Climate Change Mitigation and OPEC Economies

A Thesis submitted for the degree of Doctor of Philosophy

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By

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Declaration

In accordance with the Regulations for Higher Degrees by Research, I hereby declare that the whole thesis now submitted for the candidature of Doctor of Philosophy is a result of my own research and independent work except where reference is made to published literature. I also hereby certify that the work embodied in this thesis has not already been submitted in any substance for any degree and is not being concurrently submitted in candidature for any degree from any other institute of higher learning. I am responsible for any errors and omission present in the thesis.

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Abstract

This thesis focuses on the relationship between the Organisation of Petroleum Exporting Countries (OPEC) economies and global climate change mitigation policies with a view to determining the energy exports demand security risks of OPEC member states. The successful implementation of a universally adopted climate regime has been marred with controversies as different interest groups have raised their concerns about all the options presented so far. OPEC as the major crude oil exporting group in the world has been in the forefront of these debates and negotiations. OPEC's major concern is the envisaged adverse impacts of the industrialised countries carbon reductions on its members' economies. Several studies have shown that when industrialised countries adopt carbon dioxide emissions reduction policies in line with the United Nations Framework Convention on Climate Change, such as carbon taxes and energy efficiency strategies, OPEC's net price of crude oil decreases at the same time as a reduction in the quantity of crude oil products sold. OPEC believes that such climate change policy-induced fall in crude oil exports revenues would have a significant negative effect on its members' economies.

With the limitations related to the assumptions of the existing energy economy models on the impacts of climate change mitigation policies on OPEC's economies (Barnett et al, 2004), this study opts for a risk based model. This model quantifies the energy exports demand security risks of

OPEC members with special interest on crude oil. This study also investigates the effects of carbon reduction policies on crude oil prices vis-à-vis the impacts of crude oil prices on OPEC's economies. To address these three main issues, this thesis adopts a three-prong approach.

The first paper addresses the impacts of climate change mitigation on crude oil prices using a dynamic panel model. Results from the estimated dynamic panel model show that the relationship between crude oil prices and climate change mitigation is positive. The results also indicate that a 1% change in carbon intensity causes a 1.6% and 8.4% changes in crude oil prices in the short run and long run, respectively.

The second paper focuses on the impacts of crude oil prices on OPEC economies using a panel vector auto regression (VAR) approach, highlighting the exposure of OPEC members to the volatile crude oil prices. The findings from the panel VAR model show that the relationship between OPEC members' economic growth and crude oil prices is positive and economic growth in OPEC member states respond positively and significantly to a 10% deviation in crude oil prices by 1.4% in the short run and 1.7% in the long run.

The third paper creates an index of the risks OPEC members face when there is a decline in the demand for their crude oil exports. To show these risks, this study develops two indexes to show the country level risks and the contributions to the OPEC-wide risks exposure. The results from the indexes show that OPEC members that are more dependent on crude oil exports are faced with more energy exports demand risks.

The findings from this thesis are relevant for the development of a new OPEC energy policy that should accommodate the realities of a sustainable global climate regime. They are also useful to the respective governments of the countries that are members of OPEC and non-OPEC crude oil exporting countries. Finally, the outcomes of this thesis also contribute to the climate change and energy economics literature, especially for academic and subsequent research purposes.

Dedication

This thesis is dedicated to God almighty, my creator and the source of my knowledge; for the gift of life, for all that I am and for all that I will ever be.

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Preface

1. Motivation for the Thesis

One of the unresolved issues in the global effort towards a sustainable climate regime is the extent to which the developed countries emissions reduction measures will impact on the economies of the oil exporting countries, and how these impacts can be minimised (Barnett and Dessai, 2002). The impact of the United Nation Framework Convention on Climate Change (UNFCCC) Annex 1 countries[1] climate change mitigation policy responses on the Organisation of Petroleum Exporting Countries (OPEC) crude oil exports is an issue that will make or mar the implementation of the existing or new global agreements on climate change mitigation.
Several energy economy models suggest that responsive policies and measures to the implementation of the Kyoto Protocol and subsequent climate change policies by developed and emerging economies will reduce their demand for fossil based fuels such as crude oil. The reduction in the demand for fossil fuels by Annex 1 countries, which account for 60% of world oil and gas consumptions, would also reduce the revenues received by the fossil energy producers and suppliers (Barnett and Dessai, 2002; Henman, 2002; Barnett et al, 2004).
This thesis focuses on the implications of the impacts of climate change mitigation policies on OPEC economies. With the recent extension of the

[1]Annex 1 parties include the industrialized countries that were members of the OECD (Organisation for Economic Co-operation and Development) in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States (UNFCCC, 2010).

