one (Dickey and Fuller, 1979) and the Phillips-Perron (P-P) one (Phillips and Perron, 1988) and one that considers one structural break, the Zivot and Andrews (1992) unit root test.

2.4.1.2. The Johansen cointegration test

The second step is to examine the existence of cointegration relationships among the variables. The cointegration test investigates the existence of long run equilibrium relationships linking the variables, this meaning that they tend to move together over time:

$$y_t = \alpha + \beta x_t + \gamma z_t + \mu_t \qquad (2.4.1.2a)$$

Equation (2.4.1.2a) is a multivariate cointegration regression; if the series are cointegrated, μ_t is stationary of order zero. We apply the Johansen cointegration test based on autoregressive representation proposed by Johansen (1988, 1991) and Johansen and Juselius (1990) to determine the number of equilibrium relationships among the variables. In this study, we consider the following regression:

$$lnCO_t = \alpha + \delta t + \beta_1 lnGDP_t + \beta_2 lnPO_t + \varepsilon_t \tag{2.4.1.2b}$$

where the variables have the meaning already referred. This test applies two different likelihood ratios (LR) tests - the trace statistics test and the maximum eigenvalue test - and implies the existence of causality among the variables without determining direction of the causality relationships.

2.4.1.3. The VECM for the Granger causality test

In the third step, we determine whether the causality among the series is unidirectional or bidirectional. To achieve this goal, we investigate the short-run and the long-run Granger causality relationships among the variables and their direction through applying a Vector Error Correction Model (VECM) approach, which can be written as below:

$$\Delta lnCO_t = \alpha_1 + \sum_{i=1}^{n} \beta_{1i}\, \Delta lnCO_{t-i} + \sum_{i=1}^{n} \gamma_{1i} \Delta lnGDP_{t-i} + \sum_{i=1}^{n} \delta_{1i} \Delta\, lnPO_{t-i} + \vartheta_{1i} ECT_{t-1} + \varepsilon_{1t} \tag{2.4.1.3a}$$

$$\Delta lnGDP_t = \alpha_2 + \sum_{i=1}^{n} \beta_{2i}\, \Delta lnGDP_{t-i} + \sum_{i=1}^{n} \gamma_{2i} \Delta lnCO_{t-i} + \sum_{i=1}^{n} \delta_{2i} \Delta\, lnPO_{t-i} + \vartheta_{2i} ECT_{t-1} + \varepsilon_{2t} \tag{2.4.1.3b}$$

where ECT_{t-1} represents the error correction term. A VECM is intelligent to investigate the short and the long-run Granger causality relationships among crude oil consumption, economic growth and crude oil price.

2.4.1.3.1. The short-run Granger causality test

The first test is the non causality standard Wald chi-square test to estimate the short-run Granger causality among the variables, which computes the joint significance of the coefficients of the independent variables, indicating how dependent variables answer to the shocks in the short-run.

2.4.1.3.2. The long-run Granger causality test

The second test uses the Error Correction Term (ECT), in which the long-run Granger causality among the variables is tested via appreciating the significance of the speed of adjustment coefficient (the coefficient of the ECT), indicating how the dependent variables response to the shocks in the long-run.

2.4.1.4. The Toda-Yamamoto causality test

The second approach that we use to examine oil consumption-economic growth is the Toda-Yamamoto method proposed by Toda and Yamamoto (1995), which involves a modified Wald test in an augmented autoregressive model (Toda and Yamamoto, 1995; Dolado and Lütkepohl, 1996) regardless of the integration and cointegration of the series.

In order to perform a Toda-Yamamoto procedure, in the first step, the order of integration of the time series should be determined. For this purpose, we use the results of the ADF, the P-P and the Zivot and Andrews (1992) tests referred in the previous section, supposing that the maximum order of integration of the time series is m. In the second step, a Vector Auto-Regressive (VAR) model in the level of the data should be set up regardless of the order of integration of the series and determine the appropriate maximum lag length based on the usual information criteria, supposing that the maximum lag length is p. In the third step again a VAR model in the level of the series is set up not with its true lag order of P but with lag order of $(p + m)$. And in the last step, a non Granger causality test should be implemented via employing a standard Wald chi-square test.

2.4.2. Methodology for the panel structure studies

2.4.2.1. The panel unit root tests

In the first step, we determine the variables' order of integration through the application of the panel unit root tests. There is a consensus that the traditional unit root tests such as the Augmented Dickey-Fuller (ADF) have lower power to reject the null hypothesis of no unit root test especially in the short span time series, than the panel unit root tests. Consequently, in this study, we perform the Breitung (2000) and the Im et al. (2003) panel unit root tests.

2.4.2.1.1. The Breitung (2000) panel unit root test

The Breitung (2000) test supposes homogeneity among the cross section's unit roots, and that all the cross sections have a common unit root process. In this test, the null hypothesis is that there is a unit root and the alternative hypothesis is that there is no unit root.
According to Hloscouva and Wanger (2006) in a large sample simulation study to evaluate the performance of the panel unit root tests, the Breitung (2003) test has the highest power among the first generation panel unit root tests.

2.4.2.1.2. The Im et al. (2003) panel unit root test

Im et al. (2003) propose a panel unit root test allowing heterogeneity across the cross section's unit roots, such that each cross section has an individual unit root process. In this test, the null hypothesis is that there is a unit root and the alternative hypothesis is that some of the cross sections do not have unit roots.
This test standardizes the t-bar statistic through averaging the augmented Dickey-Fuller statistics across the groups. We find this test reliable due to the different characteristics across countries.

We began our description by using the following general autoregressive process for panel data:

$$y_{it} = \rho_i y_{it-1} + X_{it}\delta_i + \varepsilon_{it}$$

(2.4.2.1.2a)

where *i*=1,2,…,*N* represents cross sections and *t*=1,2,…,*N* represents time periods, X_{it} represents the exogenous variables in the model, including any fixed effect or individual trends, ρ_i refers to the autoregressive coefficients and ε_{it} represents the error terms that we assume to be mutually independent. If ρ_i < 1, then y_i is weakly stationary and if ρ_i =1, then y_i has a unit root. For testing the panel unit root, there are two assumptions for ρ_i, the first one assumes that the persistence parameters are common across the cross sections, so ρ_i is identical across the cross sections; Breitung (2000) applies this assumption. The second one allows ρ_i varies across the cross sections; Im et al. (2003) use this assumption.

The basic ADF specification is as follows:

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{l=1}^{p_i} \beta_{ij} \Delta y_{it-j} + X'_{it}\delta + \varepsilon_{it}$$

(2.4.2.1.2b)

The Breitung (2000) test considers the basic ADF specification, supposes a common *a*=*ρ*-1, but allows for different lag orders *(* p_i *)* across the cross sections, with the null hypothesis stating that $H_0 : \alpha = 0$ and the alternative hypothesis $H_1 : \alpha$ <0. But Im et al. (2003) specify separate ADF regressions for each cross section and allow for different orders of serial correlation, with the null hypothesis stating that $H_0 : \alpha_i = 0$ for all *i* and the alternative hypothesis of $H_1 : \alpha_i = 0$ for *i*= 1,2,…, N_1 and α_i <0 for *i*= *N+1,N+2,…,N*.

In order to implement this test first we estimate the separate ADF regressions, and then calculate the average of the *t*-statistics for α_i (2.4.2.1.2c):

$$\overline{t_{NT}} = \left(\sum_{i=1}^{N} t_{iT_i}(P_i) \right)$$

(2.4.2.1.2c)

where *t*-bar statistics has an asymptotic standard normal distribution.

2.4.2.2. The panel cointegration tests

In the second step, with respect to the variables' order of integration which should be one, the Pedroni (1999) and the Kao (1999) panel cointegration tests, both based on the Engle-Granger two-stage cointegration test frameworks are applied to determine the existence of long-run relationships among the variables.

2.4.2.2.1. The Pedroni panel cointegration test

The Pedroni (1999) test allows for heterogeneity across the cross sections in terms of intercept and trend coefficients; it considers the following regression equation:

$$lnCO_{it} = \alpha_i + \delta_i t + \beta_{1i} lnGDP_{it} + \beta_{2i} lnPO_{it} + \varepsilon_{it} \tag{2.4.2.2.1}$$

where t=1…T, i=1,…,N, α_i and δ_i represent the intercept and time trend, respectively, and lnCO, lnGDP, and lnPO are supposed to be I(1); the next step is to test the stationary of residuals (ε_{it}) obtained from equation (2.4.2.2.1) which is supposed to be I(1) under the null hypothesis of no cointegration in a heterogeneous panel.

In this regard, Pedroni (1999) proposed two groups of cointegration tests, the first group is a panel statistics test or within dimension test, which includes four statistics: panel v, panel ρ, panel pp, and panel ADF-statistics. This group pools the residuals of the regression along within the dimension of the panel and considers homogeneity across the cross sections. The second group is between dimension and a group statistics test, which includes three statistics: group ρ, group PP, and group ADF-statistics. This group pools the residuals of the regression between the dimensions of the panel and allows for heterogeneity across the cross sections.

2.4.2.2.2. The Kao panel cointegration test

The second test is Kao (1999) that follows the same basic approach as Pedroni's test but specifies the cross section specific intercepts and homogenous coefficients during the first stage, this meaning heterogeneity in intercept α_i and homogeneity in β_i , and all coefficients' trends, δ_i , to be zero.

2.4.2.2.3. The panel fully modified OLS cointegration test

Afterward, we apply the fully modified OLS (FMOLS) method of Philips and Hansen (1990) and the FMOLS for heterogeneous cointegrated panels proposed by Pedroni (2000), which is a mean group estimator of the parameters of the cointegration relationship to estimate the following equations:

$$\ln CO_{it} = \alpha_{1i} + \delta_{1i} t + \beta_{11i} \ln GDP_{it} + \beta_{12i} \ln PO_{it} + \varepsilon_{it}^{\ln CO}$$

(2.4.2.2.3a)

$$\ln GDP_{it} = \alpha_{2i} + \delta_{2i} t + \beta_{21i} \ln CO_{it} + \beta_{22i} \ln PO_{it} + \varepsilon_{it}^{\ln GDP}$$

(2.4.2.2.3b)

where t=1…T, i=1,…,N,and α_i and δ_i represent the intercept and time trend, respectively.

2.4.2.3. The panel VECM for the Granger causality test

The existence of a cointegrating relationship among the variables confirms the existence of a long-run equilibrium relationship among them, at least in one direction, but it does not specify the direction of this relationship (Engle and Granger, 1987).

In the third step, we determine direction of the causality relationship between the variables in a panel framework. To achieve this goal, we apply the panel Granger causality test based on a two-step Engle-Granger procedure of causality (Engle and Granger, 1987) via employing a panel Vector Error Correction Model (VECM).

Based on this method, given the variables are cointegrated, in the first step, we applied the panel FMOLS method proposed by Pedroni (2000) to estimate the long-run equations of (2.4.2.2.3a) and (2.4.2.2.3b) in order to obtain the residuals or the Error Correction Terms (ECT), which is a deviation of the observed values in t-1 from the long-run equilibrium relationship.

In the second step, the lagged residuals obtained from the equations (2.4.2.2.3a and 2.4.2.2.3b) will be included into the VECM framework as the ECT and then specify the following dynamic error correction models:

$$\Delta \ln CO_{it} = \alpha_{1j} + \sum_{m=1}^{n} \theta_{11im} \Delta \ln CO_{it-m} + \sum_{m=1}^{n} \theta_{12im} \Delta \ln GDP_{it-m}$$
$$+ \sum_{m=1}^{n} \theta_{13im} \Delta \ln PO_{it-m} + \gamma_{1i} ECT_{it-1}^{\ln CO} + u_{it}$$

(2.4.2.2.3c)

$$\Delta \ln GDP_{it} = \alpha_{2j} + \sum_{m=1}^{n} \theta_{21im} \Delta \ln GDP_{it-m} + \sum_{m=1}^{n} \theta_{22im} \Delta \ln CO_{it-m} +$$
$$\sum_{m=1}^{n} \theta_{23im} \Delta \ln PO_{it-m} + \gamma_{2i} ECT_{it-1}^{\ln GDP} + v_{it}$$

(2.4.2.2.3d)

where Δ indicates the first differences of the variables and *m* the lag length, after a step-down procedure; we find the appropriate lag length to fulfill the classical assumptions[23]; ECTs are the error correction terms, which are the residuals from equation (2.4.2.2.3a and 2.4.2.2.3b) and *i*=1, 2,…,26.

The widely applied method to estimate the panel data Granger causality models is the Generalized Method of Moments (GMM) technique proposed by Arellano and Bond (1991), which is a dynamic panel data model. In this study, we perform a dynamic GMM instrumental technique and use the lags of the endogenous variables as the instrument variables of the models to reach the classical assumptions.

2.4.2.3.1. The short-run panel Granger causality test

The short-run Granger causality is determined by the statistical significance of the F-statistics through a Walt test based on the null hypothesis $H_0 : \theta_{12im} = 0$ and $H_0 : \theta_{13im} = 0$ for all *i* in equation (2.4.2.2.3c), and a similar null hypothesis for equation (2.4.2.2.3.d).

2.4.2.3.2. The long-run panel Granger causality test

The long-run Granger causality is determined via the statistical significance of relevant ECT with using the *t*-statistics, in equations (2.4.2.2.3c and 2.4.2.2.3d).

2.5. Description of data

2.5.1. Description of data for Portugal

We use annual data from 1980 to 2009 for Portugal. Our multivariate model considers per capita crude oil consumption in barrels per day (lnCO), per capita real GDP in constant 2000 US$ (lnGDP) and real Brent crude oil spot price in constant 2000 US$ (lnPO). Crude oil consumption in barrels per day obtained from the BP statistical yearbook of world energy (2011) is divided by the Portuguese population obtained from the WDI[24] (CD-ROM, 2010) to achieve per capita crude oil consumption; per capita real GDP in constant 2000 US$ is obtained from the WDI (CD-ROM, 2010); moreover, nominal Brent crude oil spot price data is divided by the Portuguese consumer price index (2000=100) to obtain real Brent crude oil spot price; the first series is obtained from the BP statistical yearbook of world energy (2011) and the second series is obtained from the WDI (CD-ROM, 2010).

[23] We implemented Sargan test to examine that error terms have no serial correlation and found it over-identified in the lag length of one.
[24] WDI 2010- World Development Indicators-World Bank.

2.5.2. Description of data for OECD countries

We apply annual data from 1976 to 2009 for twenty seven OECD countries, including Australia, Austria, Belgium and Luxemburg, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Mexico, the Netherlands, New Zealand, Norway, Portugal, South Korea, Spain, Sweden, Switzerland, Turkey, the UK and the US.

Our multivariate model considers per capita crude oil consumption in barrels per day (lnCO), per capita real GDP in constant 2000 US$ (lnGDP) and real Brent crude oil spot price in constant 2000 US$ (lnPO). Crude oil consumption data that is obtained from the BP statistical yearbook of world energy (2011) is divided by the population for each country obtained from the WDI (CD-ROM, 2010) to achieve per capita crude oil consumption; per capita real GDP is obtained from the WDI (CD-ROM, 2010); nominal Brent crude oil spot price data obtained from the BP statistical yearbook of world energy (2011) is divided by each countries' domestic consumer price index (2000=100) obtained from the WDI (CD-ROM, 2010) to achieve real Brent crude oil spot price.

2.5.3. Description of data for Latin American countries

Latin America region is divided to three groups of countries, Caribbean region, Central America and South America. We apply annual data from 1980 to 2012 for panel of Caribbean countries including Bahamas, Barbados, Dominica, Dominican Republic, Grenada and Trinidad and Tobago; for panel of Central American countries including Belize, Costa Rica, El Salvador, Guatemala, Honduras and Panama; and for panel of South American countries including Argentina, Bolivia, Colombia, Ecuador, Paraguay, Peru, Uruguay and Venezuela.

Our multivariate model contains per capita crude oil consumption in barrels per day (lnCO); per capita real GDP-PPP in constant 2005 US$ (lnGDP) and real West Texas Intermediate (WTI) crude oil spot price in constant 2005 US$ (lnPO). Crude oil consumption data obtained from the EIA[25] (2012) is divided by the population for each country obtained from the WDI (CD-ROM, 2013) to achieve per capita crude oil consumption; per capita real GDP-PPP is obtained from the WDI (CD-ROM, 2013); in order to achieve real WTI crude oil spot price, we divide nominal WTI crude oil spot price obtained from the BP statistical yearbook of world energy (2013) by each countries' domestic consumer price index (2005=100) obtained from the WDI (CD-ROM, 2013).

2.5.4. Description of data for Sub-Saharan African countries

Sub-Saharan Africa region is divided in two groups of countries, net crude oil exporting countries and net crude oil importing countries. Panel of net crude oil exporting countries applies annual data from 1985 to 2011, including Angola, Cameroon, Chad, Congo Republic, Cote d'Ivoire,

[25] EIA, Energy Information Administration.

Equatorial Guinea, Gabon, Nigeria and Sudan; and panel of net crude oil importing countries uses annual data from 1985 to 2011, including Cape Verde, Central Africa Republic, Ghana, Kenya, Malawi, Mauritania, Mauritius, Niger, Senegal, Seychelles, South Africa, Swaziland, Togo and Uganda.

Our multivariate model comprises per capita crude oil consumption (lnCO), per capita real GDP-PPP in constant 2005 US$ (lnGDP) and real Brent crude oil spot price in constant 2005 US$ (lnPO). Crude oil consumption data obtained from the EIA (2012) is divided by the population for each country obtained from the WDI (CD-ROM, 2012) to achieve per capita crude oil consumption; per capita real GDP-PPP is obtained from the WDI (CD-ROM, 2012); and to achieve real Brent crude oil spot price, we divide nominal Brent crude oil spot price obtained from the BP statistical yearbook of world energy (2011) by each countries' domestic consumer price index (2005=100) obtained from the WDI (CD-ROM, 2012).

2.5.5. Description of data for MENA countries

We apply annual data from 1980 to 2008 for nine MENA countries, including Algeria, Bahrain, Egypt, Iran, Jordan, Morocco, Saudi Arabia, Syria and Tunisia.

Our multivariate model includes per capita crude oil consumption (lnCO), per capita real GDP in constant 2000 US$ (lnGDP) and real Dubai crude oil spot price in constant 2000 US$ (lnPO). Crude oil consumption data obtained from the EIA (2010) is divided by the countries' population obtained from the WDI (CD-ROM, 2010) to achieve per capita crude oil consumption; per capita real GDP is obtained from the WDI (CD-ROM, 2010); and nominal Dubai crude oil spot price data obtained from the BP statistical yearbook of world energy (2011) is divided by each countries' domestic consumer price index (2000=100) obtained from the WDI (CD-ROM, 2010) to achieve real crude oil price.

2.5.6. Description of data for Eastern and Southern Asian countries

We apply annual data from 1986 to 2008 for a panel of Eastern and Southern Asian countries. In Southern Asia we include Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka, and in Eastern Asia we include Brunei Darussalam, China, Hong Kong, Indonesia, South Korea, Malaysia, Philippine, Singapore and Thailand.

Our multivariate model includes per capita crude oil consumption (lnCO), per capita real GDP in constant 2000 US$ (lnGDP) and real Dubai crude oil spot price in constant 2000 US$ (lnPO). Crude oil consumption data obtained from the EIA (2010) is divided by the population for each country obtained from the WDI (CD-ROM, 2010) to achieve per capita crude oil consumption; per capita real GDP is obtained from the WDI (CD-ROM, 2010); and nominal Dubai crude oil spot price data obtained from the BP statistical yearbook of world energy (2011) is divided by domestic consumer price index (2000=100) for each country obtained from the WDI (CD-ROM, 2010) to achieve real Dubai crude oil spot price.

All values of the variables are converted in natural logarithm in order to reduce their variability and facilitate economic interpretations of the coefficients. Furthermore, start and end years of the series are based on data availability for all the series.

2.6. The results

2.6.1. The results of the unit root tests

In the first step, we examine the stationary properties of the series through applying the unit root tests. The results for the unit root tests are divided to two main groups, the first one includes the results of the individual unit root tests (Dickey and Fuller, 1979; and Phillips and Perron, 1988) for Portugal; and the second one includes the results of the panel unit root tests (Breitung, 2000; and Im et al., 2003) for five panel structure studies, including a panel of OECD, panels of Latin America, panels of Sub-Saharan Africa, a panel of MENA and a panel of Southern and Eastern Asia, as below:

2.6.1.1. The results of the individual unit root tests for Portugal

The first group includes the results of the individual unit root tests for Portugal. In order to test whether the series have the same order of integration, we employ two tests that do not consider the presence of structural breaks: the ADF (Dickey and Fuller, 1979) and the P-P (Phillips and Perron, 1988), all the estimated models include the intercept and trend, and the Zivot and Andrews (1992) unit root test that considers one structural break.

According to both the ADF and the P-P tests, the existence of unit root in the levels of the series and stationary in their first differences is proven, this meaning that lnCO, lnGDP and lnPO of Portugal are integrated of order one, or are I(1) (see table 6).

Table 6- Results of the unit root tests for Portugal

	ADF		P-P	
Variables	Levels	First difference	Levels	First fifference
lnCO	-0.45	-3.93**	-0.47	-5.92*
lnGDP	3.09	-5.41*	-0.9	-6.95*
lnPO	-1.7	-4.36*	-1.78	-6.54*

Lag length selection is based on Akaike Information Criterion.

*and**denote statistical significance at 1% and 5% levels, respectively.

Moreover, the Zivot and Andrews (1992) unit root test with allowing for one structural break is applied to confirm the results obtained by the ADF and the P-P tests. The results fail to reject the null hypothesis that the series contain unit roots in their levels in all the three models - break in the intercept, break in the trend and break in both the intercept and trend - the only exception is lnCO unit root with break in the intercept. Therefore, the Zivot and Andrews (1992) test confirms the results obtained by the ADF and the P-P unit root tests that lnCO, lnGDP and lnPO series contain unit roots in their levels and they are stationary in their first differences (see table 7).

Table 7-Result of the Zivot-Andrews unit root test for Portugal

Variables	Break point	Number of lags	t-statistics
	Model A		
lnCO	2005	3	-2.13
lnGDP	1994	4	-0.8
lnPO	1999	0	-2.59
	Model B		
lnCO	2003	3	-4.58*
lnGDP	2001	4	-1.55
lnPO	1994	0	-2.89
	Model C		
lnCO	2004	3	-4.24
lnGDP	2000	4	-1.49
lnPO	1993	0	-2.84

Model A: Break in the intercept.

Model B: Break in the trend.

Model C: Breaks in both the intercept and trend.

* indicates statistical significance at 5% level.

Therefore, the possibility of the presence of cointegration relations between the series can be tested.

2.6.1.2. The results of the panel unit root tests

The second group includes the results of the panel unit root tests for five panel structure studies, including a panel of OECD, panels of Latin America, panels of Sub-Saharan Africa, a panel of MENA and a panel of Southern and Eastern Asia. To achieve this goal, we apply the Breitung (2000) and the Im et al. (2003) panel unit root tests for per capita crude oil consumption, per capita real GDP and real crude oil spot price. All the models used by the tests include the intercept and trend. The results are reported in tables (8) to (12) as below:

2.6.1.2.1. The results of the panel unit root tests for OECD countries

The results prove that, there are strong evidences to confirm that in panel of OECD countries all the series have unit roots in their levels and they are stationary in their first differences, or they are I(1) (see table 8).

Table 8-Results of the panel unit root tests for OECD countries

	Level			First differences		
Unit root tests	lnCO	lnGDP	lnPO	lnCO	lnGDP	lnPO
UB	0.36	11.60	1.34	-10.57*	3.38	-6.25*
IPS	0.48	2.79	5.90	-16.59*	-5.95*	-18.78*

Lag length selection is based on Schwarz Information Criterion.

BU represents the Breitung (2000) panel unit root test.

IPS represents the Im et al. (2003) panel unit root test.

* indicates statistical significance at 1% level.

Therefore, we can go further to perform the panel cointegration test for the group of OECD countries.

2.6.1.2.2. The results of the panel unit root tests for Latin America

Based on the results from the Breitung (2000) panel unit root test, there are enough empirical evidences to prove that for three panels of Caribbean countries and Central and South America regions, the levels of the series have unit roots while their first differences are stationary, or they are I(1) (see table 9).

Table 9-Results of the panel unit root tests for Latin America

	Caribbean region	Central America	South America
	BU	BU	BU
lnCO	0.99	-0.68	3.27
lnGDP	0.87	0.72	2.99
lnPO	1.88	0.56	3.96
ΔlnCO	-6.43*	-2.53*	-5.52*
ΔlnGDP	-4.74*	-2.13**	-7.71*
ΔlnPO	-11.36*	-5.04*	-7.94*

Lag length selection is based on Schwarz Information Criterion.

BU represents the Breitung panel unit root test.

* and ** denote statistical significance at 1% and 5% levels, respectively.

Thus, we can go further to perform the panel cointegration tests for Latin America regions.

2.6.1.2.3. The results of the panel unit root tests for Sub-Saharan Africa

Based on the results, there are enough empirical evidences to prove that for both panels of net crude oil exporting and net crude oil importing Sub Saharan African countries, the levels of the series have unit roots while their first differences are stationary, or they are I(1) (see table 10).

Table 10-Results of the panel unit root tests for Sub-Saharan Africa

	Net oil exporting Africa		Net oil importing Africa	
	BU	IPS	BU	IPS
lnCO	0.21	-0.41	0.22	-1.24
lnGDP	0.98	-1.16	0.68	0.87
lnPO	2.90	0.89	2.84	-1.06
ΔlnCO	-3.90*	-10.10*	-7.37*	-15.83*
ΔlnGDP	-3.76*	-6.00*	-2.60*	-8.96*
ΔlnPO	-8.48*	-7.71*	-7.79*	-11.39*

Lag length selection is based on Schwarz Information Criterion.

BU represents the Breitung (2000) panel unit root test.

IPS represents the Im et al. (2003) panel unit root test.

* denotes statistical significance at 1% level.

Therefore, we can go further to perform the panel cointegration tests for Sub Saharan African regions.

2.6.1.2.4. The results of the panel unit root tests for MENA countries

The results indicate that, there are enough empirical evidences to prove that for panel of MENA countries, the levels of the series have unit roots while their first differences are stationary, or they are I(1) (see table 11).

Table 11-Results of the panel unit root tests for MENA countries

	Level			First difference		
Unit root tests	lnCO	lnGDP	lnPO	lnCO	lnGDP	lnPO
UB	-0.22	3.65	4.32	-6.22*	-6.45*	-6.91*
IPS	-2.50**	1.87	5.44	-12.54*	-11.18*	-12.06*

Lag length selection is based on Schwarz Information Criterion.

UB represents the Breitung (2000) panel unit root test.

IPS represents the Im et al. (2003) panel unit root test.

*and ** indicate statistical significance at 1% and 5% levels, respectively.

Hence, we can perform the panel cointegration test for the group of MENA countries.

2.6.1.2.5. The results of the panel unit root tests for Eastern and Southern Asia

The results show that, there are enough empirical evidences to prove that for panel of Eastern and Southern Asian countries, the levels of the series have unit roots while their first differences are stationary, or they are I(1) (see table 12).

Table 12-Results of the panel unit root tests for Eastern and Southern Asia

	Level			First difference		
Unit root tests	lnCO	lnGDP	lnPO	lnCO	lnGDP	lnPO
UB	3.32	2.08	5.99	-5.83*	-6.12*	-7.36*
IPS	-0.64	-1.28***	7.86	-7.92*	-7.55*	-10.96*

Lag length selection is based on Schwarz information criterion.

UB represents the Breitung (2000) panel unit root test.

IPS represents the Im et al. (2003) panel unit root test.

*and *** indicate statistical significance at 1% and 10% levels, respectively.

Consequently, we can go further and implement the panel cointegration test for the group of Eastern and Southern Asian countries.

2.6.2. The results of the cointegration tests

As the series have the same order of integration, in the second step, we go further to examine the cointegration relationships between the series. The results for the cointegration tests are also divided in two main groups. The first group includes the results of the individual Johansen cointegration test (Johansen, 1988, 1991; and Johansen and Juselius, 1990) for Portugal, and the second group includes the results of the panel cointegration tests (Pedroni, 1999; and Kao, 1999) for five panel structure studies, including panel of OECD, panels of Latin America, panels of Sub-Saharan Africa, panel of MENA and panel of Southern and Eastern Asia, as below:

2.6.2.1. The results of the Johansen cointegration test for Portugal

The first group includes the results of the individual cointegration test for Portugal. To achieve this goal, the Johansen cointegration test (Johansen, 1988, 1991; and Johansen and Juselius, 1990) is employed.

In this stage an unconstrained VAR model is set up to determine the optimum lag length; the minimum Schwarz Information Criterion (SC) is applied to optimize the lag lengths for the series under study (see table 13).

Table 13-Selection of lag lenght

Number of lags	LogL	LR	SC
1	22.67	1.46E+02*	-0.24*
2	33.8	1.63E+01	0.03
3	41.76	9.79E+00	0.54
4	48.47	6.71E+00	1.15

LogL represents Log Likelihood function

LR represents sequential modified LR test statistic.

SC represents Schwarz Information Criterion.

*denotes the optimal lag length by each criterion.