UNFCCC’s Kyoto Protocol to a second commitment period, 2013 – 2020, (UNFCCC, 2012) and the controversy trailing the limitations of the assumptions of estimated energy economy models on the first commitment period, 2008 – 2012 (Barnett et al, 2004), it is necessary to model and measure the risk exposure of OPEC members to the potential decline in crude oil demand. The literature is saturated with studies on the impacts of climate change mitigation on developed countries but there is no study on modelling the risk that OPEC economies face as a result of decline in their major source of public sector revenues – crude oil.

Article 4.8 of the UNFCCC and Article(s) 2.3 and 3.14 of the Kyoto Protocol set the groundwork for this study. Article 4.8 of the UNFCCC commits parties to give full consideration to the actions that are necessary, including actions related to funding, insurance and the transfer of technology, to meet the specific needs and concerns of developing country parties arising from the adverse effects of climate change and/or the impact of the implementation of the response measures (UNFCCC, 2012). This UNFCCC’s Article focuses on countries whose economies are highly dependent on the incomes generated from the production, processing and export, and/or on consumption of fossil fuels (UNFCCC, 2012).

The scope of this study is limited to the review and analysis of the structure of OPEC economies, climate change mitigation policy options, the effects of climate change mitigation on crude oil prices, the impacts of crude oil prices on OPEC economies and the risk index of OPEC member states as a result of decline in external crude oil demand. The research questions are also tailored in accordance with the scope of the study with an attempt to empirically investigate the relationships therein. Therefore, this study attempts to answer the following questions:

- Does climate change mitigation affect crude oil prices?
- What are the effects of crude oil prices on OPEC economies?
- What is the OPEC country-level energy exports demand security risk?, and
- What are the contributions of OPEC members to OPEC's energy exports demand security risks?

2. The Structure of OPEC Economies and Climate Change Mitigation

OPEC economies are vulnerable to the effects of climate change as well as the adverse effects of the climate change mitigation measures (OPEC, 2012b). In order to determine the energy exports demand security risks in OPEC economies, it is very important to understand the structure of OPEC economies. This section of the study focuses on the structure of OPEC economies and their exposure to the impacts of climate mitigation measures. In line with Article 4.8 of the UNFCCC, OPEC expects the revenues from their crude oil exports to drop significantly as a result of the policies and measures adopted by the Annex 1 countries, who are the dominant importers of OPEC's crude oil.

2.1OPEC: Structure and Economy

OPEC's fossil energy exports account for about 42% of the global oil supply and over 25% of global natural gas supply (EC, 2003; OPEC, 2010; 2011). OPEC is presently made up of twelve countries (Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, and Venezuela). The economies of OPEC member states are heavily dependent on crude oil exports. The decision of OPEC to nationalise the major crude oil production activities in 1973 and the oil price conflict that followed suit marked the beginning of OPEC's influence as well as the dominance of crude oil exports in their total exports. Crude oil exports revenue also became their major source of government revenues after the 1973 global oil crisis.

The economic implications of OPEC's crude oil export revenues over the years have not been solely positive as most OPEC members have experienced macroeconomic instabilities. These are usually triggered by the exogenous development in the global oil market (Van der Linden et al 2000). The 1970s were periods of high energy incomes while the 1980s saw OPEC economies grappling with low energy incomes. This was followed by the recent era of high energy incomes that started in the late 1990s. Even in these times of high energy export incomes, there are periods of economic crisis as a result of energy price shocks as the global energy market is price based and the prices are affected by many factors.