Under the Johansen cointegration framework, the maximum eigenvalue test under the null hypothesis of $H_0 : r_0 = r$ against the alternative hypothesis of $H_1 : r_0 > r$, and the trace test under the null hypothesis of $H_0 : r_0 \leq r$ against the alternative hypothesis of $H_1 : r_0 > r$, examine the cointegration relationships.

Under the both tests statistics, the null hypothesis of zero cointegration equation is rejected and the null hypothesis of one cointegating equation is accepted at 5% level of significance (see table 14). Therefore, there is one cointegration equation among lnCO, lnGDP and lnPO for Portugal.

Table 14- Results of the Johansen cointegration test for Portugal

	Rank tests	
Number of cointegration	Trace test	Max eigenvalue test
None*	0.0412*	0.0171*
At most 1	0.6679	0.7115
At most 2	0.2872	0.2872

* denotes the rejection of the null hypothesis at 5% level of significance.

The values of the table are the probabilities.

As it is stated by Narayan and Smith (2005), the existence of a cointegration relationship among the variables indicates that there must be a Granger causality relationship between them at least in one direction, but it does not specify the direction of causality relationship between the variables. Therefore, in the next step we will perform the Granger causality test in order to specify the direction of causality.

2.6.2.2. The results of the panel cointegration tests

The second group includes the results of the panel cointegration tests (Pedroni, 1999; and Kao, 1999) for five panel structure studies, including a panel of OECD, panels of Latin America, panels of Sub-Saharan Africa, a panel of MENA and a panel of Eastern and Southern Asia.

In this step, with respect to the variables order of integration that is one, the Pedroni (1999), and the Kao (1999) panel cointegration tests are applied to determine the existence of long-run relationships among the variables. Afterward, we apply the fully modified OLS (FMOLS) for heterogeneous cointegrated panels proposed by Pedroni (2000) in order to estimate the long-run elasticities.

2.6.2.2.1. The results of the panel cointegration tests for OECD countries

For a panel of OECD countries, we apply the Pedroni (1999) panel cointegration test with the intercept and no trend in the test models. The results indicate that, six of eleven statistics and weighted statistics reject the null hypothesis of no cointegration at 1%, 5% and 10% significance levels. Moreover, the Kao (1999) test with intercept and no trend rejects the null hypothesis of no cointegration at 1% significance level; hence, we conclude that there are cointegration relationships among the series in panel of OECD countries (see table 15).

Table 15-Results of the panel cointegration tests for OECD

Pedroni test	Statistic	Weighted statistic
Within dimension		
Panel v-statistic	2.90*	2.83*
Panel ρ-statistic	0.21	-0.18
Panel PP-statistic	-0.66	-1.38***
Panel ADF-statistic	-2.03**	-2.56*
Between dimension		
Group ρ-statistic	1.80	
Group PP-statistic	-0.39	
Group ADF-statistic	-2.85*	
Kao test		
ADF	-3.64*	

Lag length selection for the Pedroni tests is based on Akaike Information Criterion.
Lag length selection for the Kao test is based on Schwarz Information Criterion.
*, ** and *** reject the null of no cointegration at 1%, 5% and 10% levels of significance, respectively.

In the next step, The results of the Pedroni (2000) panel FMOLS cointegration test for OECD countries (see table 16), reveal that if crude oil consumption is the dependent variable (equation 2.4.2.2.3a), then crude oil consumption and GDP have a positive long-run relationship at 1% significance level, and if GDP increases by 1% then crude oil consumption increases by 0.96%. Moreover, crude oil price and crude oil consumption have a negative long-run relationship at 1% significance level, if crude oil price increases by 1% then crude oil consumption decreases by 0.05%. These values meaning that crude oil consumption is inelastic to changes in GDP and is almost perfectly inelastic to crude oil price oscillations.

On the other hand, if GDP is the dependent variable (equation 2.4.2.2.3b), then GDP and crude oil consumption have a positive long-run relationship at 1% significance level, and if crude oil consumption increases by 1% then GDP increases by 0.46%. Furthermore, crude oil price adversely impacts on GDP at 5% significance level, and if crude oil price increases by 1% then GDP decreases by 0.01%. This meaning that GDP is inelastic to changes in crude oil consumption and is almost perfectly inelastic to changes in crude oil prices.

Table 16-Results of the panel FMOLS for OECD

Dependent variables	Explanatory variables	
lnCO	lnGDP	lnPO
	0.96(17.61)*	-0.05(-12.17)*
lnGDP	lnCO	lnPO
	0.46(13.57)*	-0.015(-2.24)*

t-statistics values are in parenthesis.

* denotes statistical significance at 1% level.

2.6.2.2.2. The results of the panel cointegration tests for Latin America regions

For panels of Latin American regions, we apply the Pedroni (1999) panel cointegration test with intercept and no trend. The results indicate that, in panel of Caribbean region countries, eight of eleven statistics and weighted statistics reject the null hypothesis of no cointegration at 1%, 5% and 10% significance levels. In panel of Central American countries, seven of eleven statistics and weighted statistics reject the null hypothesis of no cointegration at 1% and 5% significance levels. And in panel of South American countries, six of eleven statistics and weighted statistics reject the null hypothesis of no cointegration at 5% and 10% significance levels (see table 17). Therefore, there are enough evidences to accept the existence of cointegrating relationships in every one of three panels of Latin America.

Table 17-Results of the panel cointegration test for Latin America

Pedroni test	Caribbean region		Central America		South America	
	Statistic	Weighted statistic	Statistic	Weighted statistic	Statistic	Weighted statistic
Within dimension						
Panel v-statistic	1.74**	1.04	0.86	0.98	0.86	0.87
Panel ρ-statistic	-1.26	-1.63***	-1.00	-1.82**	-0.92	-1.29***
Panel PP-statistic	-1.66**	-2.30**	-1.68**	-2.58*	-1.36***	-1.83**
Panel ADF-statistic	-1.92**	-2.89*	-1.76**	-2.07**	-1.89**	-2.05**
Between dimension						
Group ρ-statistic	-0.88		0.76		0.35	
Group PP-statistic	-2.21**		-2.38*		-0.34	
Group ADF-statistic	-2.67*		-2.21**		-1.97**	

Lag length selection is based on Akaike Information Criterion.

*, ** and *** denote statistical significance at 1%, 5% and 10% levels, respectively.

Moreover, the results of the Pedroni (2000) panel FMOLS cointegration test for Latin America (see table 18), represent that if crude oil consumption is the dependant variable (equation 2.4.2.2.3a) then:

(i) In panel of Caribbean region: GDP has a positive long-run impact on crude oil consumption at 1% significance level, and the coefficient indicates that if GDP increases by 1% then crude oil consumption increases by 0.84%, which means crude oil consumption is inelastic to changes in GDP. On the other hand, crude oil price has a negative long-run impact on crude oil consumption at 5% significance level, if crude oil price increases by 1% then crude oil consumption decreases by 0.15%, this means that crude oil consumption is inelastic to changes in crude oil price.

(ii) In panel of Central American countries: GDP has a positive long-run impact on crude oil consumption at 1% significance level, if GDP increases by 1% then crude oil consumption increases by 0.86%, which means crude oil consumption is inelastic to changes in GDP. Moreover, crude oil price has a negative long-run impact on crude oil consumption at 1% significance level, if crude oil price increases by 1% then crude oil consumption decreases by 0.17%, this indicates inelasticity of crude oil consumption to changes in crude oil price.

(iii) In panel of South American countries: GDP has a positive long-run impact on crude oil consumption at 1% significance level, if GDP increases by 1% then crude oil consumption increases by 0.66%, which shows inelasticity of crude oil consumption to changes in GDP. Furthermore, crude oil price has a negative long-run impact on crude oil consumption at 5% significance level, if crude oil price increases by 1% then crude oil consumption decreases by 0.09%, this indicates perfect inelasticity of crude oil consumption to changes in crude oil price.

On the other hand, if GDP is the dependant variable (equation 2.4.2.2.3b) then:

(i) In panel of Caribbean region: crude oil consumption has a positive long-run impact on GDP at 1% significance level, if crude oil consumption increases by 1% then GDP increases by 0.54%, which means that GDP is inelastic to changes in crude oil consumption. Moreover, crude oil price has a negative long-run impact on GDP at 10% significance level, if crude oil price increases by 1% then GDP decreases by 0.04% that means perfect inelasticity of GDP to changes in crude oil price.

(ii) In panel of Central American countries, crude oil consumption has a positive long-run impact on GDP at 1% significance level, if crude oil consumption increases by 1% then GDP increases by 0.16% that means inelasticity of GDP to changes in crude oil consumption. Furthermore, the effect of crude oil price on GDP is not statistically significant.

(iii) In panel of South American countries, crude oil consumption has a positive long-run impact on GDP at 1% significance level, if crude oil consumption increases by 1% then GDP increases by 0.54%; therefore, GDP is inelastic to changes of crude oil consumption. Moreover, crude oil price has a negative long-run impact on GDP at 1% significance level, if crude oil price increases by 1% then GDP decreases by 0.008%, which means that GDP is perfectly inelastic to changes in crude oil price.

Table 18-Results of the panel FMOLS for Latin America

Dependent variables	Caribbean region		Central America		South America	
	lnGDP	lnPO	lnGDP	lnPO	lnGDP	lnPO
lnCO	0.84 (24.42)*	-0.15 (-3.94)**	0.86 (50.05)*	-0.17 (-8.04)*	0.66 (15.36)*	-0.09 (-2.06)**
	lnCO	lnPO	lnCO	lnPO	lnCO	lnPO
lnGDP	0.54 (22.79)*	-0.04 (-1.69)***	0.16 (2.95)*	-0.03 (-0.29)	0.54 (7.03)*	-0.008 (-2.73)*

t-statistics values are in parenthesis.

*, ** and *** denote statistical significance at 1%, 5% and 10% levels.

2.6.2.2.3. The results of the panel cointegration tests for Sub-Saharan Africa

The results of the Pedroni (1999) panel cointegration with intercept and trend show that, in panel of net crude oil exporting countries eight of eleven statistics and weighted statistics reject the null hypothesis of no cointegration at 1% and 5% significance levels, and in panel of net crude oil importing countries nine of eleven statistics and weighted statistics reject the null hypothesis of no cointegration at 1% and 10% significance levels. Furthermore, based on the Kao (1999) panel cointegration test, there are long-run relationships between the series in both panels at 10% significance level. Subsequently, we accept the existence of long-run relationships among the series in both panels of Sub-Saharan Africa (see table 19).

Table 19-Results of the Panel cointegration tests for Sub-Saharan Africa

Pedroni test	Net crude oil exporting		Net crude oil importing	
	Statistic	Weighted statistic	Statistic	Weighted statistic
Within dimension				
Panel v-statistic	-0.35	-0.20	0.09	0.69
Panel ρ-statistic	-2.12**	-1.98**	-3.19*	-2.70*
Panel PP-statistic	-4.89*	-4.54*	-4.50*	-3.94*
Panel ADF-statistic	-4.54*	-3.97*	-1.87**	-3.05*
Between dimension				
Group ρ-statistic	-0.63		-1.54***	
Group PP-statistic	-3.92*		-3.75*	
Group ADF-statistic	-3.21*		-2.60*	
Kao test				
ADF	1.52***		-1.48***	

Lag length selection is based on Modified Akaike Information Criterion.
*, ** and *** denote statistical significance at 1%, 5% and 10% levels, respectively.

The results of the Pedroni (2000) panel FMOLS cointegration test for Sub-Saharan countries (see table 20) show that:

(*i*) In panel of net crude oil exporting countries, if crude oil consumption is the dependent variable (equation 2.4.2.2.3a), then crude oil consumption and GDP have a positive long-run relationship at 1% significance level, and if GDP increases by 1% then crude oil consumption increases by 1.01%. Moreover, crude oil price and crude oil consumption have a positive long-run relationship at 1% significance level, if crude oil price increases by 1% then crude oil consumption increases by 0.16%. These values mean that crude oil consumption is unit elastic to changes in GDP and is inelastic to changes in crude oil price.

On the other hand, if GDP is the dependent variable (equation 2.4.2.2.3b), then GDP and crude oil consumption have a positive long-run relationship at 1% significance level, and if crude oil consumption increases by 1% then GDP increases by 0.11%. Furthermore, crude oil price positively impacts on GDP at 1% significance level and if crude oil price increases by 1% then GDP increases by 0.04%. This means that GDP is inelastic to changes in crude oil consumption and crude oil price.

(*ii*) In panel of net oil importing countries, if crude oil consumption is the dependent variable (equation 2.4.2.2.3a), then crude oil consumption and GDP have a positive long-run relationship at 1% significance level, and if GDP increases by 1% then crude oil consumption increases by 0.56%. Moreover, crude oil price and crude oil consumption have a negative long-run relationship at 5%

significance level, if crude oil price increases by 1% then crude oil consumption increases by 0.12%. This means that crude oil consumption is inelastic to changes in GDP and crude oil price.

On the other hand, if GDP is the dependent variable (equation 2.4.2.2.3b), then GDP and crude oil consumption have a positive long-run relationship at 1% significance level, and if crude oil consumption increases by 1% then GDP increases by 0.21%. Furthermore, crude oil price negatively impacts on GDP at 1% significance level and if crude oil price increases by 1% then GDP decreases by 0.02%. This means that GDP is inelastic to changes in crude oil consumption and crude oil price.

Table 20-Results of the panel FMOLS for Sub-Saharan Africa

Dependent variables	Net oil exporters		Net oil importers	
	lnGDP	lnPO	lnGDP	lnPO
lnCO	1.01 (8.19)*	0.16 (5.24)*	0.51 (11.75)*	-0.12 (-2.92)*
	lnCO	lnPO	lnCO	lnPO
lnGDP	0.11 (6.59)*	0.04 (3.52)*	0.21 (9.27)*	-0.02 (-2.35)**

t-statistics values are in parenthesis.

*and ** denote statistical significance at 1% and 5% levels, respectively.

2.6.2.2.4. The results of the panel cointegration tests for MENA countries

We apply the Pedroni (1999) and the Kao (1999) panel cointegration tests with intercept and no trend for panel of MENA countries. The Pedroni (1999) test results reveal that, ten of eleven statistics and weighted statistics reject the null hypothesis of no cointegration at 1%, 5% and 10% significance levels. Furthermore, the Kao (1999) test results reject the null hypothesis of no cointegration at 5% significance level. Consequently, the results strongly suggest that there are long-run cointegrating relationships between the series for panel of MENA countries (see table 21).

Table 21-Results of the panel cointegration tests for MENA countries

Pedroni test	Statistic	Weighted statistic
Within dimension	2.14**	1.80**
Panel v-statistic	-1.81**	-1.40***
Panel ρ-statistic	-2.75*	-2.23**
Panel PP-statistic	-2.38*	-1.88**
Panel ADF-statistic		
Between dimension		
Group ρ-statistic	-0.55	
Group PP-statistic	-2.47*	
Group ADF-statistic	-2.08**	
Kao test		
ADF	-2.18**	

Lag length selection is based on Schwarz Information Criterion.
*, ** and *** denote statistical significance at 1%, 5% and 10% levels, respectively.

The results of the Pedroni (2000) panel FMOLS cointegration test for MENA countries (see table 22), reveal that: if crude oil consumption is the dependent variable (equation 2.4.2.2.3a) then GDP has a positive statistically significant long-run impact on crude oil consumption at 1% significance level, and the coefficient indicates that if GDP increases by 1% then crude oil consumption increases by 0.55%, which means that crude oil consumption is inelastic to changes in GDP; on the other hand, crude oil price has a negative statistically significant long-run impact on crude oil consumption at 1% significance level and if crude oil price increases by 1% then crude oil consumption decreases by 0.023%, this means that crude oil consumption is almost perfectly inelastic to crude oil price's changes.

On the other hand, if GDP is the dependent variable (equation 2.4.2.2.3b) then crude oil consumption has a positive statistically significant impact on GDP at 1% significance level, and if crude oil consumption increases by 1% then GDP increases by 0.55%, which states that GDP is inelastic to changes in crude oil consumption; moreover, crude oil price has a positive statistically significant long-run impact on GDP at 1% significance level, and if crude oil price increases by 1% then GDP increases by 0.11%, which means that GDP is inelastic to changes in crude oil price; this result is in line with theory since the majority of MENA countries of this study are net crude oil exporters; therefore, increase in crude oil prices leads to increase in their income and GDP.

Table 22-Results of the panel FMOLS for MENA

Dependent variables	Explanatory variables	
lnCO	lnGDP	lnPO
	0.55(7.33)*	-0.023(-5.33)*
lnGDP	lnCO	lnPO
	0.55(6.33)*	0.11(5.66)*

t-statistics values are in parenthesis.

* denotes statistical significance at 1% level.

2.6.2.2.5. The results of the panel cointegration tests for Eastern and Southern Asia

We apply the Pedroni (1999) and the Kao (1999) panel cointegration tests with intercept and no trend. The Pedroni test results indicate that, ten of eleven statistics and weighted statistics reject the null hypothesis of no cointegration at 1%, 5% and 10% significance levels. Moreover, the Kao (1999) test results reject the null hypothesis of no cointegration at 1% significance level (see table 23).Therefore, the results strongly suggest the existence of long-run relationship among the variables for Southern and Eastern Asian countries.

Table 23-Results of the panel cointegration tests for Southern and Eastern Asia

Pedroni test	Statistic	Weighted statistic
Within dimension	2.34*	2.28**
Panel v-statistic	-1.41***	-1.74**
Panel ρ-statistic	-3.21*	-3.57*
Panel PP-statistic	-4.03*	-4.00*
Panel ADF-statistic		
Between dimension		
Group ρ-statistic	0.01	
Group PP-statistic	-3.92*	
Group ADF-statistic	-4.05*	
Kao test		
ADF	-2.60*	

Lag length selection is based on Schwarz Information Criterion.

*, ** and ***denote statistical significance at 1%, 5% and 10% levels, respectively.

The results of the Pedroni(2000) panel FMOLS cointegration test for Southern and Eastern Asia (see table 24), show that: if crude oil consumption is the dependent variable (equation 2.4.2.2.3a), then GDP has a positive long-run impact on crude oil consumption at 1% significance level, and if GDP increases by 1% then crude oil consumption increases by 0.86%, which means that crude oil consumption is inelastic to changes in GDP. On the other hand, crude oil price has a negative long-run impact on crude oil consumption at 1% significance level, and if crude oil price increases by 1% then crude oil consumption decreases by 0.21%, this means that crude oil consumption is inelastic to changes in crude oil price.

On the other hand, if GDP is the dependent variable (equation 2.4.2.2.3b), then crude oil consumption has a positive long-run impact on GDP at 1% significance level, and if crude oil consumption increases by 1% then GDP increases by 0.84%, which indicates that GDP is inelastic to changes in crude oil consumption. Moreover, crude oil price has a positive long-run impact on GDP at 1% significance level, and if crude oil price increases by 1% then GDP increases by 0.15%, which means that GDP is inelastic to changes in crude oil price; this result is in line with theory as many of the Eastern and Southern Asian countries are crude oil producers, for instance, China, Indonesia, India and Malaysia are among the top 25 oil producing countries and Vietnam, Brunei Darussalam and Thailand produce significant amounts of crude oil. Consequently increase in crude oil price leads to increase their income.

Table 24-Results of the Panel FMOLS for Southern and Eastern Asia

Dependent variables	Explanatory variables	
lnCO	lnGDP	lnPO
	0.86(48.60)*	-0.21(-17.90)*
lnGDP	lnCO	lnPO
	0.84(63.20)*	0.15(13.86)*

t-statistics values are in parenthesis.
* denotes statistical significance at 1% level.

2.6.3. The results of the Granger causality tests

The existence of a cointegrating relationship among the variables confirms the existence of a long-run equilibrium relationship among them, at least in one direction, but it does not specify the direction of this relationship (Engle and Granger, 1987). In the third step, we use the Granger causality approaches in order to determine the direction of causality relationship between the variables.

The results for the Granger causality tests are divided to two main groups; the first one includes the results of the individual Granger causality tests for Portugal. To achieve this goal, we apply two approaches, the VECM and the Toda-Yamamoto proposed by Toda and Yamamoto (1995). The second one includes the results of the panel Granger causality tests for five panel structure studies, including a panel of OECD, panels of Latin America, panels of Sub-Saharan Africa, a panel of MENA and a panel of Eastern and Southern Asia through applying the panel Granger causality test based on the two-step Engle-Granger procedure of causality (Engle and Granger, 1987). The results are shown below.

2.6.3.1. The results of the Granger causality tests for Portugal

To achieve this goal, we apply two individual Granger causality approaches, the VECM and the Toda-Yamamoto (1995), as below:

2.6.3.1.1. The results of the VECM Granger causality tests for Portugal

According to the VECM approach (see table 25), the results of the non-causality Wald chi-sq test point to a bidirectional causality relationship between lnCO and lnGDP and a unidirectional causality running from lnPO to lnCO in the short-run. Moreover, the results of the long-run Granger causality test of the ECT confirm that, the ECT coefficient of lnCO is negative and statistically significant at 5% significance level and the ECT coefficient of lnGDP is positive and statistically significant at 1% significant level; therefore, there is a bidirectional causality relationship between crude oil consumption and GDP in the long-run.

Hence, based on the VECM approach, reduction of crude oil consumption adversely affects on economic growth in Portugal, but it is a complementary effect. As the ECT of lnPO is insignificant, then there is a unidirectional causality running from crude oil price to crude oil consumption and from crude oil price to GDP in the long-run, a rational conclusion, once international crude oil prices are not affected by the small Portuguese GDP and its small crude oil consumption.

The ECT coefficients in lnCO and lnGDP equations are, respectively, -0.12 and 0.002, which imply that, if a deviation from the long-run equilibrium occurs, then ECT returns it to the equilibrium with 0.12% and 0.002% speeds of adjustments per year, respectively.

The robustness of the VECM is assessed by achieving the relative tests; the LM test displays no serial correlation up to 12 lags, the Portmanteau test indicates no residual autocorrelation up to 12 lags, the joint Chi-square of the Jarque-Bera normality test is 7.2 with the probability of 0.29 suggesting that the residuals are multivariate normal and the Chi-sq of White Heteroskedastisity test is 58.15 with the probability of 0.54 yielding no ARCH in the residuals. Therefore, residuals are Gaussian white noise and the VECM is able to reflect correctly the dynamic relationships among the variables.

Table 25-Results of the VECM Granger causality test for Portugal

Variables	Short-run			Long-run
	Chi-sq			t-statistics
	ΔlnCO	ΔlnGDP	ΔlnPO	ECT
ΔlnCO	-	0.0046*	0.063***	-0.12 (-1.80)**
ΔlnGDP	0.084***	-	0.36	0.002 (4.46)*
ΔlnPO	0.2	0.45	-	0.008 (0.70)

*, ** and *** indicate statistical significance at 1%, 5% and 10% levels, respectively.

The values of the short-run Wald test are probabilities.

The values in parentheses are t-statistics.

2.6.3.1.2. The results of the Toda-Yamamoto Granger causality test for Portugal

The Dickey-Fuller (ADF), the Philips-Peron (PP) and the Zivot and Andrews (1992) unit root tests state that the order of integration of the time series is one, and that, according to the Schwarz Information Criterion, the appropriate maximum lag length is one. Therefore, we set up a VAR model in the level of the data with a lag length of two and then perform a non Granger causality test using a standard Wald test.

The result of the Toda-Yamamoto Wald chi-sq test gives empirical evidence that, there is a bidirectional causality relationship between lnCO and lnGDP, while there is not any causality relationship between lnPO and lnCO and also between lnPO and lnGDP. Therefore, the results from the Toda-Yamamoto approach confirms the result by the VECM approach and yields that oil conservation policies and reduction of crude oil consumption negatively affect on economic growth in Portugal (See table 26).

Table 26-Results of the Toda-Yamamoto Granger causality test for Portugal

Variables	Wald test		
	Chi-sq		
	ΔlnCO	ΔlnGDP	ΔlnPO
ΔlnCO	-	0.077(3.12)*	0.10(2.58)
ΔlnGDP	0.088(2.90)*	-	0.58(0.29)
ΔlnPO	0.33(0.93)	0.52(0.41)	-

* indicates statistical significance at 10% level.
The values of the Wald test are the probabilities.

2.6.3.2. The results of the panel VECM Granger causality tests

In the third step, we determine direction of the causality relationship between the variables in a panel framework for five panel structure studies, including a panel of OECD, panels of Latin America, panels of Sub-Saharan Africa, a panel of MENA, and a panel of Eastern and Southern Asia. To achieve this goal, we apply the panel Granger causality test based on a two-step Engle-Granger procedure of causality (Engle and Granger, 1987), with employing a panel Vector Error Correction Model (VECM), to estimate equations (2.4.2.2.3c) and (2.4.2.2.3d).The results are shown below:

2.6.3.2.1. The results of the panel VECM tests for OECD countries

The results of the panel VECM approach to estimate equations (2.4.2.2.3c) and (2.4.2.2.3d) for panel of OECD countries (see table 27) indicate that:

According to equation (2.4.2.2.3c), the F-statistics of Wald tests suggest that, in the short-run, GDP and crude oil price Granger cause crude oil consumption at 1% significant level, while in the long-run, the t-statistics of ECT indicates that there is a causality relationship running from GDP and crude oil price to crude oil consumption at 1% significance level.

Moreover, according to equation (2.4.2.2.3d), the F-statistics of Wald tests suggest that, in the short-run, crude oil consumption and crude oil price Granger cause GDP at 1% significant level, and in the long-run, the t-statistic of ECT indicates that there is a causality relationship running from crude oil consumption and crude oil price to GDP at 1% significance level. These results prove that crude oil is an important and a determinant variable for OECD economic growth.

Table 27-Results of the panel VECM for OECD

	Short-run			Long-run
Variables	ΔlnCO	ΔlnGDP	ΔlnPO	ECT
	F-statistics			t-statistics
ΔlnCO	-	33.66*	52.80*	10.65*
ΔlnGDP	31.66*	-	68.30*	5.13*

* denotes statistical significant at 1% level.

2.6.3.2.2. The results of the panel VECM tests for Latin America

The results of the panel VECM approach to estimate equations (2.4.2.2.3c) and (2.4.2.2.3d) for panels of Latin America regions (see table 28) specify that:

(i) In panel of Caribbean region countries, with respect to equation (2.4.2.2.3c), the F-statistics of Wald tests suggest that, in the short-run, GDP and crude oil price Granger cause crude oil consumption, both at 1% significance level, and in the long-run, the t-statistics of ECT shows that, there is a causality relationship running from GDP and crude oil price to crude oil consumption at 10% significance level.
Moreover, with respect to equation (2.4.2.2.3d), the F-statistics of Wald tests suggest that, in the short-run, crude oil consumption and crude oil price Granger cause GDP, both at 1% significance level, and in the long-run, the t-statistics of ECT represents that, crude oil consumption and crude oil price do not Granger cause GDP.

(ii) In panel of Central American countries, with respect to equation (2.4.2.2.3c), the F-statistics of Wald tests indicate that, in the short-run, GDP and crude oil price Granger cause crude oil consumption at 5% and 10% significance levels, respectively, and in the long-run, the t-statistics of ECT shows that, GDP and crude oil price do not Granger cause crude oil consumption.
Moreover, with respect to equation (2.4.2.2.3d), the F-statistics of Wald tests suggest that, in the short-run, crude oil consumption Granger causes GDP at 1% significance level, and crude oil price does not Granger cause GDP, and in the long-run, the t-statistics of ECT represents that, there is a causality relationship running from crude oil consumption and crude oil price to GDP at 1% level of significance.

And *(iii)* in panel of South American countries, with respect to equation (2.4.2.2.3c), the F-statistics of Wald tests show that, in the short-run, GDP and crude oil price Granger cause crude oil consumption at 1% and 10% significance levels, respectively, and in the long-run, the t-statistics of ECT shows that, there is a causality relationship running from GDP and crude oil price to crude oil consumption at 10% significance level.

Furthermore, with respect to equation (2.4.2.2.3d), the F-statistics of Wald tests suggest that, in the short-run, crude oil consumption and crude oil price Granger cause GDP at 1% and 5% significance levels, respectively, and in the long-run, the t-statistics of ECT shows that, crude oil consumption and crude oil price do not Granger cause GDP.

Table 28-Results of the panel VECM for Latin America

Variables	Short-run			Long-run
	ΔlnCO	ΔlnGDP	ΔlnPO	ECM
	F-statistics			t-statistics
Caribbean region				
ΔlnCO	-	38.45*	4.98*	1.78***
ΔlnGDP	45.87*	-	443.44*	-0.36
Central America				
ΔlnCO	-	3.09**	2.66***	-0.51
ΔlnGDP	18.31*	-	0.66	-2.80*
South America				
ΔlnCO	-	29.35*	2.56***	-1.69***
ΔlnGDP	11.48*	-	3.63**	-0.77

*, ** and *** denote statistical significance at 1%, 5% and 10% levels, respectively.

2.6.3.2.3. The results of the panel VECM tests for Sub-Saharan Africa

The results of the panel VECM approach to estimate equations (2.4.2.2.3c) and (2.4.2.2.3d) for panels of Sub-Saharan African countries (see table 29) indicate that:

(i) In panel of net crude oil importing countries, with respect to equation (2.4.2.2.3c), the F-statistics of Wald tests suggest that, in the short-run, GDP Granger causes crude oil consumption at 1% significance level, but crude oil price does not Granger cause crude oil consumption, and in the long-run, the t-statistics of ECT shows that, there is a causality relationship running from GDP and crude oil price to crude oil consumption at 1% significance level.
Moreover, with respect to equation (2.4.2.2.3d), the F-statistics of Wald tests suggest that, in the short-run, crude oil consumption and crude oil price Granger cause GDP at 1% and 10% significance levels, respectively, and in the long–run, the t-statistics of ECT shows that, there is a causality relationship running from crude oil consumption and crude oil price to GDP at 5% significance level.

(ii) In panel of net crude oil exporting countries, the F-statistics of Wald test represent that, with respect to equation (2.4.2.2.3c), in the short-run, GDP does not Granger cause crude oil consumption, but crude oil price Granger causes crude oil consumption at 10% significance level, and in the long-run, the t-statistics of ECT shows that, there is a causality relationship running from GDP and crude oil price to crude oil consumption at 1% significance level.

Moreover, with respect to equation (2.4.2.2.3d), the F-statistics of Wald tests suggest that, in the short-run, crude oil consumption Granger causes GDP at 10% significance level, but crude oil price does not Granger cause GDP, and in the long –run, the t-statistics of ECT shows that, there is a causality relationship running from crude oil consumption and crude oil price to GDP at 1% significance level.

Table 29-Results of the panel VECM for Sub-Saharan Africa

Variables	Short-run			Long-run
	ΔlnCO	ΔlnGDP	ΔlnPO	ECM
	F-statistics			t-statistics
Net crude oil importing				
ΔlnCO	-	4.90*	0.74	3.75*
ΔlnGDP	15.59*	-	2.35***	2.48**
Net crude oil exporting				
ΔlnCO	-	1.09	1.76***	14.28*
ΔlnGDP	2.55***	-	0.99	3.31*

*, ** and *** denote statistical significance at 1%, 5% and 10% levels of significance, respectively.
Values in parenthesis are coefficients.

2.6.3.2.4. The results of the panel VECM tests for MENA countries

The results of the panel VECM approach to estimate equations (2.4.2.2.3c) and (2.4.2.2.3d) for panel of MENA countries (see table 30) indicate that:

with respect to equation (2.4.2.2.3c), the F-statistics of Wald tests suggest that, in the short-run, there is a Granger causality relationship running from GDP to crude oil consumption at 1% significance level, but crude oil price does not Granger cause crude oil consumption, while in the long-run, the t-statistics of ECT indicates that there is a causality relationship running from GDP and crude oil price to crude oil consumption at 1% significance level.

Moreover, with respect to equation (2.4.2.2.3d), the F-statistics of Wald tests suggest that, in the short-run, crude oil consumption and crude oil price Granger cause GDP, both at 10% significance level, and the t-statistics of ECT shows that, in the long-run, there is a causality relationship running from crude oil consumption and crude oil price to GDP at 5% significance level.

Table 30-Results of the panel VECM for MENA countries

Variables	Short run			Long run
	ΔlnCO	ΔlnGDP	ΔlnPO	ECM
	F-statistics			t-statistics
ΔlnCO	-	40.32*	0.80	8.85*
ΔlnGDP	2.85***	-	2.97***	2.39**

*, ** and *** denote statistical significance at 1%, 5% and 10% levels, respectively.

2.6.3.2.5. The results of the panel VECM tests for Eastern and Southern Asia

The results of the panel VECM approach to estimate equations (2.4.2.2.3c) and (2.4.2.2.3d) for panel of Eastern and Southern Asia region (see table 31) show that:

with respect to equation (2.4.2.2.3c), the F-statistics of Wald tests state that, in the short-run, there are causality relationships running from GDP and crude oil price to crude oil consumption, both at 1% significance level, while in the long-run, the t-statistic of ECT indicates that, there is a causality relationship running from GDP and crude oil price to crude oil consumption at 1% significance level.

Moreover, with respect to equation (2.4.2.2.3d), the F-statistics of Wald tests reveal that, in the short-run, there are causality relationships running from crude oil consumption and crude oil price to GDP, both at 1% significance level; furthermore, the t-statistic of ECT reveals that, in the long-run, there is a causality relationship running from crude oil consumption and crude oil price to GDP at 1% significance level.

Table 31-Results of the Panel VECM for Southern and Eastern Asia

Variables	Short-run			Long-run
	ΔlnCO	ΔlnGDP	ΔlnPO	ECM
	F-statistics			t-statistics
ΔlnCO	-	55.12*	23.21*	4.72*
ΔlnGDP	49.53*	-	53.74*	7.15*

* denotes statistical significance at 1% level.

2.7. Discussion the results

2.7.1. Discussion the results of Portugal

The VECM and the Toda-Yamamoto causality tests suggest the existence of a bidirectional causality relationship between crude oil consumption and economic growth in Portugal, the results that support the feedback hypothesis. This hypothesis asserts that energy conservation policies and reduction of energy consumption adversely impact on economic growth; however, it is a complementary effect and reduction of economic growth adversely impacts on energy consumption as well.

The first conclusion is that, in Portugal economic growth is a useful variable to explain changes in future crude oil consumption, and the second conclusion is that, it is not possible to reduce crude oil consumption without adverse effect on economic growth of Portugal.
Therefore, policymakers in Portugal should take in account that implementing crude oil conservation and friendly environmental policies in order to reduce crude oil consumption affects negatively the Portuguese economic growth. In this case, the conservation policies need to reduce the amount of oil that is wasted with allocation of the appropriate policies.

The Portuguese' economy is highly dependent on crude oil. For instance, during 2009 share of fossil fuels (crude oil, natural gas and coal) usages was 78 percent out of the total energy consumption in Portugal. Among fossil fuels, share of crude oil consumption was 64.8 percent, share of natural gas consumption was 20 percent and share of coal consumption was 15.2 percent out of the total fossil fuels consumption. Consequently, the statistics indicate that, share of crude oil consumption was 50 percent out of the total energy consumption in Portugal[26]. On the other hand, Portugal being a net oil importer and has to pay higher oil prices than oil producer countries; hence, it has to pay more attention to the issue of crude oil conservation policies.
Consequently, the first suggestion is to pay more attention to the issue of energy efficiency in order to reduce the wasting of oil in households, transportation, industry and other sectors. Over the period 1990-2009, energy efficiency decreased around 4% in Portugal; the main reason of this reduction came from the industrial sector characterized by lower energy efficiency. For the same period the overall energy efficiency of industrial sector reduced 7%, increased 1% in households sector and reduced 7% in transportation sector.
Although the energy efficiency program, which was approved on 2008 by ministries council of Portugal, includes wide ranges of programs and covers all sectors, it seems essential for Portugal to achieve the targets set under 2006 approval of the European parliament on energy efficiency. With inclusive implementing of approved energy efficiency policies, the Portuguese economy will be able to reduce energy usage and particularly crude oil consumption with the minimum negative effects on economic growth.
The second policy suggestion is that, the industrial sector has to pay more attention to the issue of industries infrastructure and technology improvements and consequently to reduction of environmental pollution with replacement of old machineries with modern technologies.
And the last policy suggestion is to apply the mixture of taxes and subsidies policies as suggested by Asufa-Adjaye (2000), in order to prevent negative effects on economic growth; in this context, one of the most effective ways to reduce environmental pollution is to increase the cost of pollution generating energies including oil through increasing their taxes; however, in Portugal reduction of

[26] All data are obtained from the BP database.

crude oil consumption negatively affects on economic growth; as a solution, policymakers can in the same time allocate tax for oil and subsidize clean energy alternatives to oil such as hydroelectricity, wind energy, photovoltaic, geothermal.

2.7.2. Discussion the results of OECD countries

The results indicate that, there is a bidirectional causality relationship between crude oil consumption and GDP both in the short and in the long-run, which supports the feedback hypothesis based on the crude oil consumption-growth nexus. On the other hand, real crude oil price impacts on crude oil consumption directly and indirectly through GDP; and it impacts on GDP directly and also indirectly through crude oil consumption.

The first conclusion is that, among OECD countries, economic growth is a useful variable to analyze future changes in crude oil consumption among OECD countries. The second conclusion is that, policymakers should take into account that, crude oil conservation policies that lead to a reduction of crude oil consumption especially through increase of crude oil costs, like the implementation of higher taxes, have negative impacts on OECD countries' economic growth.

The issue of crude oil conservation policies must be considered seriously among OECD countries. This is important for OECD; as most of them are high oil consuming economies and net oil importers (if we exclude Norway and Mexico that are net oil exporters). Therefore, they have to pay higher crude oil prices than oil producing countries; consequently, they have to pay more attention to the issue of oil conservation policies.

During recent years renewable energy sources have witnessed a very rapid increase and have become the fastest growing source of world energy with a consumption increase of 3% per year among OECD countries (International Energy Outlook, 2009); whilst simultaneously, fossil fuels efficiency policies have attracted some attentions. Subsequently, during the last thirty years OECD net oil imports dropped by 14% while the amount of crude oil that OECD uses to produce one constant US$ of GDP halved after 1973 (OECD Economic Outlook, 2004). For instance, in 2005 the Swedish government established a comprehensive oil import strategy to reduce the country's oil dependency through more efficient fuel use, to reduce oil dependence of the transport sector and of the buildings' heating; it also improved the national IT infrastructure in order to enable distance work and travel-free meetings; with the intention of reaching an oil-free economy by 2020. Oil imports by the US have increased for decades except in early 1980 and over the last years, both periods being characterized by high crude oil prices, economic recession, and better energy policies. Another example is that of Japan where, in the beginning of the 1980s the Japanese manufactures emerged as world leaders in the development of fuel saving technologies for the transport sector, currently Japan is one of the most efficient energy users in the world under very strict energy conservation policies. Further example of an OECD country that followed a strict pattern of crude oil consumption reduction is South Korea, a country that had previously experienced a yearly 10% increase in crude oil consumption over 1980 to 2000. However in recent years their crude oil consumption grows more slowly (by 1% a year) as a result of shifting its economy from heavy industries toward the information and service sectors.

Despite the above-mentioned developments, this enormous geographic region still remains dependent on oil imports to accomplish its production needs. Therefore, study OECD economic growth sensitivity to crude oil consumption following global tendency towards oil conservation policies and substituting alternative energy sources rather than crude oil is necessary to propose appropriate oil conservation and environmental policies. Some policies that can decrease crude oil consumption without significant impact on production and growth, such as more efficient policies, energy saving projects, increase renewable energy usage, increase oil taxes and allocate subsidies to renewal energy sources, and shifting the countries' economies from heavy industries to light ones such as information and services can be applied.

In order to compare our bidirectional result with the other studies that examined OECD energy consumption-growth nexus but focusing on different sources of energies, such as total energy, renewable energy, electricity and coal consumptions within a Granger causality method, our result is in line with Lee et al. (2008) that examined total energy-growth nexus among OECD countries and found a bidirectional causality between them; however, Constantini and Martini (2010) revealed a unidirectional causality running from GDP to energy consumption among OECD countries; moreover, our result is in line with Apergis and Payne (2010a) that studied renewable energy-growth nexus among OECD countries and revealed a bidirectional causality among the variables; Narayan and Prasad (2008) assessed electricity consumption-growth nexus among OECD countries and found that electricity consumption Granger causes GDP in six OECD countries and are independent in the rest of twenty two countries; and Jinke et al. (2008) examined coal consumption-growth nexus in OECD countries and found evidence of a unidirectional causality running from GDP to coal consumption in Japan but did not identify any relationship among them in the rest of OECD countries.

In order to compare our results with energy consumption-GDP nexus in non-OECD countries, our results are in line with Al-mulali (2011) that revealed a bidirectional causality among oil consumption, CO_2 emission, and economic growth in a panel of MENA countries; they are in line with Pao and Tsai (2011a) that found a strong bidirectional Granger causality among energy and GDP in a panel of Brazil, Russian Federation, India and China (BRIC); and they are also in line with Al-mulali (2012) that showed a bidirectional causality between energy and CO_2 emission with economic growth and financial development in Sub-Saharan African countries.

2.7.3. Discussion the results of Latin American regions

The results show that, in panel of Caribbean region, in the short-run there is a bidirectional causality relationship between crude oil consumption and economic growth that supports the

feedback hypothesis, and in the long-run there is a unidirectional causality relationship running from economic growth to crude oil consumption that supports the conservation hypothesis.
In panel of Central America, in the short-run there is a bidirectional causality relationship between crude oil consumption and economic growth that supports the feedback hypothesis; and in the long-run there is a unidirectional causality relationship running from crude oil consumption to economic growth that supports the growth hypothesis.
And in panel of South America, in the short-run there is a bidirectional causality relationship between crude oil consumption and economic growth that supports the feedback hypothesis; and in the long-run there is a unidirectional causality relationship running from economic growth to crude oil consumption that supports the conservation hypothesis.

The first conclusion is that, in Caribbean region and South America, economic growth is a useful variable to analyze future changes in crude oil consumption; however, in Central America this variable cannot be used as predictor of crude oil consumption.

Moreover, the second conclusion is that, reducing crude oil consumption can be an appropriate instrument in Caribbean region and South America and policymakers can pursue oil conservation policies without concerning about negative effects on economic growth; however, in Central America policymakers should implement crude oil conservation policies more carefully, they need to reduce the amount of crude oil consumption through allocation of appropriate energy efficiency policies in order to minimize the negative impacts on their economic growth.

In order to compare our results with those that examined energy consumption-growth nexus in Latin America within a panel framework, these results are consistent with Apergis and Payne (2009) that found evidence of a growth hypothesis in panel of Central American countries, but is in contrast with Apergis and Payne (2010c) that found evidence of a growth hypothesis in South America. These contradictory results can be due to the application of different explanatory variables, different set of countries, different time horizons, and different sources of energies, as other studies considered total energy consumption while in this study we focused only on crude oil consumption. Moreover, our results are different from that of Al-mulali (2011) for MENA and Al-mulali and Sab (2012) for Sub-Saharan Africa.

2.7.4. Discussion the results of Sub-Saharan African regions

The results suggest that, in panel of net crude oil importing African countries there is a bidirectional causality relationship between crude oil consumption and GDP both in the short and in the long-run that supports the feedback hypothesis. On the other hand, in panel of net crude oil exporting countries, in the short-run there is a unidirectional causality relationship running from crude oil consumption to GDP, the results that support the growth hypothesis, and there is a bidirectional causality relationship between them in the long-run that supports the feedback hypothesis.

The first conclusion for these countries is that, among net crude oil importing and net crude oil exporting Sub-Saharan African countries, economic growth is a useful variable to anazlye and predict futute changes in crude oil consumption.

And the second conclusion is that, reduction of crude oil consumption has adverse impacts on GDP of both groups of countries, either in the short-run and in the long-run. Nevertheless, in the long-run for both regions it is a complementary effect and reduction of GDP adversely impacts on crude oil consumption as well.

In general, net crude oil importing developing countries are more vulnerable to oil shocks than developed countries. This is mainly because of the less efficient pattern of energy consumption of these countries. As International Energy Agency (IEA) stated, oil importing developing countries use more than twice as much oil to produce one unit of output than OECD countries use. The second reason is that they are more dependent on imported oil than oil producing countries (African Development Bank and African Union, 2009). As Sub-Saharan Africa includes 38 net crude oil importing countries and 10 net crude oil exporting countries with 70% and 30% of Sub-Saharan African population, respectively; thus, higher crude oil prices are a challenge for developing net crude oil importing African countries that includes the majority of the region's population and are an opportunity for net crude oil exporting African countries. Consequently, implementing appropriate oil conservation policies is essential for oil vulnerable Sub-Saharan African countries.

Policymakers in Sub-Saharan Africa should consider that, reduction of crude oil consumption have negative impacts on their economic growth; this means that reduction of crude oil consumption without increasing energy productivity, damages the process of development in Sub-Saharan Africa. In this situation, the best solution in order to reduce crude oil consumption and decrease oil dependency is pay more attention to the crude oil efficiency policies in order to reduce the quantity of oil that is wasting by households, transportation and industrial sectors.

In order to compare our results with those encountered by other studies that investigated energy consumption-economic growth nexus in a panel of Sub-Saharan African countries and other regions, our results are in line with Al-mulali and Sab (2012) and Eggoh et al. (2011) that both found a bidirectional causality relationships among energy consumption and GDP in Sub-Saharan African countries; and our results also confirm the results by Kedebe et al. (2010) who showed that GDP positively Granger causes energy consumption in Africa. And comparing our results with those that investigated energy consumption-economic growth nexus among oil exporting countries, our results are in line with Al-mulali (2011) that revealed a bidirectional causality relationship between oil consumption and GDP among MENA countries; however, they are in contrast with the results of

Mehrara (2007b) that found a unidirectional causality relationship running from GDP to energy consumption in oil exporting countries. Furthermore, comparing our results with studied that examined energy consumption-growth nexus among OECD countries, they are in line with Apergis and Payne (2010a) who found evidence of a bidirectional causality relationship among renewable energy consumption and GDP among OECD countries.

2.7.5. Discussion the results of MENA countries

The results show that, in panel of MENA countries, both in the short-run and in the long-run, there are bidirectional causality relationships between crude oil consumption and GDP, which supports the feedback hypothesis.

The fist conclusion is that, economic growth is a useful variable to examine and predict future changes in crude oil consumption among MENA countries.

Furthermore, the second conclusion is that, policymakers should take into account that those oil conservation policies that lead to the reduction of crude oil consumption negatively impact on economic growth of MENA countries in the short-run and in the long-run.

As the exporting of crude oil is the main funding source of most of MENA countries, most of them implement the energy subsidy policies for their domestic consumption that distort the correct pattern of consumption; therefore, reduction of their domestic crude oil consumption by correcting the consumption behavior can lead to increase exports and consequently their income. In this condition, policymakers can perform some policies that decrease crude oil consumption without significant impact on the quantity of production and growth, such as oil efficiency policies, or substitute oil by renewable energies.

In order to compare our results with similar studies that examined energy consumption-growth nexus in MENA countries with applying panel Granger causality framework, our results are in line with Narayan and Smyth (2009) that found a bidirectional causality relationship among electricity consumption and GDP in the Middle East; also are in line with Sadorsky (2011) that showed a bidirectional causality relationship between energy consumption and GDP in the Middle East; and are in line with Al-mulali (2011) which found a bidirectional causality relationship between crude oil consumption and GDP in MENA region; however, it is in contrast with the results of Mehrara (2007b) who found evidences of a unidirectional causality relationship running from GDP to energy consumption among oil exporting countries.

2.7.6. Discussion the results of Eastern and Southern Asian region

The results of this study show that, in panel of Eastern and Southern Asia region, there is a bidirectional causality relationship between crude oil consumption and GDP, both in the short-run and in the long-run, which supports the feedback hypothesis.

The first conclusion is that, economic growth is a useful variable to examine and predict future changes in crude oil consumption in this region.

And the second conclusion is that, those crude oil conservation policies, which lead to reduction of crude oil consumption, have negative impacts on economic growth of Eastern and Southern Asian emerging countries.
However, crude oil conservation policies are essential in order to reduce oil dependency in emerging Asian countries, which are experiencing high economic growth levels. Although the results indicate that, reduction of crude oil consumption have negative impact on economic growth of Eastern and Southern Asian emerging countries, but still there are some policies that decrease crude oil consumption without significant impact on the quantity of production and growth, such as crude oil efficiency policies, shift the economy from heavy energy consumption industries toward information and services sectors, and substitute renewable energies instead of crude oil. As after the three oil crises, many of Eastern Asian developing countries made changes in the composition of fossil fuels that they use. For instance, Indonesia and Malaysia increased natural gas consumption instead of crude oil, and South Korea, Taiwan, Hong Kong, China, and Vietnam increased coal consumption instead of crude oil.

In order to compare our results with similar studies, that survived energy consumption-growth nexus in Asian countries with applying a panel Granger causality framework, our results are in line with Chen et al. (2007) and Narayan et al. (2010) that found a bidirectional causality relationship among electricity consumption and GDP in Asia; however, Lee and Chang (2008) found evidences of a unidirectional causality relationship running from energy consumption to GDP and Joyeux and Ripple (2007) showed independency between household electricity consumption and GDP among Asian countries.

2.8. Conclusion

In this chapter, we investigated the causality relationship among economic growth, crude oil consumption and crude oil price among different regions in the world under six separate studies. in In the first study we examine a panel of OECD countries; the second study is a panel of Caribbean region, a panel of Central American countries and a panel of South American countries; the third study examines panels of net crude oil importing and net crude oil exporting Sub-Saharan African countries; the fourth study examines a panel of MENA countries; the fifth study examines a panel of Eastern nd Southern Asian emerging countries; and the sixth and last study is a single country of Portugal.

The results from chapter two can be categorized in three groups:

First, among OECD countries, net crude oil importing Sub-Saharan African countries, MENA countries, Eastern and Southern Asian countries and individual country of Portugal, both in the short-run and in the long-run, there are bidirectional causality relationships between crude oil consumption and economic growth, which supports the feedback hypothesis.
Second, Central America region in the short-run supports the feedback hypothesis; however, in the long-run there is a unidirectional causality relationship running from crude oil consumption to economic growth that supports the growth hypothesis; and among net crude oil exporting Sub-Saharan African countries, in the short-run there is a unidirectional causality relationship running from crude oil consumption to economic growth, result that supports the growth hypothesis, and in the long-run they support the feedback hypothesis.
Third, the results of Caribbean and South America regions in the short-run support the feedback hypothesis while in the long-run support the conservation hypothesis.

The first policy implication is related to the impact of economic growth on crude oil consumption in each region. If in a region in the long-run, the feedback or the conservation hypothesis are supported, this means that economic growth Granger causes crude oil consumption; therefore, among these regions economic growth is a useful variable to examine and forecast future changes in crude oil consumption. According to the results of this study, among the all regions under study except Central America, economic growth Granger causes crude oil consumption; therefore, in a market-linked crude oil pricing mechanism, we can use the global economic growth as an explanatory variable to explain and forecast future international crude oil prices.

The second policy implication is related to the impact of crude oil consumption on economic growth in each region. Among the regions that in the long-run, the feedback or the growth hypotheses are supported, policymakers should implement oil conservation policies more carefully and consider that reduction of crude oil consumption has negative impacts on their economic growth. Nevertheless, still there are some policies that decrease crude oil consumption without significant impacts on the quantity of production and growth, such as appropriate crude oil efficiency policies, shift the economy from heavy energy consumption industries toward information and services sectors, and substitute renewable energies instead of crude oil.
Moreover, among the regions that in the long-run the conservation hypothesis is supported, policymakers can pursue crude oil conservation policies without concerning about their negative effects on economic growth.

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Chapter 3

3. Crude oil production behaviors by OPEC member producers and Non-OPEC producers

3.1. General introduction

In this chapter the aim is to analyze production behaviors of crude oil producer countries. However, world crude oil producers are distinguished to two main groups of OPEC and non-OPEC producers. Thus, this chapter contains two separate studies, the first one investigates the determinant factors behind crude oil production by OPEC member countries (section 3.2), and the second one investigates the determinant factors behind crude oil production by non-OPEC producers (section 3.3).

3.2. Crude oil production behaviors of OPEC member countries

3.2.1. Introduction

OPEC member countries contain more than 80% of the world crude oil proven reserves; mostly are located in the Middle East with a share of 65% of OPEC total crude oil proven reserves. Moreover, five countries with the largest crude oil proven reserves are OPEC members: Saudi Arabia contains 19.8%, Venezuela 12.9%, Iran 10.3%, Iraq 8.6% and Kuwait 7.6%, in 2009 (OPEC annual report, 2010). On the other side, share of OPEC taking in account the world crude oil production is 45% and two of five countries that produced more crude oil in the world are among OPEC members: Saudi Arabia and Iran. The Russian Federation (a non-OPEC producer) with 12.9%, Saudi Arabia with 12%, the US (a non-OPEC producer) with 8.5%, Iran with 5.3% and China (a non-OPEC producer) with 4.9% shares were the largest world crude oil producers, in 2009 (BP statistics yearbook, 2012).These significant shares in proven reserves and production levels establish an enormous power for OPEC to influence the global crude oil prices.

There are various studies that explained OPEC behavior based on different models. Nevertheless, the Griffin (1985) study is the first one that systemically investigates OPEC behavior among the existing models. However, the existing studies focused mainly on determining the behavior of OPEC as an organization and they are less concentrated on identifying the determinant factors behind production of individual OPEC member countries. Therefore, in previous studies the authors built univariate models that mostly ignored the impact of domestic situations and exogenous variables on crude oil production, such as economic, political and natural events that are specified for each country.

In this study, we propose a multivariate model, which includes almost all significant quantitative and qualitative factors that may impact on crude oil production of OPEC member producers.
Our motivation to perform an inclusive investigation to recognize the determinant factors of crude oil production by OPEC member producers is that, in a market-linked mechanism situation for crude oil price formation, the amount of crude oil production is an explanatory factor for price; therefore, determining the variables that impact on production is essential in order to enable us to increase the forecasting accuracy of price.
To achieve this goal, we develop a new crude oil production model for OPEC member producers, by extending one of the initial Griffin (1985) models and the one proposed by Kaufmann et al. (2008). The crude oil market history shows that it is strongly correlated with exogenous or qualitative factors, in addition to quantitative factors. Therefore, we consider every important exogenous event that occurred during the period under study, such as wars, a presidential election that changes the political trajectory of an oil producer country, a world economic crisis, discovering a new huge oil reserve, and etc. as dummy variables of the models. Hence, we propose a model that significantly reduces the problem of omitted variable bias and that simultaneously increases the possibility of existing the cointegration relationships among the variables for each single country.

We apply quarterly data for eight OPEC member countries, including Algeria, Indonesia, Iran, Nigeria, Saudi Arabia and Venezuela from the period 1983 to 2007, Libya from the period 1990 to 2007 and Qatar from the period 1994 to 2007. Although OPEC contains more members, we exclude some countries that joined OPEC very recently like Angola that joined in 2007, Ecuador that joined in 1973, left it in 1992 and again joined it in 2007; moreover, we exclude Iraq as there is a lack of data availability due to the first Persian Gulf War and the 2003 US invasion, we keep out Kuwait as there is a lack of data availability due to the second Persian Gulf War, and we exclude the United Arab Emirates as we could not find data for all the variables during the whole period under study.

In order to perform an empirical examination, we employ two unit root tests with allowing for one structural break in the time series, the Zivot and Andrews (1992) and the Perron (1997) unit root tests.Then we perform the Autoregressive Distributed Lag (ARDL) bounds testing approach for cointegration proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) in order to estimate the cointegration relationships among the variables; furthermore, the long-run elasticity and the Granger causality among the variables are examined within an ARDL framework.

The rest of this study has the following structure: section 3.2.2 develops a literature review; section 3.2.3 provides structure of the model; section 3.2.4 proposes the methodology; section 3.2.5 describes data; section 3.2.6 provides the empirical results and section 3.2.7 presents the conclusion.

3.2.2. Literature review

There are various studies that explain crude oil production behaviours of OPEC member producers and non-OPEC producers based on different theories, such as the target revenue theory developed by ezzati (1976), Cremer and Isfahani (1980), Teece (1982) and Adelman (1982); changes in the ownership or the property right theory developed by Johany (1979); the competitive model theory explained by MacAvoy (1982) and Verleger (1987); the target price theory explained by Hammoudeh and Madan (1995), Hammoudeh (1996) and Tang and Hammoudeh (2002); the target capacity theory developed by Suranovic (1993); and the political models theory proposed by Moran (1981).

However, the Griffin (1985) study is the first one that systemically investigates OPEC behavior, including the cartel power, the competitive, the target revenue, and the property right models, using data from 1971 to 1983. In the cartel model, Griffin specifies the individual crude oil production as a function of crude oil price and production by the rest of OPEC members. The results reject the constant market sharing model, cannot reject the market sharing model and strongly confirm the partial market sharing model. Moreover, in the competitive model, the author specifies the individual production as a function of crude oil price and found evidences to confirm the competitive behavior of OPEC producers. On the other hand, in the target revenue model, the individual crude oil production is a functions of crude oil price and individual investment needs, the results reject the strict version of target revenue model; however, there are evidences that confirm the partial version of target revenue behavior. And in property rights model, the individual crude oil production is a function of the percentage that government controlled the production that likewise cannot be rejected.

In this study Griffin (1985) examines non-OPEC producers' behavior as well, and found evidences that confirm the complete rejection of the constant market sharing behavior; however, there are evidences to support the market sharing behavior and there are more evidences to confirm the partial market sharing behavior. On the other hand, the competitive model is confirmed for most of non-OPEC producer nations.

The conclusion of Griffin (1985) study is that, among OPEC member producers, the partial market sharing cartel model dominates the competitive model; nevertheless, among non-OPEC producers the competitive model dominates the market sharing cartel model.

Salehi-Isfahani (1987) modifies the target revenue model proposed by Griffin (1985), using Griffin's data and model; however, the author replaces the current crude oil price by lagged crude oil prices and assumes the individual OPEC member's production as a function of lagged crude oil price and investment needs. The results provide more evidences to support the target revenue model than Griffin.

Jones (1990) repeats the Griffin's (1985) study for the period of falling prices from 1983 to 1988 and achieves the same results of Griffin.