After the 1973 oil crisis, the industry witnessed the entrance of many non-OPEC members as producers and exporters of crude oil and gas. This led to OPEC losing its overwhelming dominant position in the global oil market (Van der Linden, 2000). This loss of dominance made the OPEC cartel weak to the rival economic interests and unable to maintain a uniform policy. The ability of OPEC to determine the prices or secure a stable crude oil exports' income has been very difficult since then. Although, there is no universal agreement in existing studies on the direction of impacts concerning the relationship between oil exporting countries' economies and crude oil prices (Ghalayini, 2011; Mahmud, 2009; Rhoubini and Setser, 2004; Ghanem, 1999; Van der Linden et al, 2000; Stevens and Hulbert, 2012; Hamilton, 1983 and Darby, 1982), the levels of impact are expected to vary with respect to the countries as a result of the polarity in the structures of the economies. With the need for domestic investment and economic development, OPEC's dependence on crude oil exports incomes has also polarised the organisation. The only thing that is similar in all the economies is their seemingly overt dependence on crude oil exports revenues. A brief review and analysis of OPEC economies is presented below to show the polarity in the structure of their economies.

(i) Algeria

Algeria has a state-dominated economy which can be traced to the country's socialist post-independence development model (TWF, 2013). The country has been undergoing a liberalisation process since the late 1990s, which has been truncated frequently by the government. This has kept the economy in a quasi-open status. Recently, the government introduced fresh restrictions on the involvement of foreign investors in its economy and is increasingly hindering the process of privatization of the state-owned industries.

Just like other OPEC economies, petroleum has long been the mainstay of the economy and currently accounts for about 60% of budget revenues, 30% of the gross domestic product (GDP), and over 95% of export earnings (TWF, 2013). Algeria is presently the sixth largest exporter of natural gas and has the tenth largest reserves of natural gas in the world. It also has the 16th largest reserves of crude oil globally. Due to the increasing revenue from oil and gas, Algeria has a two hundred billion US Dollars ($200 billion) foreign currency reserves. The country also maintains an impressive budget stabilization fund. Algeria has an external debt burden, but it is very low (at about 2% of GDP) compared to other OPEC members. The Algerian government has an interest to develop other sectors of the economy apart from the energy sector, but has been faced with the challenges of high costs and an inert state bureaucracy (TWF, 2011). The efforts of the government to diversify the economy have also been facing diverse challenges as a result of lethargic participation by the domestic investors outside the energy sector. This development has affected the economy leading to rising poverty and youth unemployment rates. According to TWF (2011), Algeria began a five-year, $286 billion development program in 2010 to update the country's infrastructure and provide jobs. The programme which is seen by many as costly and would have an adverse impact on the country’s budget is expected to boost the economy in the long run. However, this ambitious economic development programme can only be successful if structural economic problems like the heavy dependence on the energy sector and state control of the economy are addressed.

(ii) Angola

Angola became a member of OPEC in 2006 to become the latest member of the apex crude oil exporting body. In 2007, it had an OPEC production quota of 1.9 million barrels per day against the expected 2.5 million barrels per day. Presently, in 2013, Angola’s production quota has dropped to 1.65million barrels a day. Angola’s economy has witnessed a high growth rate in recent years as a result of the high international crude oil prices. An increase in oil production over the years has sustained this growth and is equivalent to about 17% on the average per year from 2005 to 2008 (TWF, 2013). Currently, crude oil production and its subsidiary activities account for about 85% of the country’s GDP, diamond production and exports account for 5% and agriculture accounts for 10%.

As a country that is recovering from a protracted civil war, the reconstruction boom and resettlement of displaced persons has led to high rates of growth in construction and agriculture, as much of the country's infrastructure is still damaged or undeveloped from the 27-year long civil war (TWF, 2013).

In carrying out the reconstruction process, the Angolan government has sourced for billions of dollars in credit lines from China, Brazil, Portugal, Germany, Spain, and the European Union (EU) to rebuild the country's public infrastructure. As a result of the dependence on these foreign credits, lower prices for oil and diamonds among other reasons, the country's economic growth was affected by the recent global recession. In 2009, Angola witnessed a contraction in GDP and many construction projects were suspended because of an accrued nine billion US Dollars ($9 billion) in arrears to foreign construction companies when government revenue fell in 2008 and 2009 (TWF, 2011).

The government also abandoned its currency peg in 2009, and subsequently signed onto an International Monetary Fund (IMF) Stand-By Arrangement loan of $1.4 billion to rebuild international reserves (TWF, 2013). Angola's inflation rate, which fell from a massive 325% in 2000 to 14% in 2010 and 10% in 2012, has remained a modest double digit figure and the country's currency – Kwanza, depreciated again in 2010 (TWF, 2011) . The modest inflation rate, depreciated currency and rising oil prices are expected to drive the economic growth. However, the dependence on the energy sector and corruption are some of the major challenges that may affect the expected economic growth.