Dahl and Yucel (1991) extend the Griffin's (1985) study via testing for dynamic decision making; moreover, the cost information is incorporated into the analysis. The authors perform the cointegration test with data from the period 1971-1987. They test several hypotheses in order to explain OPEC and non-OPEC behaviors, including the dynamic optimization, the target revenue, the cartel, the competitive, and the swing producer hypotheses. The authors state that, they do not find evidences for the dynamic optimization theory; however, there are some evidences to support that the revenue targeting may influence production in some OPEC countries and a few non-OPEC countries; moreover, the competitive behavior between OPEC members is rejected; and the strict cartel behavior or the swing production among OPEC countries is examined through the long-run cointegration test and is rejected. As the conclusion, their results suggest the loose of coordinating behavior between OPEC members.

Gulen (1996) repeats Dahl and Yucel (1991) study, to examine the relationship between OPEC member's production and the whole OPEC production; they apply the cointegration and the causality tests in order to determine whether OPEC is or is not a cartel. The author uses monthly data from 1965 to 1993 for all 13 OPEC member countries. In comparison with Dahl and Yucel (1991), the second authors use quarterly data for shorter periods and exclude some countries. The result shows evidence in favor of the coordination behavior among members; moreover, during this period the causality relationship from OPEC production to crude oil price is statistically significant.

Alhaji and Huettner (2000) extend the Griffin's target revenue model, apply four econometric models, including one static and three dynamic models, in order to investigate the target revenue behavior for OPEC members, which do not coordinate with Saudi Arabia. In their static model, individual production is supposed to be a function of crude oil price and investment need; and in their dynamic models, the first one supposes the current individual production as a function of crude oil price, investment needs and lagged production, the second one supposes the current individual production as a function of lagged crude oil price, lagged investment needs and lagged production and the third one supposes that the current individual production is a function of lagged crude oil price and lagged investment needs. Their results do not support the target revenue model for countries with free market economies; however, they support the target revenue model for countries with centrally planned and isolated economies.

Spilimbergo (2001) investigates a modified version of the Griffin's (1985) competitive model and tests the cartel and the competitive behaviors hypotheses based on dynamic models instead of static ones, among OPEC producers using data from 1983 to 1991. In this study, the author applies the market sharing cartel model proposed by Griffin (1995); however, he modifies the Griffins' study through modeling the behavior of a competitive producer with using Euler equations. The results show that there are evidences to confirm the competitive behavior for some OPEC members, to reject the collusive behavior or the market sharing cartel model, and still to confirm the partial market sharing cartel model, the same results as Griffin (1995) and Jones (1990). Ramcharan (2001) estimates a modified version of the Griffin (1985) target revenue model, using data from 1973 to 2000, through modeling the individual production as a function of crude oil price and budget surplus (instead of investment needs) of the countries; the results do not support the competitive and the strict version of target revenue models; however, there are evidences to support the partial version of target revenue behavior, which is in line with Griffin (1985). Moreover, Ramcharan (2002) expands the competitive model of Griffin (1985) by adding a trend factor to the original version of the competitive model as a proxy for measuring any supply shift, using data for the period from 1973 to 1997; their results do not support the competitive market hypothesis for OPEC members; however, supports it for non-OPEC producers. Ramcharan (2002) states that these results lend partial support to the target revenue hypothesis for OPEC countries. Kaufman et al. (2008) expand the market sharing cartel model of Griffin (1985) in order to understand the determinants of OPEC nations' production through adding two contributions to the Griffins' model. The first contribution includes the OPEC quotas variable; and the second one includes a vector of variables that affect production among individual OPEC producers. Kaufman et al. (2008) state that their model solves the problem of the omitted variable biased. Their results indicate that, quota is an important determinant factor for OPEC production; therefore, OPEC is an organization that impacts on production and price for crude oil; secondly, price has a positive impact on production, which shows that OPEC producers show a competitive behavior; and their final result proves that all nations apart from Saudi Arabia show a form of production sharing behavior.

In another study Dées et al. (2007) introduce two models for OPEC production, the first one is based on a cooperative behavior and the second one is based on a competitive behavior of OPEC producers. In the cooperative model, OPEC production is a function of the world crude oil demand, the level of OECD stocks, natural gas liquids, non-OPEC production, and the processing gains. And in the competitive model, OPEC production is a function of operable capacity, which implies that OPEC competes for market share and increases production to a rate that is constant with operable capacity.

And finally Brémond et al. (2012) use Griffin (1995) cartel model and examine OPEC and non-OPEC production behavior in order to determine if OPEC acts as a cartel, apply the cointegration and the causality tests both within the time series and the panel frameworks, use monthly data from 1973 to 2009. Their results indicate that OPEC behavior changes over time and that OPEC is a price taker on the majority of the sub periods. At the end they divide the OPEC members into two groups, savers and spenders, and conclude that OPEC acts as a cartel.

The literature reveals that there is not a general consensus regarding the production behavior of OPEC member producers and there are different suggestions about the determinant factors of crude oil production.

3.2.3. Structure of the model

In this study we extend the Griffin (1985) and the Kaufmann et al. (2008) models for crude oil production by OPEC member producers. Griffin (1985) specifies a simple cartel model for OPEC crude oil production as below:

$$Q_i = \propto_i^* Q^o \qquad i = 1, \dots, n \tag{3.2.3a}$$

where i represents the individual country (i=1, 2,…, 8), Q_i is each country's production that is a function ($\propto_i^*$) of total OPEC production (Q^O).

In order to avoid simultaneity between Q_i and Q^o, Griffin (1985) modifies equation (3.2.3a) as below:

$$Q_i = \propto_i^{'} Q^{oo} \qquad i=1,..,n \tag{3.2.3b}$$

where $\propto_i^{'} = \propto_i^* / (1-\propto_i^*)$ and $Q^{oo}=Q^o-Q_i$. He allows share to vary as a function of price; therefore, the market share coefficient ($\propto_i^{'}$) is supposed to be a function of price; then, we can write:

$$Q_i = \propto_i^{'} P_t^{\gamma i} Q_{it}^{oo} \qquad i = 1, \dots, n: T = 1, \dots, t \tag{3.2.3c}$$

and then he takes natural logarithms from both sides of equation (3.2.3c) as shown below:

$$lnQ_{it} = \propto_i + \gamma_i lnP_t + \beta_i lnQ_{it}^{oo} + \varepsilon_{it} \tag{3.2.3d}$$

where ε_{it} is the standard error term. Griffin (1985) indicates that if the value of γ_i is positive, then there is evidence of a competitive behavior; and if this value is negative there is an evidence in favor of a non-competitive behavior. Moreover, the author states that if (β_i=1, γ_i=0) then there is evidence of a constant market sharing behavior; if (β_i=1, $\gamma_i \neq 0$) there is evidence of a market sharing behavior and if ($\beta_i > 0$, $\gamma_i \neq 0$) there is evidence of a partial market sharing behavior.

Kaufmann et al. (2008) make some modifications to equation (3.2.3d), they include the official OPEC quota and a vector of variables that are specific to each individual country, such as a new installed capacity, proven reserves and etc. Their final model is shown by equation (3.2.3e):

$$lnQ_{it} = w_i + \beta_2 lnP_t + \beta_3 lnQ_{it}^{oo} + \beta_4 lnQuota_{it} + \theta lnZ_{it} + \mu_{it} \tag{3.2.3e}$$

where μ_{it} is the error term. As stated by Kaufmann et al. (2008), including quota shows the degree of cooperation of each OPEC member country with the OPEC organization.

Additionally, Griffin (1985) develops a target revenue model and states that it is a non-collusive explanation for oil pricing (Ezzati, 1976; Cremer-Isfahani, 1980; and Teece, 1984), since domestic investment needs determine oil revenue needs. Griffin (1985) specifies his target revenue model as below:

$$I_{it}=P_t Q_{it} \tag{3.2.3f}$$

where I_{it} represents the investment needs for the country *i* at time t. Griffin (1985) assumes that crude oil prices and investment needs are exogenous to crude oil production and takes logarithms from both sides:

$$lnQ_{it}=\propto_i+\gamma_i lnP_t+\delta_i lnI_{it}+\varepsilon_{it} \qquad i=1,\dots,n;\ T=1,\dots,t \tag{3.2.3g}$$

where $\boldsymbol{\varepsilon_{it}}$ is the error term. Griffin (1985) states that, for a given crude oil price, if investment needs increase, then production increases proportionally (δ_i=1); and for a given investment needs, if crude oil price increases, then production decreases proportionally ($\gamma_i=-1$), this represents the strict version of the target revenue theory. If with increasing investment needs, production increases but not proportionally ($\delta_i>0$); and with increasing of crude oil price, OPEC members produce beyond their investment needs ($\gamma_i<0$), then there is evidence in favor of the partial version of target revenue model.

In our research, we develop an original model to examine the determinant factors that impact on crude oil production of individual OPEC member countries. To achieve this goal, we extend Kaufmann et al. (2008) model, through including investment needs as proposed by Griffin (1985) in his target revenue model, and we obtain the following equation:

$$lnQ_{it}=w_i+\beta_2 lnPO_t+\beta_3 lnQ_{it}^{oo}+\beta_4 lnQuota_{it}+\beta_5 lnI_{it}+\theta D_{it}+\delta_{it} \tag{3.2.3h}$$

where PO_t represents crude oil price, D_{it} represents specific dummy variables for each OPEC member country and δ_{it} is the error term. However, the goal of this study is to determine the quantitative and qualitative factors that impact on crude oil production of OPEC member countries. In this model, in addition to considering the most important quantitative factors that may affect crude oil production, we consider exogenous events as well. As it is shown by the oil market history, crude oil market is strongly correlated with the qualitative factors, reason why, we include important exogenous events that may impact on crude oil production of OPEC member countries, including political, economic and natural events, such as wars, a new presidential election that changes the political trajectory of an oil producer country, a world economic crisis, discovering a new huge oil reserve and others, as dummy variables of the model. Hence, in comparison to the existing models for crude oil production, our model significantly reduces the problem of omitted variable bias and increases the possibility of existing the cointegration relationships among the variables.

3.2.4. Methodology

3.2.4.1. The unit root tests

The Autoregressive Distributed Lag (ARDL) bounds testing approach for cointegration is valid even if the variables' orders of integration are not the same; however, they should not be greater than one. The critical values provided by Pesaran et al. (2001) are calculated according to the $I(0)$ and $I(1)$ orders of integration. This means that their orders of integration can be 0 or 1, but it cannot be used if for example the order of integration of one of the series is 2, or if it is $I(2)$. Therefore, before applying the ARDL approach, it is necessary to perform the unit root tests in order to specify the orders of integration of the series. The common problem with the usual unit root tests such as the ADF (Augmented Dickey -Fuller) or the P-P (Phillips-Perron) is that, they do not allow for structural breaks. Perron (1989) shows that if a break occurs as a result of an exogenous shock, then the power to reject the unit root decreases when the stationary alternative is true and the structural break is ignored. In order to solve this problem, we employ two unit root tests that admit one structural break in the series, the Zivot and Andrews (1992) and the Perron (1997) tests. Both tests proceed with three models to test for a unit root. Model A, which allows for one break in the level of the series; model B, which allows for one break in the slope of the trend; and model C, which allows for one break both in the level and in the slope of the trend of the series.

3.2.4.2. The ARDL cointegration test

If the variables orders of integration are a combination of 0 and 1 (they are $I(0)$ and $I(1)$), then the Autoregressive Distributed Lag (ARDL) bounds testing approach for cointegration proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) is the only appropriate approach to examine the long-run relationship among the series. This approach has various advantages to the approaches such as Engle and Granger (1987), Johansen (1988) and Johansen and Juselius (1990). For instance, it provides better small sample properties than the other approaches (Narayan, 2005), it is an efficient estimator even if some variables are endogenous, it allows the variables to have different optimal lags, it uses a single reduced form equation, and there is no need that all the variables have the same order of integration (Acaravci and Ozturk, 2010); moreover, both the short-run and the long-run relationships can be simultaneously estimated (Wolde-Rufael, 2010).

In the first step, an ARDL model uses the lagged values of the dependent variable, and the lagged and simultaneous values of the independent variables to examine the existence of long-run relationships among the variables. For this purpose, in this study the ARDL model estimates the following unrestricted error correction regression (equation 3.2.4.2):

$$\Delta lnQ_{it} = \alpha_{1iQ} + \sum_{m=1}^{n1} a_{1imQ}\Delta lnQ_{t-m} + \sum_{m=0}^{n2} b_{1imQ}\Delta ln\,PO_{t-m} + \sum_{m=0}^{n3} c_{1imQ}\,\Delta lnQ^{OO}_{t-m} + \sum_{m=0}^{n4} d_{1imQ}\,\Delta lnQuota_{t-m} + \sum_{m=0}^{n5} e_{1imQ}\,\Delta lnI_{t-m} + \partial_{1iQ}lnQ_{t-1} + \partial_{2iQ}lnPO_{t-1} + \partial_{3iQ}lnQ^{OO}_{t-1} + \partial_{4iQ}lnQuota_{t-1} + \partial_{5iQ}lnI_{t-1} + \varepsilon_{1it} \quad (3.2.4.2)$$

where $\boldsymbol{\varepsilon_{1it}}$ is the error term and Δ is the first difference operator, i=1,...,8 (the countries) and *m* is the lag length. The appropriate lag length selection is based on the Akaike Information Criterion (AIC), the Schwartz Bayesian Criterion (SBC) and the R-BAR squared Criterion. In order to perform bounds test to examine the existence of cointegration relationships among the variables, we apply a joint F-test for the lagged levels of the variables. The null hypothesis is based on non cointegration relationships as H_0=$\partial_{1iQ} = \partial_{2iQ} = \partial_{3iQ} = \partial_{4iQ}$=$\partial_{5iQ}$ =0, against the alternative hypothesis that H_1=$\partial_{1iQ} \neq \partial_{2iQ} \neq \partial_{3iQ} \neq \partial_{4iQ} \neq \partial_{5iQ} \neq 0$. Two sets of F critical values are provided by Pesaranand Shin (1999) and Pesaran et al. (2001). One set assumes that all the variables are *I*(0) and the other assumes that all are *I*(1). According to the Pesaran et al. (2001) bounds testing approach, if the F-statistic falls above the upper critical bounds value, the null of no cointegration is rejected, regardless of the series orders of integration (being 0 or 1). Alternatively, if the F-statistic falls below the lower critical bounds value, then the null hypothesis is not rejected, regardless of the orders of integration of the variables. However, if the F-statistics falls between the lower and upper bounds values, the result is inconclusive, unless we know whether the series are *I*(0) or *I*(1).

3.2.4.3. The VECM for the Granger causality test

Given the fact that the variables are cointegrated, we conclude that there are long-run relationships among the variables for each country, where crude oil production is the dependent variable. The existence of cointegrating relationships among the variables confirm that there are causality relationships among them at least in one direction, but it does not specify the direction of this causality (Engle and Granger, 1987). In the third step of our analysis, we perform the Granger causality test to examine whether the explanatory variables Granger cause crude oil production or not. To achieve this goal, we estimate a Vector Error Correction Model (VECM) within the ARDL framework. In this study, the Granger causality test will be done through equation (3.2.4.3):

$$\Delta lnQ_{it} = \alpha_{2iQ} + \sum_{m=1}^{n1} a_{2imQ}\Delta lnQ_{t-m} + \sum_{m=0}^{n2} b_{2imQ}\Delta ln\,PO_{t-m} + \sum_{m=0}^{n3} c_{2imQ}\,\Delta lnQ_{t-m}^{OO} + \sum_{m=0}^{n4} d_{2imQ}\,\Delta lnQuota_{t-m} + \sum_{m=0}^{n5} e_{2imQ}\,\Delta lnI_{t-m} + \emptyset_i ECT_{t-1} + \varepsilon_{2it} \quad (3.2.4.3)$$

where ECT_{t-1} is the error correction term and $\emptyset_i$ is the corresponding coefficient that indicates how quickly the variables converge to equilibrium; this coefficient should be statistically significant with negative sign.

3.2.4.3.1. The short-run Granger causality test

The short-run causality is determined by the statistical significance of the Chi-squared statistic through a Wald test, based on the null hypothesis $H_0 : b_{2imQ} = c_{2imQ} = d_{2imQ} = e_{2imQ} = 0$ and the alternative one as $H_1: b_{2imQ} \neq 0$, $H_1: c_{2imQ} \neq 0$, $H_1: d_{2imQ} \neq 0$ and $H_1: e_{2imQ} \neq 0$ for all i in equation (3.2.4.3).

3.2.4.3.2. The long-run Granger causality test

The long-run causality is determined by the statistical significance of the ECT term with using the t-statistics test.

3.2.5. Description of data

We apply quarterly data from the first quarter of 1983 to the fourth quarter of 2007 for eight OPEC member countries, including Algeria, Indonesia, Iran, Nigeria, Saudi Arabia and Venezuela; moreover, we apply quarterly data from the first quarter of 1990 to the fourth quarter of 2007 for Libya; and we use quarterly data from the first quarter of 1994 to the fourth quarter of 2007 for Qatar.

Our multivariate model includes individual crude oil production by each OPEC member country (lnQ) as the dependent variable, followed by real crude oil price (lnPO), crude oil production by the rest of OPEC (lnQ^{oo}), OPEC quota (lnQuota) and investment needs (lnI) as the explanatory variables of the model.

Data for individual crude oil production and the rest of OPEC production, in thousand barrels per day, are obtained from the Monthly Energy Review (2012); real crude oil price[27] data, in constant 2000 US$, is obtained from the EIA (2012); data for OPEC quota, in thousand barrels per day, is obtained from the Annual Statistical Bulletin, 2011, published by OPEC; and real fixed capital formation data, in constant 2000 US$, is used as a proxy for investment needs, and is obtained from the WDI (CD-ROM, 2012)[28].

The choice of time span is based on data availability for quota. The first OPEC quota announcement occurred in April 1982 and the last regular announcement happened in February 2007; nonetheless, after this date there is a lack of quota announcement until November 2008, and afterward no production allocation announced by OPEC. Therefore, we chose the period from 1983 to 2007. Nevertheless, in the case of Libya and Qatar we chose shorter time span based on data availability of real fixed capital formation. All values of the variables are converted in natural logarithms.

Furthermore, as exogenous dummy variables of the model, we include the first Persian Gulf War (January 1983-October 1988) and the Second Persian Gulf War (July 1990-January 1991) to the production models of Iran and Saudi Arabia[29]; Asian economic crisis (July 1997-October 1998) is included to the production models of Indonesia, Iran, Qatar and Saudi Arabia[30]; huge increase in oil proven reserves is included to the production models of Iran (January 1986 and January 2002), Nigeria (January 1990), Qatar (January 2000 and January 2007), Saudi Arabia (January 1987) and Venezuela (January 1985 and January 2007); and selection of Chavez (January 1997) in Venezuela is included to the production model of this country.

3.2.6. The results

3.2.6.1. The results of the unit root tests

The results from the Z-A (Zivot and Andrews (1992)) unit root test indicate that: in the case of Algeria and Iran all the variables have unit roots in their levels and they are stationary in their first differences, or they are $I(1)$; however, in the rest of countries the orders of integration of the variables are a combination of 0 and 1, or they are $I(0)$ and $I(1)$.

Furthermore, the results from the Perron (1997) test show that in each of eight countries, the variables have a mixture of orders of integration 0 and 1, or they are $I(0)$ or $I(1)$.

[27] Real crude oil price is an average imported crude oil price to the US.
[28] Data for crude oil price, the rest of OPEC production, and individual productions are deseasonalized.
[29] The role of Saudi Arabia as swing producer of OPEC for many years, leads us to include political conflicts of the Middle East as dummy variables of Saudi Arabian crude oil production function.
[30] According to the BP statistical yearbook 2012, 70% of crude oil exports from OPEC Middle Eastern nations are to Asian Pacific region; therefore, 1997 Asian crisis is included into the crude oil production models of Middle Eastern nations as an exogenous variable.

Therefore, we are not able to apply the usual cointegration approaches such as Engle and Granger (1987), Johansen (1988) and Johansen and Juselius (1990) as they are efficient only if all the variables are stationary in their first differences and have the same orders of integration, or they are *I*(1). Table (32) shows the results for the model C (that allows for one break both in the level and in the slope of the trend of the series) of the unit root tests.

Table 32-Results of the unit root tests for OPEC member producers

Country	Z-A				Perron			
	Level	B-P	F-D	B-P	Level	B-P	F-D	B-P
Algeria								
lnQ	-3.82	1998-Q3	-5.62**	2002-Q3	-3.79	1998-Q2	-14.24*	2002-Q2
lnI	-3.69	1999-Q1	-3.64	2003-Q1	-3.75	1994-Q4	-12.43*	1991-Q1
lnPO	-3.81	1998-Q1	-6.42*	1991-Q1	-3.78	1997-Q4	-6.74*	1990-Q3
lnQuota	-3.91	2004-Q1	-14.11*	1998-Q3	-5.73***	2004-Q1	-17.83*	1998-Q2
lnQ^{oo}	-4.31	1988-Q4	-7.72*	1990-Q3	-4.28	1988-Q3	-15.38	1990-Q4
Indonesia								
lnQ	-3.65	1990-Q2	-15.80*	1987-Q3	-3.67	1997-Q4	-15.71*	1987-Q2
lnI	-11.61*	1998-Q1	-11.20*	1998-Q1	-11.56*	1997-Q4	-13.60*	1998-Q1
lnPO	-3.81	1998-Q1	-6.49*	1991-Q1	-3.78	1997-Q4	-6.74*	1990-Q3
lnQuota	-5.07***	2004-Q1	-13.16*	1998-Q3	-5.33***	2004-Q1	-15.91*	1998-Q2
lnQ^{oo}	-4.37	1988-Q4	-7.71*	1990-Q3	-4.34	1988-Q3	-15.26*	1990-Q4
Iran								
lnQ	-4.64	1988-Q4	-7.05*	1991-Q4	-4.68	1988-Q4	-7.25*	1989-Q4
lnI	-4.05	1992-Q1	-10.91*	1987-Q3	-4.09	1991-Q4	-12.69*	1987-Q1
lnPO	-3.81	1998-Q1	-6.49*	1991-Q1	-3.78	1997-Q4	-6.74*	1990-Q3
lnQuota	-4.00	2004-Q1	-14.14*	1998-Q3	-5.84**	2004-Q1	-18.20*	1998-Q2
lnQ^{oo}	-4.44	1988-Q4	-7.64*	1990-Q3	-4.38	1988-Q3	-6.84*	1990-Q2
Libya								
lnQ	-6.17*	2001-Q4	-7.08*	2002-Q2	-6.26**	2001-Q1	-10.12*	1993-Q2
lnI	-4.97***	2002-Q1	-9.97*	2004-Q1	-4.54	2001-Q4	-10.11*	2004-Q1
lnPO	-4,33	1998-Q1	-5.43**	1999-Q1	-4.29	1997-Q4	-5.33***	2000-Q3
lnQuota	-5.67*	2005-Q1	-11.52*	1998-Q3	-6.04**	2005-Q1	-14.21*	1998-Q2
lnQ^{oo}	-5.22**	2001-Q1	-5.77*	2003-Q4	-4.24	2001-Q2	-9.05*	2002-Q2
Nigeria								
lnQ	-4.50	1989-Q2	-10.12*	1987-Q4	-4.54	1989-Q1	-10.05*	1989-Q3
lnI	-4.99***	1995-Q1	-10.42*	1997-Q1	-4.96	1994-Q4	-11.12*	1998-Q1
lnPO	-3.18	1998-Q1	-6.49*	1991-Q1	-3.78	1997-Q4	-6.78**	1990-Q3
lnQuota	-5.14**	2004-Q1	-13.40*	1998-Q3	-5.40***	2004-Q1	-16.33*	1988-Q2
lnQ^{oo}	-4.35	1988-Q4	-7.60*	1990-Q3	-4.33	1992-Q3	-6.50*	1990-Q2
Qatar								
lnQ	-4.91***	1997-Q3	-9.44*	1998-Q3	-4.94	1997-Q2	-9.42*	1998-Q1
lnI	-5.09**	1999-Q1	-7.10*	2000-Q1	-4.57	1997-Q4	-9.44*	2000-Q1
lnPO	-3.77	1998-Q1	-5.77*	1998-Q4	-3.69	1997-Q4	-5.69**	1998-Q3

lnQuota	-6.07*	2005-Q4	-10.24*	1998-Q3	-6.46*	2005-Q4	-11.80*	1998-Q2
lnQ^{oo}	-5.04***	2001-Q1	-5.13**	2003-Q2	-3.72	2001-Q2	-8.26	2002-Q2
SaudiArabia								
lnQ	-6.77*	1990-Q4	-7.70*	1992-Q2	-6.49*	1990-Q3	-7.16*	1992-Q1
lnI	-3.11	2004-Q1	-11.48*	1992-Q3	-3.14	2004-Q1	-11.18*	1991-Q2
lnPO	-3.81	1998-Q1	-6.49*	1991-Q1	-3.65	1998-Q4	-6.74*	1990-Q3
lnQuota	-3.94	2004-Q1	-14.09*	1998-Q3	-5.71**	2004-Q1	-18.11*	1998-Q2
lnQ^{oo}	-4.1	1987-Q3	-14.07*	2003-Q3	-5.27	1990-Q3	-16.42*	1990-Q4
Venezuela								
lnQ	-4.98***	2002-Q1	-9.87*	2003-Q3	-6.11**	2003-Q1	-21.51*	2003-Q1
lnI	-3.46	2003-Q1	-10.24*	2002-Q1	-3.45	2002-Q4	-10.86*	1989-Q1
lnPO	-3.81	1998-Q1	-6.49*	1991-Q1	-3.78	1997-Q4	-6.74*	1990-Q3
lnQuota	-4.96***	2004-Q1	-13.07*	1998-Q3	-5.21	2004-Q1	-15.51*	1998-Q2
lnQ^{oo}	-4.76	1988-Q4	-8.00*	1990-Q3	-6.16**	1988-Q3	-15.05*	1990-Q4

Values are t-statistics.

Z-A indicates the Zivot and andrews (1992) unit root test.

Perron indicates the Perron (1997) unit root test.

B-P indicates the break points.

F-D indicates the first differences.

*, **, *** indicate statistical significance at 1%, 5% and 10% levels, respectively.

3.2.6.2. The result of the ARDL cointegration test

The results from the ARDL bounds testing approach for cointegration show that, for six countries, including Algeria, Iran, Libya, Nigeria, Qatar and Venezuela, there are evidences of cointegration relationships among the variables; however, the results did not show cointegration relationships among the variables in the cases of Indonesia and Saudi Arabia. Hence, in the next step we will exclude these two countries from the estimation of the long-run coefficients and from the application of the Granger causality test.

Furthermore, our estimated ARDL models passed the diagnostic tests for serial correlation, which indicate evidences of no serial correlation in all the models. Nonetheless, as the variables do not have the same orders of integration, discovering heteroscedasticity is normal. The results are reported in table (33).

Table 33-Results of the ARDL models for OPEC member producers

	Models	F-statistics	Serial correlation(P-values)
Algeria	(2,0,0,0,2)	4.85**	0.76
Indonesia	(2,0,4,0,0)	4.003	0.11
Iran	(2,0,0,1,0)	5.90*	0.51
Libya	(1,0,2,2,0)	5.87*	0.10
Nigeria	(3,2,2,0,2)	10.87*	0.87
Qatar	(1,0,0,0,0)	5.58**	0.82
Saudi Arabia	(4,4,1,0,0)	1.82	0.22
Venezuela	(2,0,1,0,2)	6.10*	0.49
	I(0)	I(1)	
F-critical valuesat 1%	3.063	4.084	
F-critical valuesat 5%	3.539	4.667	
F-critical valuesat 10%	4.617	5.786	

F is the ARDL cointegration test.

F-critical values are taken from Pesaran et al. (2001).

*, **, *** indicate statistical significance at 1%, 5% and 10% levels, respectively.

In the second step, we complement the long-run estimation in order to obtain the long-run coefficients of the variables within the ARDL framework. The results are shown in table (34).

Table 34-The estimated long-run coefficients for OPEC member producers

	lnPO	lnI	lnQuota	lnQ^{oo}
Algeria	0.89(1.94)***	0.17(2.60)**	0.35(2.08)**	-0.338(-1.29)
Iran	0.13(2.28)**	-0.18(-3.27)*	0.006(0.62)	-0.002(-0.09)
Libya	0.09(1.58)	0.13(2.43)**	0.03(1.74)***	-0.26(-0.72)
Nigeria	0.05(2.34)**	0.07(2.08)**	0.03(2.94)*	0.33(2.52)**
Qatar	0.03(0.47)	-0.18(-3.02)*	-0.28(-0.01)	0.85(2.98)*
Venezuela	-0.23(-2.91)*	0.11(1.16)	-0.005(-0.06)	0.96(2.43)**

t-statistic values are in parenthesis.

*, **, *** indicate statistical significance at 1%, 5% and 10% levels, respectively.

The results show that:

Crude oil price

There are positive long-run relationships from crude oil price to production of Algeria, Iran and Nigeria, with elasticity of 0.89%, 0.13% and 0.05%, respectively. There is a negative long-run relationship from crude oil price to production in Venezuela, with elasticity of -0.23%. Moreover, there is no evidence for existence of a long-run relationship among these variables for Libya and Qatar.

According to the Griffin (1985) competitive model, with respect to equation (3.2.3h), the countries show a competitive behavior if $(\beta_2 > 0)$ and a cartel behavior if $(\beta_2 < 0)$. Consequently, our results show evidence of a competitive behavior for Algeria, Iran and Nigeria, and a cartel behavior for Venezuela.

In order to compare our results to others presented in previous studies, Griffin (1985) finds evidences of a cartel behavior for five OPEC nations and evidences of a competitive behavior for six; Jones (1990) confirms cartel behavior for two OPEC nations; Dahl and Yucel (1991) find cartel behavior for eight OPEC nations; Ramcharan (2002) shows cartel behavior for seven OPEC nations; and Kaufmann et al. (2008) do not find cartel behavior for any of OPEC countries.

The rest of OPEC production

There are positive long-run relationships from the rest of OPEC production to production of Nigeria, Qatar and Venezuela, with elasticity of 0.33%, 0.85% and 0.96%, respectively. However, the results do not show any long-run relationship among the variables for Algeria, Iran and Libya.

Based on equation (3.2.3h), Griffin (1985) proposed a market sharing behavior as a form of cartel model under three conditions: *a)* a constant market sharing behavior $(\beta_3 = 1, \beta_2 = 0)$; *b)* a market sharing behavior $(\beta_3 = 1, \beta_2 > 0 \; or \; \beta_2 < 0)$; and *c)* a partial market sharing behavior $(\beta_3 > 0, \beta_2 > 0 \; or \; \beta_2 < 0)$. According to our results, Nigeria, Qatar and Venezuela show a partial market sharing behavior.

In comparison to the other studies, Griffin (1985) and Jones (1990) find evidences of a partial market sharing behavior for eleven OPEC members, Kaufmann et al. (2008) find partial market sharing behavior for six of eight nations under analyze, and Brémond et al. (2012) that investigate OPEC behaviors on various sub-periods show that OPEC behaves as a price taker since 1973 and in the majority of the considered sub-periods.

OPEC quotas

There are positive long-run relationships from quota to production of Algeria, Libya and Nigeria, with elasticity of 0.35%, 0.03% and 0.03% respectively. However, we did not find any evidence for existence of a long-run relationship among the same variables for Iran, Qatar and Venezuela.

Kaufmann et al. (2008) indicate that, including quota in the model permits us to evaluate OPEC's organizational behavior. Based on equation (3.2.3h), if quota has a positive statistically significant coefficient that impacts on production $(\beta_4 > 0)$, then OPEC can be considered as an organization with influence on production and price; alternatively if the coefficient of quota is not statistically significant, then OPEC is only a trade organization of competing producers.

Our results show that, only for North African members of OPEC, including Algeria, Libya and Nigeria, OPEC quota influences on production. These results are not completely match in accordance to the results of Kaufmann et al. (2008) that show six of eight OPEC members follow their quotas.

Investment needs

There are positive long-run relationships from investment needs to production of Algeria, Libya and Nigeria, with elasticity of 0.17%, 0.13% and 0.07%, respectively. Moreover, there are negative long-run relationships from investment needs to production of Iran and Qatar, with elasticity of -0.18% in both countries. However, there is no evidence for a long-run relationship among the series in Venezuela.

According to the Griffin (1985) target revenue model, based on equation (3.2.3h), for a given crude oil price, an increase in investment needs leads to a proportionate increase in production ($\beta_5 = 1$), and for a given investment needs, an increase in crude oil price leads to a proportionate cutback in crude oil production ($\beta_2 = -1$), which represent the strict version of target revenue model. Nevertheless, he considered the partial version of target revenue model as well ($\beta_5 > 0 \; or \; \beta_2 < 0$). Our results indicate that, all the countries under study confirm the partial version of target revenue theory. So that, in the case of Algeria, Iran, Libya, Nigeria and Qatar, the coefficients associate to investment needs are statistically significant, and in the case of Venezuela the coefficient of crude oil price is negative and statistically significant.

In comparison to other studies, Griffin (1985) finds evidences of the partial variant target revenue model for nine OPEC nations, Jones (1990) confirms the results of Griffin (1985), Dahl and Yucel (1991) did not find any evidence to confirm the target revenue model, and Alhajji and Huettner (2000) find evidences in favor of the existence of target revenue behavior for three OPEC countries.

The results presented by literature reveal that there is not a consensus regarding the OPEC behavior and the results of our study are not exceptions for this conclusion as well. As Kaufmann et al. (2008) stated, there is no reason for expecting that a simple model can explain the production decision of members of an international organization that contains independent countries with vastly different geographical location, different economic structures, and political and social aims. Specially because OPEC does not use any punitive or incentive tools in order to control the productions of its members. Nevertheless, our results show that the target revenue model is the dominant model among others.

As the goal of this study is to identify the determinant factors of crude oil production by each OPEC member country, our conclusions for this aim are summarized in table (35):

Table 35-The determinant factors of production for OPEC member producers

Country	
Algeria	Price, investment needs, quotas
Iran	Price, investment needs
Libya	Investment needs, quotas
Nigeria	Price, investment needs, quotas, the rest of OPEC production
Qatar	Investment needs, the rest of OPEC production
Venezuela	Price, the rest of OPEC production

As a result, in order to stabilize production and consequently crude oil price, we recommend imposing punitive and incentive tools by OPEC for obliging its members to follow the appropriate production behavior.

3.2.6.3. The results of the VECM Granger causality tests

According to the equation (3.1.4.3), we investigate the short and the long-run sources of causation, which suggest the following results (see table 36):

The short-run causations:

The Chi-squared statistics of Wald tests suggest that in the short-run: *a*) crude oil price Granger causes production for Algeria, Iran and Nigeria at 5% and for Venezuela at 1% levels of significance. *b*) Investment needs Granger cause production for Algeria and Nigeria at 10%, Libya at 5%, and Iran, Qatar and Venezuela at 1% levels of significance. *c*) Quota Granger causes production for Algeria and Libya at 5% and Nigeria at 10% levels of significance. And *d*) the rest of OPEC production Granger causes production for Algeria, Libya and Nigeria at 1%, Iran and Qatar at 5% levels of Significance, and it does not Granger cause production for Venezuela.

The long-run causations:

Furthermore, the t-statistics of ECTs show that in the long-run, for each of six countries, there are causality relationships running from crude oil price, investment needs, quotas and the rest of OPEC production to individual crude oil productions at 1% level of significance. Therefore, these variables are useful to forecast the production of crude oil and consequently to forecast crude oil price.

Table 36-Results of the Granger causality tests for OPEC member producers

	Short-run				Long-run
	dlnPO	dlnI	dlnQuota	$dlnQ^{oo}$	ECM
	Chi-sq				t-statistics
Algeria	4.67**	3.76***	4.47**	25.70*	-0.24(-3.85)*
Iran	6.37**	13.03*	0.24	6.00**	-0.53(-5.72)*
Libya	2.04	7.45**	4.15**	44.04*	-0.19(-4.09)*
Nigeria	6.96**	3.61***	5.98***	28.17*	-1.13(-7.19)*
Qatar	0.24	6.86*	0.11	5.98**	-0.67(-5.35)*
Venezuela	7.32*	15.35*	0.004	2.24	-0.74(-5.61)*

t-statistic values are in parenthesis.

*, **, *** indicate statistical significance at 1%, 5% and 10% levels, respectively.

3.2.7. Conclusion

The main goal of this study is to examine the determinant factors that impact on crude oil production of individual OPEC member producers. To achieve this goal, we developed an original production model via extending the two initial models of Griffin (1985) and Kaufmann et al. (2008).

In our proposed multivariate model, individual crude oil production by each OPEC member country is a dependent variable; and a set of variables, including real crude oil price, the rest of OPEC production, OPEC quotas and investment needs are the explanatory variables of the model.
Moreover, we consider a set of exogenous events that may affect on crude oil production of OPEC member countries, including political, economic and special events, such as wars, a presidential election that changes the political structure of an oil producer country, a world economic crisis, discovering of new huge oil reserves, and etc., all of them as dummy variables. Hence, we proposed a model that significantly reduces the problem of omitted variable bias and increases the possibility of existing the cointegration relationships among the variables.

We applied quarterly data for eight OPEC member countries, including Algeria, Indonesia, Iran, Nigeria, Saudi Arabia and Venezuela with data from 1983 to 2007, Libya from 1990 to 2007, and Qatar from 1994 to 2007.

The results indicate that, for six countries including Algeria, Iran, Libya, Nigeria, Qatar and Venezuela, there are cointegration relationships among the variables; nevertheless, the results did not show any cointegration relationship among the same variables for Indonesia and Saudi Arabia. In the next step, we complemented the long-run elasticity estimation and the Granger causality test within the ARDL framework.
We found that, for Algeria, the set of crude oil price, investment needs and quota are the determinant factors; for Iran it is the set of crude oil price and investment needs; for Libya it is the

set of investment needs and quota; for Nigeria the set includes crude oil price, investment needs, quota and the rest of OPEC production; for Qatar the set contains investment needs and the rest of OPEC production; and for Venezuela the set is composed of oil price and the rest of OPEC production. The entire variables that compose different sets are the determinant factors for the up-referred countries.

Furthermore, the results from Granger causality test indicate that; in the short-run, for Algeria and Nigeria all the variables Granger cause production; for Iran all the variables except quota; for Libya all the variables except price; for Qatar investment needs and production by the rest of OPEC; and for Venezuela price and investment needs Granger cause production. However, in the long-run, for all countries, the explanatory variables Granger cause production.

Consequently, each OPEC member nation shows different behavior in terms of crude oil production and there is not a unique set of the explanatory variables that we can suggest as the determinant factors of OPEC crude oil production. This diversity in results is very normal as each country has its own geographical location, a different economic structure, and different social and political aims, and the fact of being a member of an international organization without any punitive or incentive tools could not oblige them to follow the same production function.

As a result, in order to stabilize crude oil market, we recommend imposing punitive and incentive tools by OPEC for obliging its member countries to follow the appropriate production behavior in order to stabilize crude oil prices.

3.3. Crude oil production behaviors of non-OPEC producer countries

3.3.1. Introduction

Crude oil producer countries outside of OPEC contain almost 18.67% of the world's crude oil proven reserves. Among them, for instance, the Russian Federation contains 5.6%, Libya 3.3%, Kazakhstan 3%, Canada 2.5%, the US 2.1%, China 1.1% and Brazil 1% of the world's crude oil proven reserve, in 2009 (BP statistical yearbook , 2012). Moreover, non-OPEC producer countries contain 55% share of the world crude oil production. For instance, the Russian Federation with a share of 12.9% was the largest worldcrude oil producer; moreover, the US with 8.5%, China 4.9%, Canada 4.1% and Mexico with 3.9% of the world crude oil production, in 2009 were among the big producers (BP statistical yearbook, 2012). Consequently, the large share of non-OPEC producer nations provides them the power to affect OPEC share of the world's crude oil production significantly; thus, they affect OPEC's ability to influence on prices (Kaufmann, 1995). For instance, the second oil crisis which occurred in 1979-1980 encouraged non-OPEC producer countries to increase their production in order to obtain more benefits. At the same time, new oil resources that were discovered during 1970s were coming available. Therefore, OPEC faced an oversupply, and after 1980 crude oil prices began a six years period of decline. As a result, oil market stability is achievable only through cooperation between OPEC and non-OPEC producer countries. For this reason, during the recent years several non-OPEC producers such as Mexico, Norway, Oman and the Russian Federation, started to cooperate with OPEC and cut their productions in order to stabilize the market and recover crude oil prices (OPEC, 2012).

All the existing studies that investigated the production behavior of non-OPEC producer nations assumed that these countries produce crude oil based on a competitive behavior and their production is only a function of crude oil prices. Although most of the producers outside of OPEC can be considered as price takers; however, the economic models for production by non-OPEC nations are mostly unreliable, as there is not a simple relation among real crude oil prices and production by non-OPEC producer nations (Kaufmann and Cleveland, 2001; Dées et al., 2007). For instance, from the end of the Second World War in 1945 to 1970 crude oil price declined but crude oil production of the US increased significantly; conversely, from 1970 to 1985 price increased greatly, but production decreased (Dées et al., 2007). The same authors explain that these contradictions can be explained by other factors such as changes in crude oil reserves, economic and political situations and etc.

Therefore, with respect to the increasing role of non-OPEC producer countries on crude oil market and consequently on crude oil prices, there is a lack in literature about investigating the production behavior by these nations. In this study, we attempt to examine the determinant factors of crude oil production by non-OPEC producer countries through developing an original multivariate econometric model, which contains both quantitative and qualitative factors.

Our motivation to perform an inclusive investigation to recognize the determinant factors of crude oil production by non-OPEC member producers is that, in a market-linked mechanism situation of crude oil price formation, production of crude oil is an explanatory factor for price; therefore, determining the variables that impact on production is essential to enable us to increase the forecasting accuracy of crude oil price.

For this purpose, we extend an initial target revenue model proposed by Griffin (1985)[31]. Our model departs from the Griffin's model through including more quantitative and qualitative factors that minimize the problem of omitted variable bias.
We extend the Griffin's (1985) study through four main contributions. First, we include two new variables to the initial target revenue model, one is crude oil production by OPEC nations, which represents the market sharing behavior of non-OPEC producer countries, and another is crude oil proven reserves. Therefore, our multivariate model includes individual crude oil production by each non-OPEC producer country as the dependant variable, and real crude oil price, crude oil production by OPEC nations, investment needs, and crude oil proven reserves are the explanatory variables. Second, we include a set of qualitative factors that impact crude oil production exogenously, including political, economic and other special events, such as revolutions, economic crisis, and oil spills as dummy variables of the model. Third, In order to avoid spurious regression for non stationary variables, we perform the recently developed ARDL bounds testing approach for cointegration. And fourth, we use more recent data than the previous studies.

We applied quarterly data for the period 1980 to 2011. In order to achieve the empirical examination of the model, we perform two unit root tests with allowing for one structural break in the time series, the Zivot and Andrews (1992) and the Perron (1997) unit root tests. Then we apply the Auto-Regressive Distributed Lag (ARDL) bounds testing approach for cointegration proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) to estimate the cointegration relationships between the variables. Furthermore, the long-run elasticities and the Granger causalities among the variables are examined.

The rest of this study has the following structure: section 3.3.2 develops a literature review; section 3.3.3 provides structure of the model; section 3.3.4 proposed the methodology; section 3.3.5 describes data; section 3.3.6 provides the empirical results; and section 3.3.7 presents the conclusion.

[31] In the Griffin's study, the author applied target revenue model only to examine the production behaviour of OPEC member nations.

3.3.2. Literature review

There are vast numbers of studies that develop econometric models to explain crude oil production by OPEC countries (see Griffin, 1985; Jones, 1990; Suranovic, 1993; Spilimbergo, 2001; Ramcharan, 2001 and 2002; Smith, 2005; Kaufmann, 2008; and Bremond, 2012); however, there are few studies that propose a model to investigate crude oil production by non-OPEC producer countries. Among them, Griffin (1985) investigates crude oil production of non-OPEC producer countries through a competitive model in which individual production is a function of real crude oil price, and through a cartel model in which production is a function of real crude oil price and production by OPEC members, using data from the period 1971 to 1982. This author shows that the competitive model cannot be rejected for ten countries, and that the partial market sharing model cannot be rejected for eight of eleven countries.

Ramcharan (2002) updates the competitive model of Griffin (1985) through using data from the period 1973 to 1997, and shows that the competitive model cannot be rejected for seven of nine countries.

Kaufmann (1991) assesses crude oil production for the period 1938 to 1999, through using a method that combines curve fitting and the econometric models. The author examines economic, geological, and institutional determinant factors of crude oil production for the lower 48 states of the US. In his model, individual crude oil production is a function of the annual rate of individual crude oil production, real crude oil price and dummy variables specific to each country.

Dées et al. (2007) update Kaufmann's study, using quarterly data for the period 1984 to 2002 rather than the annual data and for all non-OPEC crude oil producer regions in the world in addition to the lower 48 states of the US. Their result indicates that crude oil price is positively correlated with production for all nine non-OPEC producer regions; thus, confirming the competitive model.

3.3.3. Structure of the proposed model

In this study, we develop a model for crude oil production of non-OPEC producer countries. For this purpose, we extend the target revenue model proposed by Griffin (1985). In this model, the author specifies the target revenue model as below:

$$I_{it}=P_tQ_{it} \qquad i=1,\dots,n;\ t=1,\dots,T \qquad (3.3.3a)$$

where I_{it}, P_t and Q_{it} represent investment needs, crude oil price, and crude oil production by individual country i, respectively. Griffin (1985) assumes that crude oil prices and investment needs are exogenous to crude oil production and apply natural logarithms to both sides, as it is shown is 3.3.3b:

$$lnQ_{it} = \propto_i + \gamma_i lnP_t + \delta_i lnI_{it} + \varepsilon_{it} \tag{3.3.3b}$$

where ε_{it} is the error term. Griffin (1985) states that, for a given crude oil price, if investment needs increase, production increases proportionally (δ_i=1); and for a given investment needs, if price increases, production decreases proportionally ($\gamma_i = -1$), and this represents a strict version of the target revenue theory. If with increasing investment needs production increases but not proportionally ($\delta_i > 0$), and with increasing price, countries produce beyond their investment needs ($\gamma_i < 0$), then there is evidence in favor of a partial version of the target revenue model.

Subsequently, our modifications to the Griffin (1985) model are, first, the inclusion of two more explanatory variables to equation (3.3.3b), the first variable is crude oil production by OPEC member countries and the second one is oil proven reserves by each country. And second, we include a set of exogenous variables specific for each country, as dummy variables. Crude oil market is strongly correlated with qualitative factors; therefore, we include important exogenous events that may impact crude oil production of non-OPEC producer countries. These exogenous factors contain political, economic and other special events, such as revolutions, economic crisis, and oil spills that are included to the models as dummy variables. Hence, in comparison with the existing non-OPEC production models that have been proposed until now (e.g., Griffin, 1985; and Ramcharan, 2002) we propose a model that minimizes the problem of omitted variable bias and increases the possibility of existing the cointegration relationships among the variables. Our proposed model is given by equation (3.3.3c):

$$lnQ_{it} = \propto_i + \gamma_i lnPO_t + \delta_i lnI_{it} + \partial_i lnQ_t^O + \emptyset_i lnRES_{it} + \theta D_{it} + \emptyset_{it} \tag{3.3.3c}$$

where $\emptyset_{it}$ is the new error term and PO_t, I_{it}, Q_t^O, RES_{it} and D_{it} represent real crude oil price, investment needs, the whole crude oil production by OPEC countries, crude oil proven reserves by individual country *i* and dummy variables for each country *i*, respectively.

3.3.4. Methodology

3.3.4.1. The unit root tests

The Autoregressive Distributed Lag (ARDL) bounds testing approach for cointegration is valid even if the variables' orders of integration are not equal; however, they should not be greater than one. The critical values provided by Pesaran et al. (2001) are calculated according to the *I*(0) and *I*(1) orders of integration. This means that their orders of integration can be 0 or 1, but it cannot be used if for example the order of integration of one of the series is 2 or it is *I*(2). Therefore, before applying the ARDL approach, it is necessary to perform unit root tests in order to specify the orders of integration of the series. The common problem with usual unit root tests such as the ADF (Augmented Dickey -Fuller) or the P-P (Phillips-Perron) is that, they do not allow for structural breaks. Perron (1989) shows that if a break occurs as a result of an exogenous shock, then the power to reject the unit root decreases when the stationary alternative is true and the structural break is ignored. In order to solve this problem, we employ two unit root tests that admit one structural break in the series, the Zivot and Andrews (1992) and the Perron (1997) tests. Both tests proceed with three models to test for a unit root. Model A, which allows for one break in the level of the series; model B, which allows for one break in the slope of the trend; and model C, which allows for one break both in the level and in the slope of the trend of the series.

3.3.4.2. The ARDL cointegration test

If the variables orders of integration are a combination of 0 and 1 (they are *I*(0) and *I*(1)), then the Autoregressive Distributed Lag (ARDL) bounds testing approach for cointegration proposed by Pesaran and Shin (1999) and Pesaran et al. (2001) is the only appropriate approach to examine the long-run relationship among the series. This approach has various advantages to the approaches such as Engle and Granger (1987), Johansen (1988) and Johansen and Juselius (1990). For instance, it provides better small sample properties than the other approaches (Narayan, 2005), it is an efficient estimator even if some variables are endogenous, it allows the variables to have different optimal lags, it uses a single reduced form equation, and there is no need that all the variables have the same order of integration (Acaravci and Ozturk, 2010); moreover, both the short and the long-run relationships can be simultaneously estimated (Wolde-Rufael, 2010).

In the first step, an ARDL model uses the lagged values of the dependent variable, and the lagged and simultaneous values of the independent variables to examine the existence of the long run relationships among the variables. For this purpose, in this study the ARDL estimates the following unrestricted error correction regression (equation 3.3.4.2):

$$\Delta lnQ_{it} = \propto_{1iQ} + \sum_{m=1}^{n1} a_{1imQ}\, \Delta lnQ_{t-m} + \sum_{m=0}^{n2} b_{1imQ}\, \Delta lnPO_{t-1} + \sum_{m=0}^{n3} c_{1imQ} \Delta lnI_{t-m} + \sum_{m=0}^{n4} d_{1imQ}\, \Delta lnQ^{O}_{t-m}$$
$$+ \sum_{m=0}^{n5} e_{1imQ}\, \Delta lnRES_{t-m} + \partial_{1iQ} lnQ_{t-1} + \partial_{2iQ} lnPO_{t-1} + \partial_{3iQ} lnI_{t-1} + \partial_{4iQ} lnQ^{O}_{t-1}$$
$$+ \partial_{5iQ} lnRES_{t-1} + \varepsilon_{1it} \qquad (3.3.4.2)$$

where ε_{1it} is the error term and Δ is the first difference operator, i=1,...,8, and *m* is the lag length. The appropriate lag length selection is based on the Akaike Information Criterion (AIC), the Schwartz Bayesian Criterion (SBC) and the R-BAR squared Criterion. In order to perform the bounds test to examine the existence of a cointegration relationship between the variables, we apply a joint F-test for the lagged levels of the variables. The null hypothesis is based on no cointegration relationship between the variables as H_0=$\partial_{1iQ} = \partial_{2iQ} = \partial_{3iQ} = \partial_{4iQ}$= ∂_{5iQ} =0, against the alternative hypothesis that H_1=$\partial_{1iQ} \neq \partial_{2iQ} \neq \partial_{3iQ} \neq \partial_{4iQ} \neq \partial_{5iQ} \neq 0$.

Two sets of critical *F* values are provided by Pesaran and Shin (1999) and Pesaran et al. (2001). One set assumes that all the variables are *I*(0) and another assumes that all are *I*(1). According to the Pesaran et al. (2001) bounds testing approach, if the F-statistic falls above the upper critical bounds value, the null of no cointegration is rejected, regardless of the series orders of integration. Alternatively, if the F-statistic falls below the lower critical bounds value, then the null hypothesis is not rejected, regardless of the orders of integration of the variables. However, if the F-statistics falls between the lower and upper bounds values, the result is inconclusive, unless we know whether the series are *I*(0) or *I*(1).

3.3.4.3. The VECM for the Granger causality tests

Given that the variables are cointegrated, there are long run relationships between them, where crude oil production is the dependent variable. The existence of cointegrating relationships among the variables confirms the existence of causality relationship among them at least in one direction, but it does not specify the direction of this causality (Engle and Granger, 1987). In the third step, the Granger causality test is used to examine whether the explanatory variables Granger cause crude oil production or not. To achieve this goal, we estimate a Vector Error Correction Model (VECM) within the ARDL framework. In this study, the Granger causality test will be done through equation (3.3.4.3):

$$\Delta lnQ_{it} = \propto_{2iQ} + \sum_{m=1}^{n1} a_{2imQ}\, \Delta lnQ_{t-m} + \sum_{m=0}^{n2} b_{2imQ}\, \Delta lnPO_{t-1} + \sum_{m=0}^{n3} c_{2imQ} \Delta lnI_{t-m} + \sum_{m=0}^{n4} d_{2imQ}\, \Delta lnQ^{O}_{t-m} + \sum_{m=0}^{n5} e_{2imQ}\, \Delta lnRES_{t-m} + \emptyset_i ECT_{t-1} + \varepsilon_{2it} \quad (3.3.4.3)$$

where ECT_{t-1} is the error correction term and $\emptyset_i$ is the coefficient of error correction term, which indicates how quickly the variables converge to the equilibrium, and it should be statistically significant with negative sign.

3.3.4.3.1. The short-run Granger causality test

The short-run causality is determined by the statistical significance of the Chi-squared through a Wald test, based on the null hypothesis $H_0 : b_{2imQ} = c_{2imQ} = d_{2imQ} = e_{2imQ} = 0$ and alternative as $H_1\!: b_{2imQ} \neq 0$, $H_1\!: c_{2imQ} \neq 0$, $H_1\!: d_{2imQ} \neq 0$ and $H_1\!: e_{2imQ} \neq 0$ for all *i* in equation (3.3.4.3).

3.3.4.3.2. The long-run Granger causality test

The long-run causality is determined by the statistical significance of the ECT with using the t-statistics.

3.3.5. Description of data

We apply quarterly data for eight non-OPEC crude oil producer countries, including Canada, China, Egypt, Mexico, Norway, the Russian Federation, the UK and the US, from the first quarter of 1980 to the last quarter of 2011. Our multivariate model includes individual crude oil production by each non-OPEC producer country (lnQ), real crude oil price (lnPO), total crude oil production by OPEC nations ($\ln Q^{O}$), investment needs (lnI), and crude oil proven reserves (lnRES).

Data for individuals non-OPEC and the whole OPEC productions in thousand barrels per day are obtained from the Monthly Energy Review (2012), real crude oil price[32] data that is in constant 2000 US$ and data for crude oil proven reserves are obtained from the EIA (2012), real fixed capital formation data in constant 2000 US$ is used as a proxy for investment needs, which is obtained from the WDI (CD-ROM, 2012)[33].
All values of the variables are converted in natural logarithm in order to reduce their variability and facilitate economic interpretations of the coefficients.

Furthermore, the global economic crisis (January 2008Q1-February 2009) is included to the production models of Canada, Mexico, Norway, the Russian Federation, the UK and the US; the Asian economic crisis (July 1997-October 1998) is included to the production model of China; the oil spills are included to the production models of China (March 1997-April 1998) and Mexico (February 2010-April 2010), and the revolution (January 2011-April 2011) and the government decision (March 1985-March 1986) are included to the production model of Egypt, as dummy variables.

3.3.6. The results

3.3.6.1. The results of the unit root tests

The results from the Zivot and Andrews (1992) unit root test indicate that: for Norway and the US all the variables have unit root in their levels and they are stationary in their first differences, or they are $I(1)$; however, in the rest of the countries the order of integration of the variables are a combination of $I(0)$ and $I(1)$. Furthermore, the results from the Perron(1997) test show that, for all countries, the variables have a mixture of orders of integration; hence, they are $I(0)$ and $I(1)$ (see table 37).

[32] Real crude oil price is an average imported crude oil price to the US.
[33] Data for crude oil price, the rest of OPEC production, and individual productions are deseasonalized.

Hence, we are not able to apply the common cointegration approaches such as Engle and Granger (1987), Johansen (1988) and Johansen and Juselius (1990), as these approaches are efficient only if all the variables are stationary in their first differences and have the same order of integration, or they are *I*(1).