(iii) Ecuador

Ecuador is also heavily dependent on the energy sector as its petroleum exports have contributed over half of the country's total export earnings within the last five years. In recent years, crude oil exports have accounted for about 40% of the government revenues. With Ecuador's GDP contracting by approximately 5% in 1999, the country suffered a severe economic crisis which led to an increase in poverty level, collapse of the financial sector and a default on its external debt. As a response to the economic crisis, Ecuador adopted the US Dollar as its legal tender and the government introduced a series of structural reforms. The Dollarization of the Ecuador economy in 2000, high oil prices, remittances, and increased non-traditional exports stabilized the economy, and stimulated positive growth in the following years (TWF, 2012). Subsequently, the country's economy witnessed an average of 5.2% growth per year from 2001 to 2005, the highest five-year average in 25 years (TWF, 2008).

This economic turn-around was followed by continuous positive economic growths as a result of the rising oil prices and the improving public sector investments. According to TWF (2011), in December 2008 Ecuador defaulted on its sovereign debt of approximately US$3.2 billion, which represented about 80% of Ecuador's private external debt. Although, the country bought back 91% of its external debt defaults, its economy is currently facing lethargic reactions from private investors. In 2009, this development led to a GDP contraction of 0.4% due to uncertainty of the government policies, global financial crisis and sharp declines in global crude oil prices and remittance flows. However, the government estimates indicated a 3.3% economic growth rate in 2010 and 8% in 2011 before dropping to 4% in 2012.

(iv) Iran

Iran's economy is significantly dependent on crude oil exports and state controlled. Petroleum exports account for almost 90% of the government's revenues and about 85% of the total exports. The system of governance in the country has discouraged major private sector activities and existing private sector activities are usually small-scale in nature.

Apart from the governance related structural rigidities that have undermined the potential for substantive economic growth, the increasing international sanctions on Iran have also affected the economy adversely. Economic issues like subsidies, price control and product rationing among other issues are the drivers of the thriving informal market activities in Iran. The country's policy to reduce subsidies on food and energy, which has not been implemented for fear of public disenchantment and the rising inflation rate, is meant to introduce a system of wealth re-distribution in favour of the lower class.

The increased petroleum exports revenue as a result of the rising crude oil prices has cushioned the impacts of the recent international sanctions on Iran. Apart from the sanctions, the major economic challenges facing Iran are the rising double digit unemployment and underemployment (TWF, 2013).

(v) Iraq

With an improving security environment and a reconstruction boom, Iraq’s economy has attracted tremendous foreign investments. The ongoing economic activities, particularly in the energy, construction, and retail sectors have re-positioned Iraq on a near steady pace. However, expectations of the government’s introduction of major policy reforms on continued development of Iraq's massive oil reserves have stalled the entrance of more foreign investors. The foreign investors are also discouraged by the regulatory impediments and difficulties in acquiring land for projects. The country’s economy is dominated by the energy sector, especially crude oil, which accounts for over 85% of total exports, 90% of government revenue and 80% of foreign exchange earnings. As the civil crisis is gradually coming to an end, the crude oil export earnings and government revenues have bounced back to pre-crisis era levels, along with increasing global oil prices.

Iraq’s 2011 budget projected a crude oil exports quota of 2.4 million barrels per day and 2.6 million barrels a day in 2012, due to the return and influx of new international oil companies. The country is keen on boosting economic growth and is making modest progress in this regard. Recently, Baghdad has encouraged the improvement of the institutions needed to implement the ongoing reforms and economic policy. According to TWF (2011), Baghdad signed a new agreement with both the IMF and World Bank in 2010 for conditional aid programs that will help strengthen Iraq's economic institutions. With a reform-oriented government, the country is seeking to pass legislations as well to strengthen the economy. The proposed legislations would include laws to initiate a modern legal framework for the energy sector and a proactive mechanism to divide oil revenues equitably in the country. Iraq will need to upgrade its oil processing, pipeline, and export infrastructure to enable the recent deals and contracts with major oil companies to stimulate the expansion of its oil revenues.