Table 37-Results of the unit root tests for non-OPEC producers

Country	Z-A				Perron			
	Level	B-P	F-D	B-P	Level	B-P	F-D	B-P
Canada								
lnQ	-5.7*	1980-Q1	-5.6*	1986-Q2	-4.7	1989-Q2	-17.4*	1984-Q4
lnI	-4.2	1991-Q1	-5.3**	1989-Q2	-4.1	1990-Q4	-12.3*	1997-Q1
$lnPO$	-3.4	1997-Q4	-8.5*	1999-Q2	-3.4	1996-Q4	-8.4*	1986-Q2
lnQ^O	-3.9	1998-Q4	-8.4*	1985-Q4	-5.2***	2000-Q4	-16.2*	1986-Q4
$lnRES$	-68.3*	2003-Q1	-12.3*	2003-Q1	-68.5*	2002-Q4	-153.3*	2003-Q1
China								
lnQ	-6.63*	1987-Q4	-13.5*	1985-Q3	-6.5*	1987-Q3	-13.5*	1985-Q3
lnI	-4.8***	1980-Q1	-12.5*	1991-Q1	-4.8	1988-Q4	-12.5*	1990-Q4
$lnPO$	-3.4	1997-Q4	-8.5*	1999-Q2	-3.4	1996-Q4	-8.4*	1986-Q2
lnQ^O	-3.9	1998-Q4	-8.4*	1985-Q4	-5.2***	2000-Q4	-16.2*	1986-Q4
$lnRES$	-4.1	2003-Q1	-11.8*	2003-Q1	-4.1	2002-Q4	-13.5*	2003-Q1
Egypt								
lnQ	-3.1	1986-Q4	-7.9*	2006-Q4	-4.4	1986-Q3	-10.2*	1986-Q3
lnI	-3.3	1991-Q1	-12.5*	1993-Q3	-3.3	1990-Q4	-12.5*	1993-Q1
$lnPO$	-3.4	1997-Q4	-8.5*	1999-Q2	-3.4	1996-Q4	-8.4*	1986-Q2
lnQ^O	-3.9	1998-Q4	-8.4*	1985-Q4	-5.2***	2000-Q4	-16.2*	1986-Q4
$lnRES$	-7.3*	1995-Q1	-11.5*	1995-Q1	-7.3*	1994-Q4	-16.4*	1995-Q1
Mexico								
lnQ	-5.0***	2002-Q4	-7.6*	1996-Q1	-5.7**	1995-Q4	-21.8*	1995-Q4
lnI	-	-	-11.4*	1996-Q1	-3.9	1985-Q1	-13.1*	1995-Q1
$lnPO$	-3.4	1997-Q4	-8.5*	1999-Q2	-3.4	1996-Q4	-8.4*	1986-Q2
lnQ^O	-3.9	1998-Q4	-8.4*	1985-Q4	-5.2***	2000-Q4	-16.2*	1986-Q4
$lnRES$	-2.1**	2000-Q1	-8.2*	2000-Q1	-4.2	1999-Q4	-10.0*	2003-Q1
The Russian Fed								
lnQ	-5.5*	2003-Q2	-5.1**	2004-Q4	-5.1	2003-Q2	-8.3*	2004-Q3
lnI	-5.0***	2007-Q1	-9.0*	2008-Q3	-4.9	2006-Q4	-9.0*	2009-Q1
$lnPO$	-3.4	1997-Q4	-8.5*	1999-Q2	-3.4	1996-Q4	-8.4*	1986-Q2
lnQ^O	-3.9	1998-Q4	-8.4*	1985-Q4	-5.2***	2000-Q4	-16.2*	1986-Q4
$lnRES$	-	-	-8.5*	2003-Q3	-	-	-	-
Norway								
lnQ	-3.1	1995-Q4	-9.0*	1986-Q3	-4.5	1986-Q2	-16.6*	1986-Q2
lnI	-4.4	1989-Q1	-11.9*	1993-Q1	-4.4	1988-Q4	-12.2*	1990-Q1
$lnPO$	-3.4	1997-Q4	-8.5*	1999-Q2	-3.4	1996-Q4	-8.4*	1986-Q2
lnQ^O	-3.9	1998-Q4	-8.4*	1985-Q4	-5.2***	2000-Q4	-16.2*	1986-Q4
$lnRES$	-2.8	1997-Q1	-8.7*	1992-Q2	-2.8	1996-Q4	-8.9*	1992-Q1

The UK								
lnQ	-3.7	1993-Q3	-14.3*	1991-Q3	-3.7	1993-Q2	-14.3*	1991-Q2
lnI	-3.6	2006-Q1	-12.1*	1988-Q3	-3.6	2005-Q4	-12.4*	1988-Q1
lnPO	-3.4	1997-Q4	-8.5*	1999-Q2	-3.4	1996-Q4	-8.4*	1986-Q2
lnQ^O	-3.9	1998-Q4	-8.4*	1985-Q4	-5.2***	2000-Q4	-16.2*	1986-Q4
lnRES	-5.4**	1987-Q1	-6.0*	1989-Q1	-5.3*	1986-Q4	-6.9*	1988-Q1
The US								
lnQ	-3.7	2005-Q3	-15.8*	2006-Q1	-3.7	2005-Q2	-18.6*	2005-Q4
lnI	-3.0	2004-Q1	-12.3*	1992-Q1	-3.0	2003-Q4	-12.3*	1992-Q4
lnPO	-3.4	1997-Q4	-8.5*	1999-Q2	-3.4	1996-Q4	-8.4*	1986-Q2
lnQ^O	-3.9	1998-Q4	-8.4*	1985-Q4	-5.2***	2000-Q4	-16.2*	1986-Q4
lnRES	-3.4	1991-Q1	-11.5	2006-Q1	-3.4	1990-Q4	-11.6	1998-Q1

Values are t-statistics.

Z-A indicates the Zivot and andrews (1992) unit root test.

Perron indicates the Perron (1997) unit root test.

B-P indicates the break points.

F-D indicates the first differences.

*, **, *** indicate statistical significance at 1%, 5% and 10% levels, respectively.

3.3.6.2. The result of the ARDL cointegration test

The results from the ARDL bounds testing approach state that, for all countries under this study, there are cointegration relationships among the variables (see table 38).

The ARDL models that we estimate, passed diagnostic tests for serial correlation, which indicate evidences of no serial correlation for all the models; nonetheless, as the variables don’t have the same order of integration, discovering heteroscedasticity is normal. Table (38) represents the results of the ARDL models.

Table 38-Results of the ARDL models for non-OPEC producers

	Models	F-statistics	Serial correlation(p-value)
Canada	(2,3,5,5,3)	7.4*	0.15
China	(4,2,0,0,4)	5.28**	0.81
Egypt	(2,2,2,1,3)	7.67*	0.17
Mexico	(2,0,3,5,1)	4.74**	0.27
Norway	(4,2,4,3)	7.19*	0.15
The Russian Federation	(1,0,0,2,0)	5.42**	0.95
The UK	(1,0,0,0,0)	4.84**	0.22
The USA	(2,2,0,0,1)	5.35**	0.43
	I(0)	I(1)	
F-critical values at 1%	3.063	4.084	
F-critical values at 5%	3.539	4.667	
F-critical values at 10%	4.617	5.786	

F is the ARDL cointegration test.

F-critical values are taken from Pesaran et al. (2001).

*and** indicate statistical significance at 1% and 5% levels, respectively.

In the second step, we complement the long-run estimation in order to obtain the long-run coefficients of the variables within the ARDL approach (see table 39).

Table 39-The estimated long-run coefficients for non-OPEC producers

	lnPO	*lnI*	lnQ^O	*lnRES*
Canada	0.05(1.74)***	-0.17(-1.45)	-0.19(-2.19)**	0.003(0.31)
China	-0.09(-3.52)*	0.06(0.63)	-0.31(-2.14)**	-0.1(-1.01)
Egypt	-0.27(-3.39)*	0.11(0.47)	-1.34(-2.74)*	0.38(1.85)***
Mexico	-0.05(-0.46)	-0.4(-0.85)	1.55(1.69)***	-0.04(-0.22)
Norway	-0.7(-4.27)*	-1.1(-1.86)***	0.19(0.26)	-
The Russian Federation	-0.03(-0.36)	0.81(2.10)**	1.09(1.52)	0.08(0.19)
The UK	-0.44(-5.65)*	-0.35(-0.86)	0.58(1.46)	0.52(4.01)*
The US	0.009(0.34)	-0.25(-3.35)*	-0.32(-3.21)*	0.24(1.00)

t-statistic values are in parenthesis.

*, **, *** indicate statistical significance at 1%, 5% and 10% levels, respectively.

The results show that:

Real crude oil price

There is a positive long-run relationship running from crude oil price to production for Canada, with elasticity of 0.05%. And there is a negative long-run relationship running from crude oil price to production for China, Egypt, Norway and the UK, with elasticities of -.0.9%, -0.27%, -0.70% and -0.44%, respectively. Moreover, the signs of the long-run relationships running from crude oil price to production for Mexico and the Russian Federation are negative and this sign for the US is positive but they are not statistically significant.

According to the Griffin's (1985) competitive model, with respect to equation 3.3.3c, countries confirm a competitive behavior if ($\gamma_i > 0$), and a cartel behavior if ($\gamma_i < 0$). Consequently, our results represent that for four countries, China, Egypt, Norway and the UK, there are evidences of cartel behavior, and only Canada shows a competitive behavior.

In comparison with other studies, our results are in contrast with Griffin (1985) that finds competitive behaviors for ten of eleven countries, with Ramcharan (2002) who finds evidences of competitive behaviors for seven of nine nations, and with Dées et al. (2007), which find evidences of the competitive behaviors for all nine regions under study.

Among the above studies, the competitive model is dominant among non-OPEC producer countries; however, in our study four of eight nations show a cartel behavior and only one nation presents a competitive behavior. These contradictory results can be due to various reasons. The first reason is the difference time span of our study in comparison with others. As in recent years a general consensus appeared based on the fact that the oil market stability is achievable only through cooperation between OPEC and non-OPEC producer countries, during recent years several non-OPEC producer countries, including Mexico, Norway, Oman, and the Russian Federation started to cooperate with OPEC and cut or increase their production in order to stabilize the market and price (OPEC, 2012). For instance, during 1998, reduction of crude oil price caused that non-OPEC producers, specifically Mexico and Norway, cooperate with OPEC and restrict their production. Another reason is related to the target revenue theory. According to the Griffin's (1985) target revenue model explanation, based on equation 3.3.3c, for a given crude oil price, an increase in investment needs leads to a proportionate increase in production ($\delta_i = 1$), and for a given investment needs, an increase in crude oil price leads to a proportionate cutback in crude oil production ($\gamma_i = -1$), which represent a strict version of the target revenue model. Nevertheless, he consideres the partial version of the target revenue model as well ($\delta_i > 0 \; or \; \gamma_i < 0$). This theory can be true, even if an increase in crude oil price is greater than an increase in investment needs of a country; in this case, increase in crude oil price leads to a reduction in production.
As the conclusion, we can explain the reason why in some non-OPEC producer countries there is a negative long-run effect from crude oil price to production, as some non-OPEC producer countries follow the target revenue theory and they produce up to the level that they become able to provide their investment needs and in the case of an increase in crude oil price, they cut back their productions.

Investment needs
There is a negative long-run relationship running from investment needs to production for Norway and the US, with elasticities of -1.1% and -0.25%, respectively. And there is a positive long-run

relationship running from investment needs to production for the Russian Federation with elasticity of 0.81%.

According to the Griffin (1985) target revenue theory that is explained above, for a given crude oil price we find evidences of the target revenue model for three countries. Moreover, for a given investment needs, we find evidences of the target revenue model for four countries. As a conclusion, there are evidences of the target revenue model for six nations of eight, including China, Egypt, Norway, the Russian Federation, the UK and the US. Therefore, there is relatively strong evidences for the existence of a target revenue model among non-OPEC producer nations.

To the best of our knowledge, there is no published paper in peer-reviewed journals that examines the target revenue theory or impacts of investment needs on crude oil production among non-OPEC producer countries; hence, this is a relevant contribution of our study.

OPEC production

There are negative long run-relationships running from OPEC production to individual productions for Canada, China, Egypt, and the US, with elasticities of -0.19%, -0.31%, -1.34%, and -0.32%, respectively. And there is a positive long-run relationship from OPEC production to individual production for Mexico, with elasticity of 1.55%. Moreover, for Norway, the Russian Federation, and the UK the signs of OPEC production relationship with individual productions are positive; however, they are not statistically significant.

Based on equation 3.3.3c, Griffin (1985) proposed the market sharing behavior as a form of the cartel model under three conditions: *a)* a constant market sharing behavior ($\partial_i = 1, \gamma_i = 0$); *b)* a market sharing behavior ($\partial_i = 1, \gamma_i > 0 \; or \; \gamma_i < 0$); and *c)* a partial market sharing behavior ($\partial_i > 0, \gamma_i > 0 \; or \; \gamma_i < 0$). With respect to this information, our results indicate that, there are evidences in favor of the partial market sharing behavior for five countries including Canada, China, Egypt, Mexico and the US.

In comparison with other studies, our results are close to Griffin (1985), which shows that the partial market sharing model cannot be rejected for eight of eleven countries.

Proven reserves

There is a positive long-run relationship running from proven reserves to production for Egypt and the UK, with elasticities of 0.38% and 0.52%, respectively. Nevertheless, for the other countries this relationship is not statistically significant[34]. Hence, there is no strong evidence that proven reserves impact productions of non-OPEC producer countries.

[34] We exclude proven reserves from the production model of Norway, because for this country; there is co-linearity between proven reserves and the other variables.

To the best of our knowledge, there is no published paper in peer-reviewed journals that examines impact of proven reserves on crude oil production among non-OPEC producer countries, which is another relevant contribution of our study.

In summary, the above-described results present that, there is not a consensus regarding to the production behavior of non-OPEC producer countries, the same conclusion as the OPEC members production behavior, described in the first study of this chapter. As we mentioned in the first study of this chapter, about OPEC members production behaviors, this conclusion is not unexpected, as there is no reason for expecting that a simple model can explain the production decision of OPEC member nations as members of an international organization that contains independent countries (Kaufmann et al., 2008). This explanation applies to non-OPEC producer countries more strongly, as they have wide diversity of geographical location, and economic, political, and social structures, and they are not members of any international organization.

Although, the goal of this study is to identify the determinant factors behind crude oil production by each non-OPEC producer country as much as possible; the results can be summarized as table (40):

Table 40-The determinant factors of production for non-OPEC producers

Country	
Canada	Price, OPEC production
China	Price, OPEC production
Egypt	Price, OPEC production, Proven reserves
Mexico	OPEC production
Norway	Price, Investment needs
The Russia Federation	Investment needs
The UK	Price, proven reserves
The US	Investment needs, OPEC production

3.3.6.3. The results of the VECM Granger causality tests

In this step, we investigate the short-run and the long-run sources of causality relationships through a VECM model within the ARDL framework (see table 41). The results suggest that:

The short-run causations

The Chi-squared statistics of Wald tests indicate that that in the short-run: *a*) crude oil price Granger causes production for Canada at 10% , China at 5%, and Norway and the UK at 1% levels of significance. *b*) Investment needs Granger causes production for Canada, Mexico, and Norway at 1% level of significant. *c*) OPEC production Granger causes individual production in all countries at 1%

level of significance, except for the Russian Federation that Granger causes at 5% and the UK at 10% levels of significance. And *d*) proven reserves Granger causes production for Canada at 5%, China and the UK at 1%, and Mexico at 10% levels of significance.

The long-run causations:

Furthermore, the t-statistics of the ECTs show that in the long-run, for each of eight countries, there are causality relationships running from crude oil price, investment needs, OPEC production and proven reserves to individual crude oil productions at 1%, 5%, and 10% levels of significance. Therefore, in the long-run, the suggested explanatory variables can be used to forecast crude oil production by each non-OPEC country and consequently to analyze future crude oil prices.

Table 41-Results from the Granger causality tests for non-OPEC producers

Countries	Short-run				Long-run
	dlnPO	dlnINV	$dlnQ^O$	dlnRES	ECM
	Chi-sq				t-statistics
Canada	6.79***	15.31*	22.85*	8.33**	-0.46(-4.66)*
China	6.56**	0.42	7.26*	14.34*	-0.16(-3.78)*
Egypt	3.86	1.74	29.14*	6.02	-0.13(-2.89)*
Mexico	0.19	28.40*	17.35*	2.71***	-0.10(-2.31)**
Norway	11.23*	2.77	17.09*	-	-0.17(-2.41)**
The Russian Federation	0.14	4.19	6.33**	0.03	0.07(1.93)***
The UK	12.04*	0.88	2.82***	10.46*	-0.15(-3.56)*
The US	3.66	10.32*	8.86*	0.88	-0.26(-3.64)*

t-statistic values are in parenthesis.

*, **, *** indicate statistical significance at 1%, 5% and 10% levels, respectively.

3.3.7. Conclusion

In this study, we investigated the determinant factors that impact on crude oil production by non-OPEC producer countries.

Our multivariate model includes individual crude oil production by each non-OPEC producer country as the dependent variable, followed by real crude oil price, crude oil production by OPEC countries, investment needs, and crude oil proven reserves as the explanatory variables of the model. We apply quarterly data from the first quarter of 1980 to the last quarter of 2011, for the eight non-OPEC crude oil producer countries, including Canada, China, Egypt, Mexico, Norway, the Russian Federation, the UK and the US.

The results indicate that, there are long-run cointegrating relationships among the variables for each of eight countries. Moreover, in the long-run, for Canada and China, crude oil price and OPEC production are the determinant factors of production; for Egypt, crude oil price, OPEC production and proven reserves; for Mexico, only OPEC production; for Norway crude oil price and investment needs; for the Russian Federation, investment needs; for the UK crude oil price and proven reserves; and for the US, investment needs and OPEC production are the determinant factors of production. In summary, there is not enough evidence to confirm a competitive behavior among non-OPEC producers; however there are evidences to confirm the cartel behavior among some non-OPEC producers; moreover, the target revenue theory and the market sharing behavior can be confirmed strongly.

Furthermore, the results from the Granger causality tests indicate that, in the short-run, for Canada all the variables Granger cause production; for China and the UK all the variables except investment needs Granger cause production; for Egypt and the Russian Federation only OPEC production Granger causes production; for Mexico all the variables except crude oil price Granger cause production; for Norway crude oil price and OPEC production Granger cause production; and for the US investment needs and OPEC production Granger cause production. Moreover, in the long-run, in each of eight countries, all the explanatory variables Granger cause production. Therefore, in the long-run, the suggested explanatory variables can be used to forecast crude oil production by each non-OPEC producer countries and consequently to examine changes in future crude oil prices.

The conclusion is that, there is not a consensus regarding the non-OPEC producer countries' behavior. This conclusion is not unexpected, as they have wide diversity of geographical location, and economic, political, and social structures, which lead them to follow their own crude oil production policies.

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Chapter 4

4. Crude oil price modeling and short-term forecasting: a comparative survey

4.1. Introduction

Forecasting crude oil prices, as the largest demanded energy in the world, plays a crucial role on the world's economy, including of public and private sectors and households (Alquist et al., 2011). Public sectors such as central banks use crude oil price forecast to predict and prevent the macroeconomics factors' risks and to develop the appropriate economic policies. In addition, there are some private economic sectors that depend directly on crude oil price forecasts, in order to manage their business, such as airlines corporations that need crude oil price forecast to set their airfares; automobile companies need crude oil price forecast to choose their product menu and decide about product prices; and utility companies need crude oil price forecast for deciding about extending capacity or not; moreover, crude oil price forecasts are also important for households that need to decide about investment in energy intensive goods such as automobiles or new technologies for home air conditioning systems (Alquist et al., 2011).
Therefore, forecasting crude oil prices and its fluctuations is one of the most favorable subjects for energy researchers and economists and achieving to a reliable forecast is an important issue for a wide range of applicants.

Among the existing literature, there are a vast numbers of attempts and techniques to forecast crude oil prices; that we can classify in, a) time series methods, that forecast the price through using historical data based on ARIMA class of models (see Pindyck, 1999; Radchenko, 2005; Lanza et al., 2005; and Xie et al., 2006), and based on ARCH/GARCH class of models (see Kang et al., 2009; Cheong, 2009; Wei et al., 2010; Vo, 2009; and Mohammadi and Su, 2010); b) financial methods, which estimate the relationship among spot and future prices (see Bopp and Lady, 1991; Morana, 2001; Cortazar and Schwartz, 2002; Chernenko et al., 2004; Abosedra and Baghestani, 2005; Sadorsky, 2006; Coppola, 2008; Murat and Tokat, 2009; and Hung el al., 2011); and c) structural methods, which suppose crude oil price as a function of a group of fundamental explanatory variables, such as OPEC behavior (see Tang and Hammoudeh, 2002), petroleum inventory level (see Ye et al., 2002, 2005, 2006; and Merino and Ortiz, 2006), combination of inventory level and OPEC behavior models (see Dées et al., 2007; Kaufmann et al., 2008; and Chevillon and Christine, 2009), crude oil consumption and production (Mirmirani and Li, 2004; and Yang et al., 2005), and some non oil variables such as economic activity, interest rate, exchange rate, and other commodity prices (see Lalonde et al., 2003).

Our motivation to perform this study is to forecast crude oil price by developing innovative and comparative models, which increase the forecasting accuracy of the benchmark methods. For this purpose, we extend the existing literature via providing the short term monthly forecasts for the nominal spot price of Brent crude oil during the year 2008 and the year 2012. The reason of choosing these two years is due to the oil price boosts that occurred during 2008 and 2012.

Many quantitative and qualitative factors contributed to crude oil price increase during these two years. For instance, OECD spare capacity erosion, petroleum reserves decline and worries about peak oil, crude oil inventories levels, and speculation. Furthermore, some geopolitical events and natural disasters had strong but short term effects on crude oil prices' shocks, such as the US Katrina and the Gulf of Mexico hurricane in 2005, Nigerian turmoil in 2006-2008, Israel and Lebanon conflict in 2006, ongoing conflict in Iraq, and worries about Iranian nuclear plans.

Besides the mentioned factors, during 2002-2005 the majority of OPEC oil producers continued to adopt the policy of low production quota, and this strategy combined with insufficient non-OPEC countries' production. During this period, although supply has declined but demand has grown strongly that led to a boost in crude oil price during 2007 and 2008, when it rose from 60 US$ per barrel in August 2005 to 147 US$ per barrel in 2008. The price increscent continued until 2008, when the global recession appeared. The recession caused a decline in crude oil demand in the late 2008; consequently crude oil prices fell from 147 US$ per barrel in July 2008 to 32 US$ per barrel in December 2008.

Crude oil prices reached 75 US$ per barrel in November 2009, and 84 US$ per barrel in November 2010; however, price rose again to 105 US$ per barrel in November 2011 and to 113 US$ per barrel in April 2012. The most important geopolitical factors that contributed to the recent crude oil price boost during 2011-2012 were disruption of crude oil production in Libya due to the revolution, and global concern on Iranian nuclear program.

In order to achieve our goal, we develop several structural models to experimentally explain drivers behind crude oil price movements during the year 2008 and the year 2012, and compare their forecasting results, to understand which factors were the main reasons of the shocks. For this purpose, we apply an initial autoregressive model to forecast crude oil price as a benchmark, then we develop it through including different determinant factors and building nine extended forms models.

First, we develop four extended forms of the autoregressive models with including the relevant inventory level factor introduced by Ye et al. (2005), the Kilian index for global real activity proposed by Kilian (2009), the OECD industrial production index, and long positions held by non-commercials in the crude oil market as a proxy for speculation in this market. Next, we build five extended forms of the relevant inventory model with including the Kilian index, the OECD industrial production index, and speculation factors to the initial form of the relative inventory model. And at last, we compare the forecasting ability of the ten models to understand which of them generates better explanations for the price movements that occurred during 2008 and 2012. We generate short term monthly forecasts for one, three, six, nine and twelve months ahead.

This study is additive to the literature through various contributions. a) The first main contribution is due to the explanatory variables that we apply in order to build the structural models; for instance, most of the existing studies that perform structural models to investigate and forecast crude oil prices are based on crude oil consumption and production; however, forecasting the global crude oil consumption is a difficult task. Crude oil consumption for each country is a function of economic growth of that country and real crude oil price; therefore, in this study, we apply two indexes as proxies for crude oil consumption, one is the Kilian index for global real activity and another one is the OECD industrial production index. These indexes are provided in global scale; therefore, the results are more reliable than forecasting based on individual countries crude oil consumption. b) the second contribution is that, the role of speculation on crude oil price is mostly neglected among the relevant studies that we examine it in this study. c) the third contribution is related to the five multivariate models that we propose, they are innovative and never have been applied before in order to modeling crude oil prices. d) The fourth contribution is that, our study is comparative; the proposed univariate structural models that are based on the Kilian index, the OECD industrial production index, speculation and the relative inventory level can reflect the magnitude of share of each factor in price movements during the years 2008 and 2012. d) And the fifth contribution is analyzing, modeling and forecasting crude oil price during the years 2008 and 2012, while both years experienced oil shocks; however, as the years under study are very recent, this is the first study among peer reviewed ones that investigate crude oil price movements during these years.

We use monthly data from January 1988 to December 2012. The choice of starting date is due to the new market-related pricing mechanism for crude oil. Failing the OPEC administered pricing system in 1986-1988 led to a new pricing mechanism; the power to set crude oil prices shifted from OPEC to crude oil markets (Fattouh, 2011). Market-related pricing mechanism started in 1986 and was widely accepted by most of the crude oil exporting countries from 1988 to nowadays, it is the main oil pricing mechanism in international crude oil markets (Fattouh, 2011).

The rest of the paper has the following structure: section 4.2 extends the literature review; section 4.3 describes structure of the forecasting models; section 4.4 provides the forecasts evaluation results; and section 4.5 reveals the conclusion.

4.2. Literature review

In structural models, the crude oil price movement is a function of a group of fundamental variables. The explanatory variables that commonly used to explain the behavor of crude oil price are OPEC behavior, oil inventory level, oil consumption and production, and some non oil variables such as economic activity, interest rate, exchange rate, and other commodity prices. In this context, there are many studies that investigate crude oil prices based on fundamental variables and some of them explain the price movements fairly well; however, it does not mean that they show good forecasting performance, as there is limitation on availability for future values of the explanatory variables; therefore, due to the difficulties and complexities of structural models there is a small number of studies that performed structural analyses in order to forecast crude oil prices. Following, we categorize the structural models that are used to forecast crude oil prices based on five different models: *a)* OPEC behavior models, *b)* inventory models, c) combination of inventory and OPEC behavior models, d) supply and demand models, and e) non-oil models.

a) The OPEC behavior models

Tang and Hammoudeh (2002) perform an empirical investigation on OPEC attempts to control prices within a target zone model during the period from 1988 to 1999. They employ the basic target zone model proposed by Krugman and Miller (1992) which have been applied in oil market by Hammoudeh and Madan (1996). They use monthly spot the average basket price of seven types of OPEC members' crude oil products. During 1988-1999 still OPEC was not officially following a target zone policy, as the first price band was announced by OPEC in March, 2000. However, the authors state that there are evidences that OPEC supported target zone model during 1988-1999. They explain that, as oil is the major source of income for almost all OPEC member nations; hence, OPEC supports a lower limit for price; on the other side, high crude oil prices encourage investment by non-OPEC nations and reduce OPEC's market share; therefore, OPEC has a strong reason to put an upper limit on the price. According to this, they establish a crude oil price model based on production quotas, inventory levels and an expectation term, which is the expected rate of changing market price based on information available at the current time. The out-of-sample forecasting results suggest that basic target zone model offers good forecasting ability, the model performs well when price is approaching upper or lower band without any market jump and it shows a big forecasting error when the price is inside or outside of the band, this means that the model performs poor if there is a jump in the market.

b) The inventory models

Ye et al. (2002) declare a completely opposite condition with the target zone model that Tang and Hammoudeh (2002) describe for OPEC during 1990s. The authors state that during 1991-2001, OPEC did a little attempt to adjust production in order to accommodate changes in demand, and if the action was taken, it was not sufficient. Therefore, during this period prices showed a large volatility. In this study the authors focus on the position of OECD petroleum inventory level to forecast crude oil prices. They perform a short-run forecast on nominal WTI monthly spot prices. In this model, WTI spot price is a function of OECD relative petroleum inventory level, which is a deviation of actual inventories from the normal inventory level; the lower than normal OECD inventory level, which capture the asymmetric; price changes in response to changes in inventory when the inventory level is below the normal level; and the annual differences in monthly inventory. They use data from January 1992 to February 2001. The in-sample forecasting indicates that the model shows good forecasting performance.

Ye et al. (2005) modify the study of Ye et al. (2002). They predict short term one month ahead nominal WTI crude oil spot price by assessment the impact of the relative inventory level. In this model, the only explanatory variables is OECD industrial relative petroleum inventory level; moreover, September 11, 2001 terrorist attack and OPEC quota tightening at 1999 are dummy variables of the model. The authors exclude the lower than normal OECD inventory level variable from their new model as this variable increases the out-of-sample forecast error. They use monthly data from January 1992 to April 2003. They compare the results from the above relative stock model to benchmarks forecasting models: naïve autoregressive forecasting model, and modified alternative model. The in and out-of-sample evaluation criterias indicate that the relative stock model shows the best forecasting performance and the naïve model shows the poorest one.

Ye et al. (2006) extend the work by Ye et al. (2005) suggest a nonlinear model to forecast monthly nominal WTI crude oil spot prices. They declare that, the short-run crude oil prices are expected to behave differently when the inventory level is near to its lower band than when it varies around its mid-range, and this happens because inventory has a zero lower bound or some minimum operating inventory requirement. In this model inventory is split into the low and high inventory levels and price is a function of relative OECD industrial crude oil inventory level and nonlinear low and high inventory variables; moreover, 11 September 2001 terrorist attack and OPEC quota tightening in 1999 are dummy variables of the model. They use monthly data from January 1992 to October 2003 and they found that, the low inventory level variables are more significant than the high inventory level variables, this was expected because of the psychological effect of the low inventories, which leads to an asymmetric response: the price response to the low inventory is bigger that when the inventory level is high. The results indicate that the forecasting power of the new nonlinear model outperforms the previous simple linear model by Ye et al. (2005) in terms of the in and-out-of sample forecasting performance, especially when the inventory level is very low or very high. Merino and Ortiz (2005) extend the inventory model that was proposed by Ye et al. (2005). They use monthly data from January 1992 to June 2004; in the first step, the authors forecast crude oil price with using the initial inventory model proposed by Ye et al. (2005) and they obtain the price premium of this model, which is a deviation of estimated price from actual price. In this model, the relative OECD petroleum industrial inventory level is the only explanatory variable of the model. In the next step, the authors attempt to explain the price premium through testing the Granger causality between a group of variables with price premium and investigate the systematic information that each new variable can add to the original inventory model, these new variables contain a wide range of variables including the oil market variables and financial and commodity prices. The oil market variables contain backwardation (the difference between actual prices and future prices), speculation, OPEC spare capacity, the US gasoline relative inventory level, open interest, and the US refinery capacity. Among non oil variables, they choose the US interest rate, the US dollar/euro exchange rate, the US dollar exchange rate versus, spread, and non-energy commodity prices. They perform the Granger causality test among each of the mentioned variables with price premium during three spans, 1992-2004, 1996-2004 and 1999-2004. The results indicate that, there are Granger causality from speculation, OPEC spare capacity and the US gasoline relative inventory level to price premium; however, there is not causality from any of non oil variables to price premium. Consequently, in the last step, they estimate the three extended models to forecast crude oil prices. In model A, the relative OECD petroleum industrial inventory level and speculation are explanatory variables; in model B, the relative OECD petroleum industrial inventory level and OPEC spare capacity are explanatory variables; and in model C, the relative OECD petroleum industrial inventory level and the US gasoline relative inventory level are explanatory variables of crude oil price. They find that only speculation and crude oil prices are cointegrated or there is a long-run relationship among them; therefore, the only variable that adds systematic information to the model is speculation. As the result, they forecast the price with using model A, and compare its forecasting power with the initial inventory model of Ye et al. (2005). The result indicates that, models generate the same forecasts during 1992-2001; however, during 2001-2004 the extended model generates a better forecast, the only exception is during 2000-2001 that the extended model presents a worsen forecast than the basic model.

c) The combination of inventory and OPEC behavior models

Kaufmann (1995) proposes a Project Link model to describe world oil market during 1954 to 1989. He investigates the effect of economic, geological, and political events on crude oil prices. In this model, world crude oil price is a function of market condition and strategic behavior of OPEC. The key factors are OPEC and non-OPEC capacity utilization, OPEC capacity, OPEC share from the world crude oil production, and OECD inventory level; moreover, OPEC quota and 1974 oil shock are included as dummy variables. The results indicate that the model has good power to describe world oil market.

Kaufmann et al. (2004) investigate the impact of OPEC behavior on real crude oil prices. The authors examine Granger causality relationship between OPEC capacity utilization, OPEC quotas, OPEC members cheating from quotas, and days of forward consumption of OECD crude oil stocks that is calculated via dividing OECD crude oil stocks by OECD crude oil demand. Furthermore, they incorporate Persian Gulf War and seasonal dummies into the model. They use quarterly data from 1986 to 2000, and perform the cointegration test between variables that confirms the existence of a long-run relationship between real crude oil price and variables of the model; subsequently, the Granger causality test by Vector Error Correction Model (VECM) indicates that there are evidence of Granger causality from OPEC behavior variables to real crude oil prices but not vice versa.

Dées et al. (2007) examine the forecasting ability of the Kaufmann et al. (2004) model. The static and dynamic forecasting results from 1995-2000 display that forecasting performance of the model is fairly well and it is more depends to the time period and the volatilities in real crude oil prices that are caused by the exogenous shocks in that special time. The model performs well for the in-sample forecasting; however, it shows weak performance of the out-of-sample forecasting (2004-2006). This bias indicates that the model is suffering from the omitted variables that are responsible for the increase in crude oil prices among 2004-2006.

In order to develop this model and solve the problem of omitted variable bias, Kaufmann et al. (2008) extend the work by Dées et al. (2007) with including the US refinery utilization rate, non-linearity in supply condition and expectations to the existing model; however, they eliminate OPEC quotas from the model and fold cheating on OPEC quotas to the capacity utilization variable. They use a compiling observation on the price of the near month contract and the four month contract for WTI as a proxy for the expectations. Moreover, they update quarterly data from 1986-2006. The results indicate that explanatory variables Granger cause real crude oil prices very rapidly; and the one step ahead out-of-sample forecasting results show that the forecasting power of model is well and is able to account for much of the 27$ rise in crude oil price among 2004-2006. Finally the authors perform a forecast with the time series random walk model and a forecast based on future contracts as benchmarks; the results suggest that the structural econometric model produces more accurate forecasts than random walk or future markets.

And Chevillon and Christine (2009) assess the impact of physical market on the clearing price. In this study, the authors investigate determinant factors of real Brent crude oil spot price. They apply quarterly data from 1988 to 2005. In this model price is a function of six explanatory variables, including OECD and non-OECD demands, OPEC quotas, OECD and non-OECD stocks, and OPEC implicit target for real price; moreover, the first and the second Iraq wars, terrorist attack of September 11, 2001, and Afghan war are included as dummy variables of the model. To the best of our knowledge, this study is the first one that incorporates non-OECD inventory level to their price forecasting model. They perform a VAR analysis and concluded that worries alien to the physical market caused to increase in crude oil prices.

d) The supply and demand models

Yang et al. (2002) introduce a model to determine the variables that impact on the US crude oil price. Their model mainly focuses on OPEC production, real GDP of the US, and price and income elasticity of demand for crude oil in the US. They use monthly data from January 1975 to September 2000. The main purpose of this study is to investigate the world economy prosperity and recession effects on demand and consequently on crude oil prices. The authors apply GARCH model to describe volatility of crude oil price; then they perform a cointegration test and a VECM to investigate the short-run and the long-run relationships between crude oil demand with, crude oil price, real GDP, and natural gas and coal prices in order to identify the price and income elasticity of demand. In the next step, they perform a simulation of potential crude oil prices under different scenarios of OPEC production reduction, and conclude that in the case of OPEC production reduction, crude oil price will increase but the magnitude and extension of this increscent depends on the harsh of recession and increase of domestic production by the US or other non-OPEC producers.

Moreover, Mirmirani and Li (2004) perform a structural analysis to predict crude oil prices. For this purpose, the authors compare the VAR and the artificial neural network (ANN) methods to predict crude oil price. They use monthly data for light sweet crude oil future prices traded on NYMEX (lagged oil price), crude oil supply, petroleum consumption, and money supply as the explanatory variables of the model, covering the period from January 1980 to December 2002. The results prove that the ANN method outperforms the VAR approach.

e) The non-oil variables models

Lalonde et al. (2003) investigate the effects of the non-oil variables on real WTI crude oil spot prices. The authors apply quarterly data from 1974-2001. In this model, real WTI crude oil spot price is a function of world output gap[35] and the real US dollar effective exchange rate gap[36]; moreover, three dummy variables are included to the model, including Iranian 1979 revolution followed by Iran-Iraq war in 1980, mid 1980s collapse of OPEC discipline, and crude oil price collapse at 1986 as the result of ceasing the role of swing producer by Saudi Arabia in late 1985. The result indicates that the real US dollar effective exchange rate gap is not a significant variable; therefore, they exclude this variable from the model and include petroleum inventory level. The out-of-sample forecasting results show that the forecasting ability of this model outperforms the random walk and the autoregressive models benchmarks. However, the important point is that, the forecasting ability of the model excluding the inventory level is worsen that the two benchmarks.

4.3. Structures of the forecasting models

4.3.1. The autoregressive model (the AR model)

In the first step, we examine an autoregressive model as a benchmark; however, we extend the simple autoregressive model through including the political and economic events as dummy variables. The model is shown in equation (4.3.1):

$$Brent_t = \alpha_1 + \sum_{i=1}^{n} \beta_{1i} Brent_{t-i} + \gamma_1 DACRISIS + \delta_1 D911 + \theta_1 DGULF + \vartheta_1 DOPEC1 + \mu_1 DOPEC_2 + \varepsilon_{1t} \tag{4.3.1}$$

where Brent_t is the nominal spot price of Brent crude oil in month t, obtained from the EIA (2012) database, subscript i refers to the ith month prior to the tth month. DACRISIS refers to dummy variable for Asian crisis that occurred between July 1997 to December 1998, D911 refers to dummy variable for 11 September 2001, terrorist attack in the US that covers the period between October

[35] Difference between the world actual output and output at full capacity.
[36] Difference between the actual exchange rate and its equilibrium level.

2001 to March 2002, DGULF refers to dummy variable for the second Persian Gulf War or Iraq-Kuwait war, which started in August 1990 and occupation of Kuwait by Iraq continued until February 1991, DOPEC1 refers to dummy variable for the first OPEC tightening policy between February 1998 to November 1999, and DOPEC2 refers to dummy variable for the second OPEC tightening policy between January 2007 to December 2007. The best fit forecasting equation for this model is shown in table (42).

Table 42-Autoregressive model equation

Variables	Coefficient	Std. error	t-statistic
α_1	0.031	0.029	1.073
Brent(-1)	1.224	0.057	21.110*
Brent(-2)	-0.238	0.073	-3.246*
Brent(-4)	-0.102	0.054	-1.885***
Brent(-6)	0.109	0.036	2.954*
D911	-0.026	0.036	-0.725
DACRISIS	-0.070	0.024	-2.807*
DGULF	0.016	0.034	0.481*
DOPEC1	0.040	0.022	1.793***
DOPEC2	0.021	0.026	0.823
Adjusted R-squared	AIC	SBC	D-W
0.98	-2.041	-1.915	2.008

*and*** denote statistical significance at 1% and 10% levels, respectively.

AIC: Akaike Information Criterion.

SCB: Schwartz Criterion.

D-W: Durbin Watson test.

In the next steps, we investigate whether the alternative explanatory factors increase the predictive power of the benchmark autoregressive model. Therefore, we will examine nine extended forms models as below.

4.3.2. The relative inventory model (the RIN model)

Total petroleum inventory levels are the measures of interaction between petroleum production and consumption; they reflect the market presure on crude oil prices, and provide a reasonable indicator for changes in crude oil prices in the short-run (Ye et al., 2005). The contribution of inventory variable on crude oil price is developed in both theoretical studies (see Pyndick, 1994; Pyndick, 2001; Conisine and Larson, 2001) and experimental works (see Ye et al., 2002, 2005, 2006; Dées et al., 2003; Zamani, 2004; Merino and Ortiz, 2005).

However, our aim is to investigate the effect of the inventory level on crude oil price in the short term, in order to identify whether this factor improves the predictive power of the initial AR model, and compare its forecasting results with the ones obtained from the other models that are developed in this study.

For this purpose, we apply a relative inventory variable that is suggested by Ye et al. (2005). The authors explain that the normal or desired inventory level is determined by normal demand and normal supply; however, the relative inventory level responds to market fluctuations. In order to build this variable, first we de-seasonalize and de-trend the OECD total petroleum inventory level historical data to achieve the normal inventory level, as below:

$$IN_t^* = a_0 + b_1 T + \sum_{K=2}^{12} b_k D_k \tag{4.3.2a}$$

While the actual inventory level is:

$$IN_t^* = a_0 + b_1 T + \sum_{K=2}^{12} b_k D_k + u_t \tag{4.3.2b}$$

where IN_t^* is the normal inventory level in month t, IN_t is the actual inventory level in month t, T is the linear trend variable, D_k, *k*=2, 3,…, 12 are 11 seasonal dummy variables and u_t is the error term in month t. Moreover, a_0, b_1 and b_k , *k*=2,3,…,12 are the estimated coefficients that are obtained from de-seasonalizing and de-trending the observed total petroleum OECD inventory level. The relative inventory level is the difference between the normal and actual inventory levels, as below:

$$RIN_t = IN_t - IN_t^* = u_t \tag{4.3.2c}$$

where RIN_t is the relative inventory level in month t that reflects the short-run market fluctuations. The initial relative inventory model proposed by Ye et al. (2005) is a dynamic model that can be formulated as:

$$P_t = a + \sum_{i=0}^{k} b_i \, RIN_{t-i} + \sum_{i=0}^{5} c_j \, D_j 911 + dLARP99 + eP_{t-1} + \varepsilon_t \tag{4.3.2d}$$

where P_t is the price of crude oil in month t, subscript *i* refers to *i*th month prior to the *t*th month. $\mathrm{D_j}$911 is a set of dummy variables related to September 11, 2001 terrorist attack in the United States and LARP99 is a dummy variable related to OPEC quota tightening in April 1999. The relative inventory level should be negatively correlated to crude oil prices, as a positive relative inventory indicates that market is in an oversupply situation and the level of inventory is more than normal, and a negative relative inventory level identifies that market is in a tightening situation and the level of inventory is less than normal.

We depart from the Ye et al. (2005) model by including more exogenous factors, either political or economic events, as the new dummy variables introduced to the model. In order to build the relative inventory variable, we use the total petroleum stocks in OECD countries, which are obtained from the Monthly Energy Review, 2013. The RIN model is expressed in equation (4.3.2.e):

$$Brent_t = \alpha_2 + \sum_{i=1}^{n} \beta_{2i} Brent_{t-i} + \sum_{i=0}^{n} \emptyset_{2i} RIN_{t-i} + \gamma_2 DACRISIS + \delta_2 D911 + \theta_2 DGULF + \vartheta_2 DOPEC1 + \mu_2 DOPEC_2 + \varepsilon_{2t} \quad (4.3.2.e)$$

The best fit forecasting equation for this model is shown in table (43).

Table 43-RIN model equation

Variables	Coefficient	Std. error	t-statistic
α_2	0.026	0.028	0.925
Brent(-1)	1.214	0.055	22.009*
Brent(-2)	-0.301	0.058	-5.197*
Brent(-7)	0.082	0.022	3.609*
RIN	-2.333	0.536	-4.353*
RIN(-2)	2.414	0.545	4.427*
D911	-0.011	0.035	-0.319
DACRISIS	-0.054	0.024	-2.225**
DGULF	0.003	0.033	0.109
DOPEC1	0.023	0.023	0.978
DOPEC2	0.008	0.025	0.340
Adjusted R-squared	AIC	SBC	D-W
0.98	-2.103	-1.965	2.006

*and**denote statistical significance at 1% and 5% levels, respectively.

AIC: Akaike Information Criterion.

SCB: Schwartz Criterion.

D-W: Durbin Watson test.

4.3.3. The global real activity model (the KILIAN model)

It is well established in natural resource theory that low expected real interest rate and high real aggregate output lead to increase real oil price (Alquist et al., 2011).

In this section, our aim is to examine whether considering the real aggregate output increases the predictive power of the initial AR model for crude oil prices. To the best of our knowledge, the only available monthly proxy for the global aggregate output is the index of global real activity that is proposed by Kilian (2009). This index is built in order to measure fluctuations in the global demand for industrial commodities associated with the global business cycles; therefore, it does not depend on countries weights and is strictly global (Alquist et al., 2011), being constructed from ocean shipping freight rates (Kilian, 2009)[37]. The Kilian index should be positively correlated to crude oil prices.

Kilian and Murphy (2010) develop a structural model for the global price of crude oil based on oil production, the Kilian index for global real activity, the OECD inventory level and crude oil price; later Alquist et al. (2011) applied their model to forecast crude oil price. They find strong evidence of Granger causality relationship from the Kilian index to real crude oil price, which proves predictability of crude oil price by this index; however, their forecasting results specify that the Kilian index does not necessarily improve the prediction power of the models in all forecasting periods.

We extend the initial AR model that is shown in equation (4.3.1), with including the Kilian index in order to examine whether this index improves the forecasting ability of the AR model or not, and explore its predictive power in compare with other factors. The KILIAN model is shown in equation (4.3.3), KILIAN refers the Kilian index for global real activity:

$$Brent_t = \alpha_3 + \sum_{i=1}^{n} \beta_{3i}\, Brent_{t-i} + \sum_{i=0}^{n} \sigma_{3i} KILIAN_{t-i} + \gamma_3 DACRISIS + \delta_3 D911 + \theta_3 DGULF + \vartheta_3 DOPEC1 + \mu_3 DOPEC_2 + \varepsilon_{3t} \tag{4.3.3}$$

The best fit forecasting equation for this model is shown in table (44).

Table 44-KILIAN model equation

Variables	Coefficient	Std. error	t-statistic
α_3	0.034	0.029	1.154
Brent(-1)	1.199	0.057	20.872*
Brent(-2)	-0.280	0.060	-4.649*
Brent(-7)	0.073	0.023	3.179*
KILIAN	0.001	0.000	2.590**
KILIAN(-1)	-0.001	0.000	-1.921***
D911	-0.017	0.036	-0.486
DACRISIS	-0.067	0.024	-2.728**
DGULF	0.026	0.034	0.767
DOPEC1	0.051	0.023	2.206
DOPEC2	0.001	0.027	0.042
Adjusted R-squared	AIC	SBC	D-W
0.98	-2.061	-1.923	2.011

*,**and*** denote statistical significance at 1% , 5% and 10% levels, respectively.

[37] For further information about the Kilian index for the real global economic activity see Kilian (2009).

AIC: Akaike Information Criterion.

SCB: Schwartz Criterion.

D-W: Durbin Watson test.

4.3.4. The OECD industrial production model (the IP model)

The second proxy for global real activity is the world industrial production. The UN monthly bulletin of statistics provides global industrial production data for a short period from 2011 to 2013 that is not enough to this research. Therefore, instead of it we use the monthly data on industrial production index for OECD countries, provided by OECD, as a proxy for global real activity. This index should be positively correlated to crude oil prices. Alquist et al. (2011) examine the relationship between this index and crude oil price and find strong evidence of Granger causality relationship from the OECD industrial production index to the crude oil price, thus proving predictability of crude oil price from this index.

We extend the initial AR model (equation 4.3.1), by adding the OECD industrial production index, in order to examine whether this index improves or not the predictive power of the AR model, and compare the forecasting results with the other models. Let IP denotes the OECD industrial production index. The IP model is shown in equation (4.3.4):

$$Brent_t = \alpha_4 + \sum_{i=1}^{n} \beta_{4i} \, Brent_{t-i} + \sum_{i=0}^{n} \tau_{4i} IP_{t-i} + \gamma_4 DACRISIS + \delta_4 D911 + \theta_4 DGULF + \vartheta_4 DOPEC1 + \mu_4 DOPEC_2 + \varepsilon_{4t} \tag{4.3.4}$$

The best fit forecasting equation for this model is shown in table (45).

Table 45-IP model equation

Variables	Coefficient	Std. error	t-statistic
α_4	-0.821	0.274	-2.995*
Brent(-1)	1.126	0.057	19.689*
Brent(-2)	-0.264	0.057	-4.557*
Brent(-7)	0.101	0.022	4.550*
IP	4.042	0.818	4.939*
IP(-1)	-3.829	0.819	-4.674*
D911	-0.060	0.035	-1.714***
DACRISIS	-0.088	0.024	-3.655*
DGULF	0.078	0.034	2.283**
DOPEC1	0.017	0.023	0.731
DOPEC2	0.002	0.025	0.091
Adjusted R-squared	AIC	SBC	D-W
0.98	-2.141	-2.003	2.061

*,**and*** denote statistical significance at 1%, 5% and 10% levels, respectively.

AIC: Akaike Information Criterion.

SCB: Schwartz Criterion.

D-W: Durbin Watson test.

4.3.5. The speculation model (the SPU model)

There is an idea that the recent crude oil price fluctuations cannot be clarified only through petroleum market fundamentals-supply-demand-inventory levels; however, the increasing financialization of oil future markets played a crucial role on that (Fatthouh et al., 2012). Kilian and Murphy (2010) state that from the economic point of view, anyone buys crude oil not for current consumption, but for future use is a speculator. However, in reality there are two types of traders in crude oil future markets, (i) traders with commercial interest, such as oil companies and airlines, called hedgers, and (ii) non-commercial traders without physical position to offset, called speculators (Fatthouh et al., 2012), the second type is the one considered in this study.

In this model, we investigate whether speculation is a determinant factor of crude oil price and increases or not the predictive power of the initial AR model. In order to achieve this purpose, we include the long positions held by non-commercials in the crude oil market, obtained from the CFTC[38], as the speculation factor to the initial AR model. Let SPU denotes speculation factor. The SPU model is shown in equation (4.3.5):

$$Brent_t = \alpha_5 + \sum_{i=1}^{n} \beta_{5i}\, Brent_{t-i} + \sum_{i=0}^{n} \omega_{5i}\, SPU_{t-i} + \gamma_5 DACRISIS + \delta_5 D911 + \theta_5 DGULF + \vartheta_5 DOPEC1 + \mu_5 DOPEC_2 + \varepsilon_{5t}$$

[38] CFTC denotes US Commodity Futures Trading Commission.

(4.3.5)

The best fit forecasting equation for this model is shown in table (46).

Table 46-SPU model equation

Variables	Coefficient	Std. error	t-statistic
α_5	-0.298	0.057	-5.150*
Brent(-1)	1.145	0.058	19.71*
Brent(-2)	-0.263	0.062	-4.232*
Brent(-6)	0.096	0.051	1.854***
SPU	0.096	0.012	7.798*
SPU(-1)	-0.035	0.013	-2.736*
D911	-0.019	0.032	-0.588
DACRISIS	-0.053	0.022	-2.395**
DGULF	0.151	0.035	4.217*
DOPEC1	-0.031	0.022	-1.376
DOPEC2	0.011	0.023	0.502
Adjusted R-squared	AIC	SBC	D-W
0.98	-2.262	-2.111	1.972

*,** and*** denote statistical significance at 1%, 5% and 10% levels, respectively.

AIC: Akaike Information Criterion.

SCB: Schwartz Criterion.

D-W: Durbin Watson test.

4.3.6. The RIN-KILIAN model

In this model, we include the Kilian index for global real activity to the original relative inventory model (equation 4.3.2e), in order to examine how this index improves the predictive power of the relative inventory model and to compare its forecasting results with the other models. The RIN-KILIAN model is expressed in equation (4.3.6):

$$Brent_t = \alpha_6 + \sum_{i=1}^{n} \beta_{6i}\, Brent_{t-i} + \sum_{i=0}^{n} \emptyset_{6i}\, RIN_{t-i} + \sum_{i=0}^{n} \sigma_{6i}\, KILIAN_{t-i} + \gamma_6 DACRISIS + \delta_6 D911 + \theta_6 DGULF + \vartheta_6 DOPEC1 + \mu_6 DOPEC_2 + \varepsilon_{6t} \quad (4.3.6)$$

The best fit forecasting equation for this model is shown in table (47).

Table 47-RIN-KILIAN model equation

Variables	Coefficient	Std. error	t-statistic
α_6	0.034	0.029	1.193
Brent(-1)	1.178	0.055	21.09*
Brent(-2)	-0.278	0.058	-4.750*
Brent(-7)	0.092	0.023	3.883*
RIN	-2.383	0.534	-4.461*
RIN(-2)	2.349	0.540	4.347*
KILIAN	0.001	0.000	2.408**
KILIAN(-1)	-0.001	0.000	-1.589
D911	0.000	0.035	0.012
DACRISIS	-0.050	0.024	-2.054**
DGULF	0.013	0.034	0.407
DOPEC1	0.038	0.024	1.560
DOPEC2	-0.014	0.027	-0.538
Adjusted R-squared	AIC	SBC	D-W
0.98	-2.054	-1.868	1.958

*and**denote statistical significance at 1% and 5% levels, respectively.

AIC: Akaike Information Criterion.

SBC: Schwartz Criterion.

D-W: Durbin Watson test.

4.3.7. The RIN-IP model

In this model, we include the OECD industrial production index to the original relative inventory model (equation 4.3.2e), in order to examine how this index develops the predictive power of the relative inventory model, and compare its forecasting results with the other models. The RIN-IP model is shown in equation (4.3.7):

$$Brent_t = \alpha_7 + \sum_{i=1}^{n} \beta_{7i}\, Brent_{t-i} + \sum_{i=0}^{n} \emptyset_{7i}\, RIN_{t-i} + \sum_{i=0}^{n} \tau_{7i}\, IP_{t-i} + \gamma_7 DACRISIS + \delta_7 D911 + \theta_7 DGULF + \vartheta_7 DOPEC1 + \mu_7 DOPEC_2 + \varepsilon_{7t} \tag{4.3.7}$$

The best fit forecasting equation for this model is shown in table (48).

Table 48-RIN-IP model equation

Variables	Coefficient	Std.error	t-statistic
α_7	-0.778	0.296	-2.625*
Brent(-1)	1.108	0.058	18.991*
Brent(-2)	-0.202	0.070	-2.892*
Brent(-7)	0.132	0.029	4.581*
RIN	-0.178	0.292	-0.610
IP	3.916	0.833	4.700*
IP(-1)	-3.715	0.839	-4.427*
D911	-0.059	0.035	-1.675***
DACRISIS	-0.089	0.024	-3.662*
DGULF	0.079	0.034	2.293**
DOPEC1	0.024	0.026	0.914
DOPEC2	0.002	0.025	0.116
Adjusted R-squared	AIC	SBC	D-W
0.98	-2.138	-1.974	2.022

*,** and*** denote statistical significance at 1%, 5% and 10% levels, respectively.

AIC: Akaike Information Criterion.

SBC: Schwartz Criterion.

D-W: Durbin Watson test.

4.3.8. The RIN-SPU model

Merino and Ortiz (2005) examine the Granger causality relationship between speculations in the oil market, measured by non-commercial long positions, and price premium from the relative inventory model proposed by Ye et al. (2005), and find that this variable Granger causes price premium and improves the original relative inventory model.

In this study, we include speculation to the original relative inventory model (equation 4.3.2e), in order to observe how this factor impacts the predictive power of the relative inventory model and we compare its forecasting results with the other models. The RIN-SPU model is shown in equation (4.3.8):

$$Brent_t = \alpha_8 + \sum_{i=1}^{n} \beta_{8i}\, Brent_{t-i} + \sum_{i=0}^{n} \emptyset_{8i}\, RIN_{t-i} + \sum_{i=0}^{n} \omega_{8i} SPU_{t-i} + \gamma_8 DACRISIS + \delta_8 D911 + \theta_8 DGULF + \vartheta_8 DOPEC1 + \mu_8 DOPEC_2 + \varepsilon_{8t} \tag{4.3.8}$$

The best fit forecasting equation for this model is shown in table (49).

Table 49-RIN-SPU model equation

Variables	Coefficient	Std. error	t-statistic
α_8	-0.293	0.058	-5.035*
Brent(-1)	1.131	0.058	19.475*
Brent(-2)	-0.233	0.066	-3.493*
Brent(-4)	-0.078	0.042	-1.853***
Brent(-7)	0.084	0.027	3.110*
RIN	-0.807	0.657	-1.229
RIN(-1)	0.496	0.665	0.747
SPU	0.093	0.012	7.428*
SPU(-1)	-0.034	0.013	-2.667*
D911	-0.021	0.032	-0.670
DACRISIS	-0.055	0.022	-2.436**
DGULF	0.154	0.036	4.235*
DOPEC1	-0.020	0.024	-0.858
DOPEC2	0.010	0.023	0.465
Adjusted R-squared	AIC	SBC	D-W
0.98	-2.268	-2.092	1.95

*,** and*** denote statistical significance at 1%, 5% and 10% levels, respectively.

AIC: Akaike Information Criterion.

SBC: Schwartz Criterion.

D-W: Durbin Watson test.

4.3.9. The RIN-IP-SPU model

In this model, we include the OECD industrial production index and speculation to the original relative inventory model, in order to examine which model has a better predictive power and compare its forecasting results with the other models. The RIN-IP-SPU model is shown in equation (4.3.9):

$$Brent_t = \alpha_9 + \sum_{i=1}^{n} \beta_{9i}\, Brent_{t-i} + \sum_{i=0}^{n} \emptyset_{9i}\, RIN_{t-i} + \sum_{i=0}^{n} \omega_{9i} SPU_{t-i} + \sum_{i=0}^{n} \tau_{9i}\, IP_{t-i} + \gamma_9 DACRISIS + \delta_9 D911 + \theta_9 DGULF + \vartheta_9 DOPEC1 + \mu_9 DOPEC_2 + \varepsilon_{9t} \quad (4.3.9)$$

The best fit forecasting equation for this model is shown in table (50).

Table 50-RIN-IP-SPU model equation

Variables	Coefficient	Std. error	t-statistic
α_9	-0.233	0.291	-0.799
Brent(-1)	1.101	0.058	18.934*
Brent(-2)	-0.245	0.061	-3.980*
Brent(-6)	0.125	0.051	2.409**
RIN	-0.588	0.647	-0.907
RIN(-1)	0.178	0.665	0.268
SPU	0.089	0.012	7.030*
SPU(-1)	-0.032	0.013	-2.449**
IP	2.911	0.792	3.675*
IP(-1)	-2.931	0.795	-3.686*
D911	-0.023	0.033	-0.698
DACRISIS	-0.051	0.022	-2.261**
DGULF	0.167	0.036	4.624*
DOPEC1	-0.012	0.025	-0.497
DOPEC2	0.012	0.023	0.512
Adjusted R-squared	AIC	SBC	D-W
0.98	-2.289	-2.089	2.023

*and** denote statistical significance at 1% and 5% levels, respectively.

AIC: Akaike Information Criterion.

SBC: Schwartz Criterion.

D-W: Durbin Watson test.

4.3.10. The RIN-KILIAN-SPU model

In this model, we include the Kilian index for global real activity and speculation to the original relative inventory model, in order to examine which model fits better and improves the predictive power, and we compare its forecasting results with the other models. The RIN-KILIAN-SPU model is shown in equation (4.3.10):

$$Brent_t = \alpha_{10} + \sum_{i=1}^{n} \beta_{10i}\, Brent_{t-i} + \sum_{i=0}^{n} \emptyset_{10i}\, RIN_{t-i} + \sum_{i=0}^{n} \omega_{10i} SPU_{t-i} + \sum_{i=0}^{n} \sigma_{10i}\, KILIAN_{t-i} + \gamma_{10} DACRISIS + \delta_{10} D911 + \theta_{10} DGULF + \vartheta_{10} DOPEC1 + \mu_{10} DOPEC_2 + \varepsilon_{10t} \quad (4.3.10)$$

The best fit forecasting equation for this model is shown in table (51).