The government's strategy is to boost additional foreign investments in the economy by amending the National Investment Law (NIL) to redefine the multiple international trade and investment negotiations as well as potential participation in joint ventures with state-owned enterprises (TWF, 2011). At the local level, the provincial councils are also using the local budgets to encourage and aid investments but these investments are stifled by inadequate infrastructure, insufficient essential services, widespread corruption, and obsolete commercial laws and regulations. These structural rigidities have continued to constrain the growth of private sector especially the non-energy sectors. The country's exchange rate controlled by the Central Bank has been effectively held at approximately 1,170 Iraqi Dinar per US Dollar since January 2009 and 1,166 Iraqi Dinar per US Dollar in 2012 (TWF, 2013). The level of inflation in Iraq has decreased consistently since 2006 as a result of the improved security situation. Apart from the structural rigidities mentioned above, the government would have to overcome the issues of unemployment and improve the diversification of the economy in order to translate the macroeconomic gains into improved lives for the citizenry.

(vi) Kuwait

Geographically, Kuwait is small and runs a relatively open economy. With a crude oil reserve of about 102 billion barrels - about 7% of world reserves, the country's economy is driven by the petroleum sector. Crude oil relatively accounts for about 50% of the GDP, 95% of total exports, and 95% of the government's revenue. According to TWF (2011), the Kuwaiti government is committed to increasing oil production to 4 million barrels per day by 2020. The economy of Kuwait has witnessed positive growths in 2010 due to the rise in oil prices. The increased earnings from crude oil exports have been stimulating the government consumption and economic growth. In 2010, Kuwait experienced about 20% rise in government budget revenues. Kuwaiti government has developed programmes to diversify its economy but has faced challenges from the poor business climate and the acrimonious relationship between the Legislative and the Executive arms of government, and the favourable positive fiscal situation over the years.

Although, these challenges have affected the economic reforms adversely, the government has renewed focus on the need to diversify the economy by passing a privatization bill that allows the government to sell assets to private investors, and in January, 2011 passed an economic development plan that pledges to spend up to $130 billion towards diversification within five years (TWF, 2011).

The Kuwaiti government has attracted more investment recently and is focused on stimulating the private sector participation in the economy. However, the ambitious nature of the programme would require more government expenditures.

(vii) Libya

The Libyan economy is heavily dependent on petroleum exports. Crude oil exports revenues contribute about 95% of exports earnings, 80% of the country's GDP, and 99% of government revenues. In 2009, Libya witnessed a decline in petroleum income and a constrained economic growth due to the sharp decline in global oil prices. Libya has one of the highest per capita GDPs in Africa as a result of the small size of the population and the significant revenue from crude oil. Although, Libya has a huge crude oil revenue base, the lower class of the population are not benefitting from this largesse. The country's efforts to stimulate further economic growth by introducing economic reforms have been relatively successful before the Arab Spring protests that ended Gaddafi's rule. The economic reforms were seen as part of a broader national campaign to reintegrate the country into the international fold (TWF, 2011). With the UN sanctions lifted in 2003 and Libya's resolve to abandon programmes to build weapons of mass destruction, the government concentrated on reinforcing the economic reforms. In 2006, all sanctions on Libya were removed, enhancing Libya's foreign direct investment, especially in the energy sector.

Before the recent revolution that started as a result of the Arab Spring in 2011, the Libyan National Oil Corporation (NOC) had set a goal of nearly doubling oil production to 3 million barrel per day by 2012. With the outcome of the Arab Spring, Libya's Transitional government faces a long road ahead in rebuilding the country and liberalizing the socialist-oriented economy. The non-oil manufacturing and construction sectors, which account for more than 20% of GDP, are expected to expand from processing mostly agricultural products to include the production of petrochemicals, iron, steel, and aluminium. The transition to a more market based economy would suffer some setback but already designed steps like applying for the World Trade Organisation (WTO) membership, reducing some subsidies, and announcing plans for privatization alongside the reconstruction process would herald the foundation for a transition to a more market-based economy.

Libya is expected to continue importing about 80% of its food due to the unfavourable climatic conditions and poor soils which have severely limited agricultural output.