Table 51-RIN-KILIAN-SPU model equation

Variables	Coefficient	Std. error	t-statistic
α_{10}	-0.276	0.059	-4.625*
Brent(-1)	1.137	0.057	19.725*
Brent(-2)	-0.289	0.056	-5.132*
Brent(-7)	0.058	0.022	2.629*
RIN	-0.877	0.66	-1.329
RIN(-1)	0.539	0.665	0.810
SPU	0.09	0.012	7.191*
SPU(-1)	-0.034	0.013	-2.662*
KILIAN	0.001	0.000	1.688***
KILIAN(-1)	0.000	0.000	-1.223
D911	-0.016	0.032	-0.495
DACRISIS	-0.049	0.022	-2.188**
DGULF	0.154	0.037	4.176*
DOPEC1	-0.011	0.025	-0.467
DOPEC2	0.000	0.025	-0.032
Adjusted R-squared	AIC	SBC	D-W
0.98	-2.262	-2.073	1.977

*,**and*** denote statistical significance at 1%, 5% and 10% levels, respectively.

AIC: Akaike Information Criterion.

SBC: Schwartz Criterion.

D-W: Durbin Watson test.

4.4. Forecasting evaluation results

In this step, we assess the explicative degree of each model on crude oil price movements during our sample years: 2008 and 2012. For this purpose, we generate the out-of-sample short term forecasts of one month ahead, three month ahead, six month ahead, nine month ahead and twelve month ahead. To evaluate the forecasting ability of the above described models, we use the Root Mean Square Error (RMSE, henceforth) evaluation criteria.

The process of generating the out-of-sample forecasts starts by fitting the models from January 1988 to November 2008 and computing a one month ahead forecast for December 2008; the model is fitted from January 1988 to September 2008 and a three month ahead forecast from October to December 2008 is generated; the model is fitted from January 1988 to June 2008 and a six month ahead forecast from July to December 2008 is generated; the model is fitted from January 1988 to March 2008 and a nine month ahead forecast from April to December 2008 is generated; and the model is fitted from January 1988 to December 2007 and a twelve month ahead forecast from January to December 2008 is generated (see table 52). The same process is applied for the year 2012 (see table 53).

4.4.1. Forecasting evaluation results for the year 2008

We begin by analyzing the results for the year 2008, table (52). In the first step, we compare the forecasting ability of the four extended forms of the AR model, including the RIN, the KILIAN, the IP and the SPU models to the benchmark AR model. The RMSE evaluation results indicate that, the relative inventory level factor increases the forecasting ability of the AR model for all forecasting periods except the twelve month ahead. The Kilian index for global real activity and the OECD industrial production increase the forecasting power of the AR model for all forecasting periods; and the speculation in crude oil market increases the forecasting power of the AR model for all forecast periods except the one month ahead. Therefore, the RIN, the IP, the KILIAN and the SPU models definitely outperform the AR model. Among the mentioned extended forms models, the IP model generates the least RMSE for all forecasting periods except the twelve month ahead, case in which the KILIAN model shows the best forecast.

In the next step, we extend the relative inventory model by including more independent variables to conclude that the Kilian index and the OECD industrial production index increase the forecasting power of the RIN model for all forecasting periods; moreover, speculation increases forecasting ability of the RIN model for all forecast periods except the one month ahead. Therefore, the RIN-KILIAN, the RIN-IP and the RIN-SPU multivariate models outperform the univariate RIN model.

In the last step, we extend the RIN-KILIAN and the RIN-IP models by including the speculation factor. The results show that, including speculation decreases the forecasting power of both models for all forecasting periods except for the twelve month ahead forecast of the RIN-IP-SPU model.

Among the whole models, the IP model generates the best forecasts for the three and six month ahead, the RIN-IP model generates the best forecasts for the one and nine month ahead and the RIN-IP-SPU model generates the best forecast for the twelve month ahead. In contrast the SPU and the RIN models generate the worst forecasts for the one and three month ahead, respectively; and the benchmark AR model generates the worst forecasts for the six, nine and twelve month ahead.

As the conclusion of this section, the reason of surge in crude oil price that occurred at 2008 can be explained mainly by the increase of the world's industrial production proxied by the OECD industrial production. However, the inventories level and speculation show significant roles as well. In summary, during 2007-2008 OPEC producers continued the policy of low production quota and this strategy was combined with insufficient non-OPEC countries production. Although supply declined but demand increased strongly as a result of the boost in world industrial production, which led to a low level of inventories, these factors combined with high rates of speculation and caused a boost in price during 2007 and 2008.

These results are confirmed by figures (1-4) in appendix, show that crude oil prices in 2008 moved with the other factors; namely, with the OECD industrial production and the relative inventory level.

Table 52-2008 crude oil price short term forecasts

Models	1 month	3 months	6 months	9 months	12 months
	2008M12	2008M10-12	2008M07-12	2008M04-12	2008M01-12
AR	0.238	0.664	0.700	0.683	0.382
RIN	0.175	0.589	0.641	0.371	0.392
KILIAN	0.207	0.500	0.573	0.393	0.317
IP	0.077	0.288	0.363	0.285	0.373
SPU	0.295	0.640	0.554	0.394	0.351
RIN-KILIAN	0.196	0.534	0.564	0.378	0.331
RIN-IP	0.070	0.439	0.369	0.279	0.368
RIN-SPU	0.290	0.645	0.444	0.397	0.342
RIN-IP-SPU	0.179	0.579	0.464	0.352	0.310
RIN-KILIAN-SPU	0.280	0.650	0.576	0.406	0.369

4.4.2. Forecasting evaluation results for the year 2012

We continue the analysis with the presentation of the results for the year 2012, table (53). In the first step, we compare the forecasting ability of the four extended forms of the AR model, including the RIN, the KILIAN, the IP and the SPU models. The RMSE evaluation results indicate that, the relative inventory level factor increases the forecasting power of the AR model at the six and twelve month ahead forecasts, does not change it at the one month ahead and decreases it at the three and nine month ahead forecasts. The Kilian index for global real activity decreases the forecasting ability of the AR model for the one, six and twelve month ahead forecasts and increases it for the three and nine month ahead forecasts. The OECD industrial production index increases the forecasting power of the AR model for all forecasting periods except the twelve month ahead. And speculation increases the forecasting ability of the AR model for all forecasting horizons. Therefore, the IP and the SPU models strictly outperform the AR model; nevertheless, we did not find enough evidences to confirm that the RIN and the KILIAN models perform better than the AR model. Among the four mentioned univariate models, the SPU model outperforms the other models for the three, nine and twelve month ahead forecasts, and the IP and the RIN models outperform the other models for the one and six month ahead forecasts, respectively.

In the next step, we extend the relative inventory model by including other independent variables and we conclude that, the Kilian index increases the forecasting power of the RIN model for the three and nine month ahead forecasts, the OECD industrial production index increases the forecasting power of the RIN model for one, nine and twelve month ahead forecasts, and speculation increases the forecasting power of the RIN model for all forecasting periods except the three month ahead. Therefore, the only model that strictly beats the RIN model is the RIN-SPU model.

In the last step, we extend the RIN-KILIAN and the RIN-IP models by including the speculation factor. The results indicate that speculation increases the forecasting power of the RIN-IP model for the three, six and nine month ahead, and it increases the forecasting power of the RIN-KILIAN model for all forecasting periods expect the three month ahead. Therefore, the RIN-IP-SPU model outperforms the RIN-IP model and the RIN-KILIAN-SPU model outperforms the RIN-KILIAN model. This result is in contrast with the results of 2008 that showed speculation does not increase the forecasting power of the RIN-KILIAN and the RIN-IP models.

Among the whole models, the RIN-IP model generates the best forecasts for the one month ahead, the SPU model generates the best forecasts for the three and nine month ahead, and the RIN-IP-SPU model generates the best forecasts for the six and twelve month ahead. In contrast, the RIN-KILIAN, the RIN-IP, the KILIAN and the RIN models generate the worst forecasts for the one and twelve month ahead, the three month ahead, the six month ahead, and the nine month ahead, respectively.

In summary, the reason of the surge in crude oil price that occurred in 2012 can be explained mainly by speculation in crude oil markets, followed by the OECD industrial production and the relative inventory level.
The most important geopolitical factors that contributed to the recent crude oil price boost during 2011-2012 were disruption of crude oil production in Libya due to the revolution, and global concern about the Iranian nuclear program that have increased the possibility of Military action in the Middle East. In addition to the political causes, our results harshly confirm the role of speculation in crude oil market in 2012 price movements; while the roles of the OECD industrial production and the level of inventories cannot be denied as well.

This results show the increasing role of financial markets on crude oil price fluctuations. Therefore, in order to stabilize the price we recommend imposing more restrictions against growing financialization in the crude oil market.

As it is shown in appendix, figures 1-4, crude oil price at 2012 is not moving with the Kilian index; however, it is moving with the OECD industrial production and the relative inventory level and is moving more closely with speculation than other factors.

Table 53-2012 crude oil price short term forecasts

Models	1 month	3 months	6 months	9 months	12 months
	2012M12	2012M10-12	2012M07-12	2012M04-12	2012M01-12
AR	0.030	0.051	0.185	0.144	0.080
RIN	0.030	0.055	0.131	0.197	0.106
KILIAN	0.047	0.039	0.255	0.105	0.334
IP	0.011	0.047	0.149	0.102	0.082
SPU	0.020	0.021	0.143	0.085	0.079
RIN-KILIAN	0.068	0.047	0.233	0.117	0.364
RIN-IP	0.009	0.084	0.154	0.122	0.073
RIN-SPU	0.010	0.064	0.120	0.119	0.072
RIN-IP-SPU	0.014	0.066	0.102	0.126	0.072
RIN-KILIAN-SPU	0.024	0.057	0.167	0.099	0.158

4.5. Conclusion

The goal of this research is to develop several structural models to experimentally explain the drivers behind crude oil price movements during the year 2008 and the year 2012, and compare their forecasting results in order to understand, from the econometrics point of view, which are the main factors of crude oil price shocks.

For this purpose, we apply an autoregressive model as a benchmark, then we develop it by including different determinant factors and we build nine extended models. In the first step, we develop the autoregressive model by including the relevant inventory level, the Kilian index for global real activity; the OECD industrial production index, and long positions held by non-commercials in crude oil market as the proxy of speculation in crude oil markets, and we generate four univariate structural models. In the second step, we generate new models with combining the same variables and we build five multivariate structural models.

The results indicate that, although for both years, all the variables increase the prediction ability of the benchmark autoregressive model; however, 2008 crude oil price shock can be explained mainly by the surge in the OECD industrial production; and crude oil price movements in 2012 can be clarified mainly by speculation at crude oil market. Nevertheless, the roles of the other variables are significant as well. These results specify the increasing role of financial markets on crude oil price fluctuations. Therefore, in order to stabilize the price we recommend imposing more restrictions against growing financialization in crude oil markets.

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Appendix

Figure 1

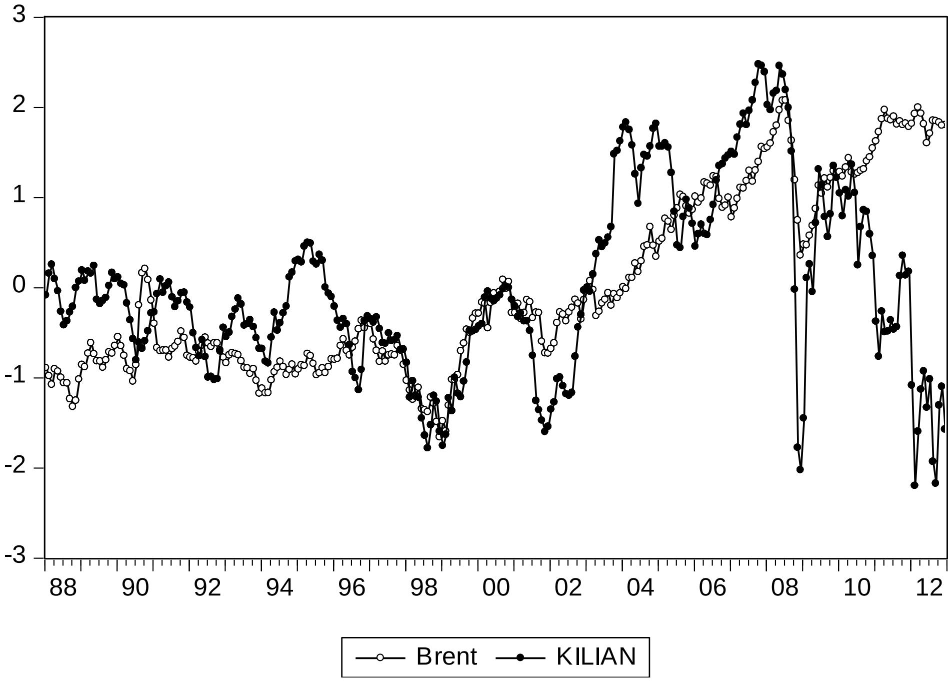


Figure 2

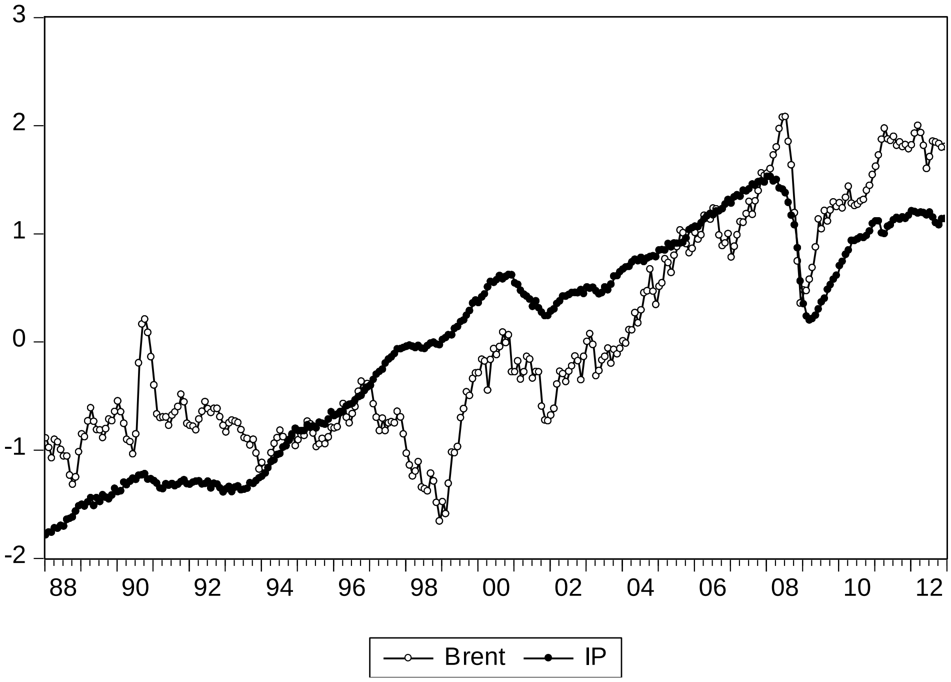


Figure 3

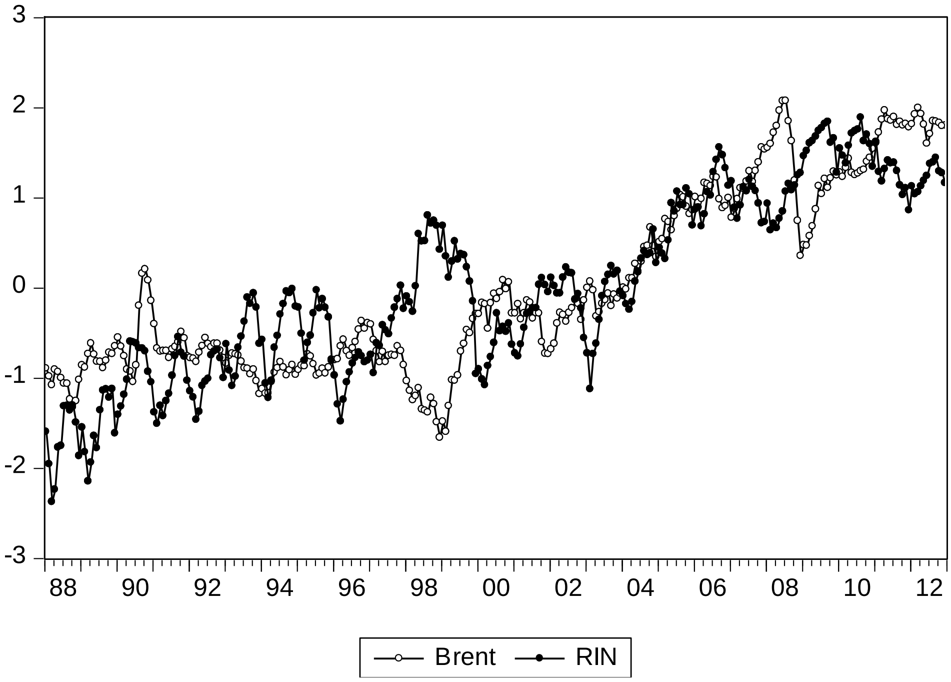
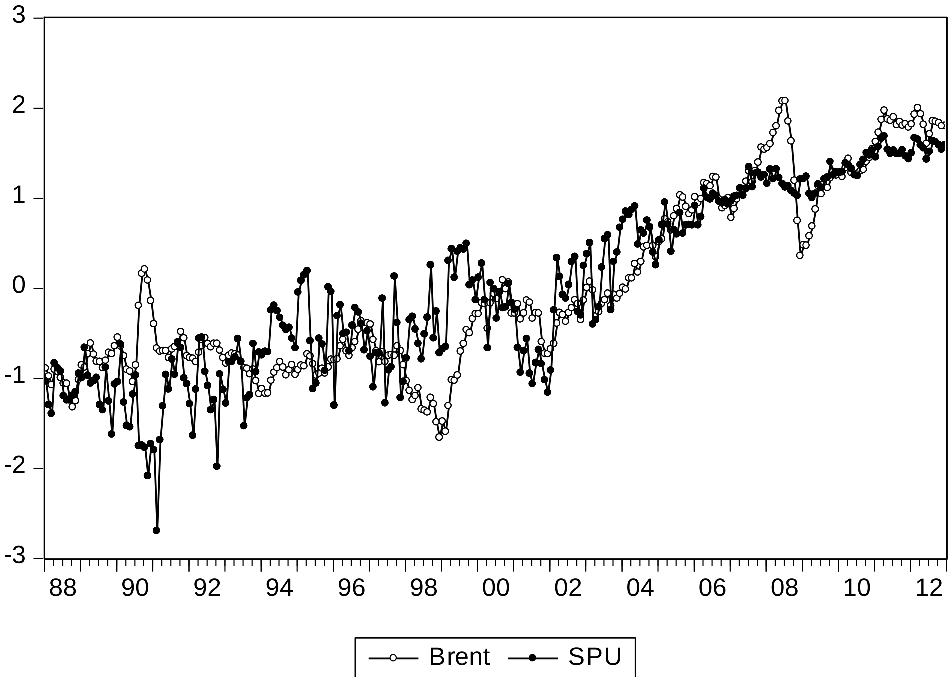


Figure 4



Chapter 5

5. Summary and future work

5.1. Summary

We have investigated the market for crude oil in a worldwide scale, including consumption and production sides in order to determine the drivers behind crude oil price fluctuations and forecasting the price. The results are reported in nine contributions to the literature: Bashiri Behmiri and Pires Manso (2012a); Bashiri Behmiri and Pires Manso (2012b); Bashiri Behmiri and Pires Manso (2012c); Bashiri Behmiri and Pires Manso (2012d); Bashiri Behmiri and Pires Manso (2013a); Bashiri Behmiri and Pires Manso (2013b); Bashiri Behmiri and Pires Manso (2013c); Bashiri Behmiri and Pires Manso (2013d) and Bashiri Behmiri and Pires Manso (2013e), which are grouped into three major categories:

5.1.1. Crude oil consumption-economic growth nexus: a worldwide investigation

The main goal of this chapter is to analyze the causality relationships between crude oil consumption and economic growth, using crude oil price as control variable of the model, in a regional scale.

There are two main purposes to investigate these relationships. The first one is to identify the main explanatory variables behind crude oil markets fluctuations and consequently behind price, in order to build the appropriate structural models to analyze crude oil price and finally to forecast it. The second one is to adopt and formulate the appropriate energy efficiency policies.

To achieve this goal, we apply the unit root and the cointegration tests and the VECM Granger causality approach to examine the Granger causality relationships between crude oil consumption and economic growth for Portugal in Bashiri Behmiri and Pires Manso (2012a), the results provide evidences of the existence of bidirectional causality relationships between the series in the short-run and in the long-run (thus supports the feedback hypothesis).

Moreover, we apply the panel unit root tests, the panel cointegration tests and the panel VECM approach in order to investigate the Granger causality relationships between crude oil consumption and economic growth, using different data panels, each one related to a different region. These data panels are the following: a panel of OECD countries in Bashiri Behmiri and Pires Manso (2012b), which reveal bidirectional causality relationships between crude oil consumption and economic growth in the short-run and in the long-run (thus supports the feedback hypothesis).

Panels of Latin American regions, divided in three panels: a panel of Caribbean, a panel of Central American and a panel of South American countries, in Bashiri Behmiri and Pires Manso (2012c), which show that among Central American countries in the short-run there is a bidirectional causality relationship between the series (thus supports the feedback hypothesis); however, in the long-run there is a unidirectional causality relationship running from crude oil consumption to economic growth (thus supports the growth hypothesis); moreover, among Caribbean and South American regions in the short-run there are bidirectional causality relationships between the series (thus support the feedback hypothesis); nevertheless, in the long-run there are unidirectional causality relationships running from economic growth to crude oil consumption (thus support the conservation hypothesis). A panel of MENA countries in Bashiri Behmiri and Pires Manso (2012d) that found evidences of the existence of bidirectional causality relationships among the series in the short-run and in the long-run (thus supports the feedback hypothesis). Panels of Sub-Saharan African countries, divided in two panels: a panel of net oil importing and a panel of net oil exporting countries, in Bashiri Behmiri and Pires Manso (2013a), which reveal that in panel of net oil importing countries there are bidirectional causality relationships between the series in the short-run and in the long-run (thus supports the feedback hypothesis); however, in panel of net oil exporting countries in the short-run there is a unidirectional causality relationship running from crude oil consumption to economic growth (thus supports the growth hypothesis) and in the long-run there is a bidirectional causality relationship between the series (thus supports the feedback hypothesis). And a panel of Southern and Eastern Asian emerging markets in Bashiri Behmiri and Pires Manso (2013b) that found evidences favoring of the existence of bidirectional causality relationships between the series in the short-run and in the long-run (thus supports the feedback hypothesis).

5.1.2. Crude oil production behaviors by OPEC member producers and non-OPEC producers

The main goal of this chapter is to examine the determinant factors, which impact on crude oil production of crude oil producer countries, including OPEC member countries, which is reported in Bashiri Behmiri and Pires Manso (2013c) and non-OPEC countries, which is reported in Bashiri Behmiri and Pires Manso (2013d).

The importance behind identifying the determinant factors of crude oil production in a worldwide scale is that, in a market-linked pricing mechanism, crude oil production is an explanatory factor for crude oil price; therefore, determining the variables that impact on crude oil production is essential in order to analyze crude oil market and to increase the forecasting accuracy of future crude oil prices.

In Bashiri Behmiri and Pires Manso (2013c) we investigate the determinant factors, such as economic and political events that impact on crude oil production of OPEC member countries, including Algeria, Indonesia, Iran, Nigeria, Saudi Arabia, Venezuela, Libya and Qatar. We propose an original crude oil production model for OPEC member producers and we apply the unit root

tests, the ARDL bounds testing approach for cointegration and the VECM Granger causality approach to examine it for each individual country.
Our multivariate model includes individual crude oil production as a dependent variable, and real crude oil price, production by the rest of OPEC members, OPEC quotas, and investment needs are the explanatory variables of the models for each country. Moreover, we consider a group of exogenous variables, such as economic, political and special events, that are specific for each individual country, as dummy variables of the models. The results indicate that there are long-run cointegrating relationships among the series for six of these countries; the exceptions are Indonesia and Saudi Arabia. Furthermore, there are evidences to show that each nation has a different production behavior and there is not a unique set of explanatory variables that can be suggested as the determinant factors of OPEC member countries' production.

Moreover, in Bashiri Behmiri and Pires Manso (2013d) we investigate the determinant factors that impact on crude oil production of non-OPEC producer countries, including Canada, China, Egypt, Mexico, Norway, the Russian Federation, the UK and the US. We develop an original crude oil production model for non-OPEC producers and we apply the unit root tests, the ARDL bounds testing approach for cointegration and the VECM Granger causality approach to examine it for each individual country.
Our multivariate model includes individual crude oil production as a dependent variable, and real crude oil price, crude oil production by OPEC member producers, investment needs and crude oil proven reserves are the explanatory variables of the models for each country. Furthermore, we consider a group of exogenous variables, such as economic, political and natural events, that are specific for each individual country, as dummy variables of the models. The results indicate that, there are long-run cointegrating relationships among the variables for each of the eight countries. Moreover, we conclude that each one of the countries have different production behavior, which are based on their geographical location and their economic, political and social structures and there is not a unique set of explanatory variables that can be suggested as the determinant factors of non-OPEC producer countries.

5.1.3. Crude oil price modeling and forecasting: a comparative study

Finally in Bashiri Behmiri and Pires and Manso (2013e) we develop various structural models in order to enhance the forecasting ability of a benchmark autoregressive (AR) model to forecast crude oil price in the short term. We provide the short term monthly forecasts for the nominal spot price of Brent crude oil for the years 2008 and 2012. We analyze the determinant factors that impact on crude oil price by developing nine structural models to explain the drivers behind crude oil price movements. At first, we develop four univariate models based on the relative inventory level, the Kilian index for global real activity, the index for OECD industrial production, and speculation.

Next, we build five multivariate models based on the combinations of the same explanatory factors.
The results indicate that, although for both years, all the variables increase the prediction ability of benchmark autoregressive model; however, there are strong evidences that the 2008 price shock mainly can be explained by the surge in OECD industrial production, and that the 2012 price movement mainly can be clarified better by level of speculation in crude oil market. Nevertheless, the roles of the other factors are significant as well.

To summarize, in this thesis we conclude that:

- Among different regions in the world, there is a bidirectional causality relationship between crude oil consumption and economic growth that supports the feedback hypothesis, or there is a unidirectional causality relationship running from crude oil consumption to economic growth that supports the growth hypothesis, or there is a unidirectional causality relationships running from economic growth to crude oil consumption that supports the conservation hypothesis.

  The first policy implication is related to the impact of crude oil consumption on economic growth in each region. Among the regions that support the feedback or the growth hypothesis in the long-run, policymakers should formulate and implement carefully oil conservation policies, taking in account that reduction of crude oil consumption has negative impacts on economic growth. Nevertheless, there are still some policies that decrease crude oil consumption without significant negative impacts on commodities production and economic growth levels, such as appropriate crude oil efficiency policies. Moreover, among the regions that support the conservation hypothesis in the long-run, policymakers can adopt crude oil conservation policies without concerning the negative effects on economic growth.

  The second policy implication is related to the impact of economic growth on crude oil consumption in each region. Among the regions that support the feedback or the conservation hypothesis in the long-run, economic growth is an explanatory variable of crude oil consumption and is useful to analyze it in the future; consequently, it is an explanatory variable to analyze future crude oil price fluctuations. According to the results of this study, among all the regions under investigation, except Central America, economic growth Granger causes crude oil consumption; reason why, global economic growth can be used as an explanatory variable to analyze future fluctuations of international crude oil prices.

- Each crude oil producer country has a different production behavior based on its domestic conditions; this applies to OPEC and non-OPEC producers. We recommend the adoption of punitive and incentive tools by OPEC as an international organization to oblige its member countries to follow the appropriate production behavior in order to stabilize crude oil prices. Moreover, countries domestic conditions are difficult to predict and change; therefore OPEC members' quota as an official criterion is a helpful variable to control and explain future fluctuations of international crude oil prices.

- 2008 crude oil price shock can be better explained by the surge in the OECD industrial production, and 2012 crude oil price movement can be better explained by increasing the levels of speculation in crude oil markets. These results show the increasing role of financial markets on crude oil price fluctuations; thus, we recommend more attention to these markets and the adoption of some restrictions on financialization of crude oil markets.

5.2. Future works

- In chapter 2 we develop crude oil consumption-economic growth nexus under panel frameworks. This work determined the possibility of reduction of crude oil consumption in a regional scale; however, the results for each single country are ambiguous. Thus, can be a subject for future studies.

- Moreover, in chapter 2 we only consider crude oil-economic growth relationship; however, this work should be extended to other sources of fossil fuels, including natural gas and coal as environmental polluters.

- In chapter 2 we examine the total crude oil consumption-economic growth nexus; however, still there is not a sectorial analyzes on this issue. Thus, the analysis could be extended to the four major sectors - industrial, transportation, households and agricultural sectors - since the reduction effects of crude oil consumption on growth in each sector is not always equal. A sectorial analyzes can be a subject for future studies in order to clarify in which sectors policymakers should be more concerned or in which sectors' reduction can be adopted without damaging the economic growth.

- In chapter 2 we conclude that increasing oil tax in order to reduce crude oil consumption can damage countries' economic growth; consequently we recommended the formulation of appropriate energy efficiency policies instead of increasing energy taxes. However, we did not discuss those policies yet. Chapter 2 can also be extended in order to include adequate sectorial analysis' policies, aiming to reduce crude oil consumption (or total energy consumption) without damaging economic growth, at a country level.

- In chapter 4 we examine the short term forecasting power of various proposed structural models for crude oil price, one to twelve months ahead; however, we did not examine yet the quality/capacity of our models for the long term forecasting. This issue can be done in future researches.