(viii) Nigeria

Political instability, corruption, inadequate infrastructure, and poor macroeconomic management are the likely features to describe the Nigerian economy for the better part of the last three decades. However, since the transition from military to democratic rule in 1999, Nigeria has witnessed immense economic growth due to the aggressive pursuit of diverse economic reforms. Like other OPEC members, Nigeria's economy is dependent on the capital-intensive oil sector, which accounts for about 95% of its foreign exchange earnings and about 80% of its budgetary revenues. Nigeria received a favourable debt restructuring deal from the Paris Club and a $1 billion credit from the IMF, following the signing of an IMF stand-by agreement in 2000 (TWF, 2011). According to TWF (2011), Nigeria pulled out of this IMF program in 2002, after failing to meet spending and exchange rate targets, making it ineligible for additional debt forgiveness from the Paris Club.

However, the country won the Paris Club approval for a debt-relief deal that eliminated $18 billion of debt in exchange for $12 billion in payments - a total package worth $30 billion of Nigeria's total $37 billion external debt (TWF, 2011). In a bid to implement its market-oriented reforms urged by the IMF, the government introduced economic reforms such as modernizing the banking system, curbing inflation by blocking excessive wage demands, and resolving regional disputes over the distribution of earnings from the oil industry. The government is also on the brink of removing the petroleum subsidy but faces nationwide opposition led by the labour unions.

Nigeria's GDP has remained strong since 2007 primarily because of increased oil exports and high global crude oil prices, and the enhanced infrastructural development in the ongoing economic reforms. In Nigeria, the lack of adequate infrastructure is the main impediment to economic growth. In recognition of this problem, the government has focused on developing the power sector blueprint that includes privatization of the state-run electricity generation and distribution facilities. While the government is developing infrastructure, it is also working to strengthen the financial sector which was affected by the recent global financial and economic crisis, and working towards developing stronger public-private partnerships in all sectors of the economy, especially the agricultural sector.

(ix) Qatar

Qatar has the highest per-capita income ahead of Liechtenstein and one of the countries with the lowest unemployment rate (TWF, 2011). The country has been able to create wealth among its citizenry with the massive revenues from oil and gas exports. The oil and gas sector currently accounts for more than 50% of GDP, about 85% of export earnings, and 70% of government incomes (TWF, 2013). In 2010, Qatar had the world's highest economic growth rate despite the global financial crisis and fluctuating crude oil prices. During the global financial crisis, Qatari government sought to protect the local banking sector with direct investments into domestic banks (TWF, 2013). This ensured the protection of the country's economy from the crisis. Qatar's GDP has largely benefitted from the increase in global oil prices and the rising natural gas exports. The government's focus is on developing the country's non-associated natural gas reserves and stimulating private and foreign investments in the non-energy sectors. With oil reserves of about 25 billion barrels and natural gas reserves of over 25 trillion cubic meters - about 14% of the world's total gas reserves and third largest in the world, it is expected that Qatar's economy will continue to grow with output at current levels for the next 57 years (TWF, 2011). Qatar's economy is also expected to benefit from the likely constructions of large-scale infrastructure projects as a result of the country's successful 2022 world cup bid.

(x) Saudi Arabia

Currently, Saudi Arabia has a crude oil dependent economy with strong government controls over major economic activities (TWF, 2011). The Kingdom of Saudi Arabia is the largest exporter of crude oil and possesses about 17% of the world's proven crude oil reserves. The country is a major player in OPEC and the petroleum sector accounts for about 80% of the budget revenues, 45% of GDP, and approximately 90% of export earnings (TWF, 2013). In order to diversify its economy and create jobs for its citizenry, Saudi Arabia is encouraging private sector growth and focusing on power generation, telecommunications, natural gas exploration, and development of the petrochemical sectors.

The Saudi government has begun the establishment of six "economic cities" in different regions of the country to stimulate foreign investment and has a development plan that sees the country spending about $373 billion between 2010 and 2014 on social development and infrastructure projects to advance Saudi Arabia's economic development. Although, it employs over five million foreign workers in the oil and service sectors of the economy, unemployment of its nationals has become a major concern to the government. The government's policy thrust is to create employment for its large youth population, which generally lacks the education and technical skills the private sector requires (TWF, 2011).

(xi) United Arab Emirates (UAE)

According to TWF (2011), the UAE has an open economy with a high per capita income and a sizable annual trade surplus. The UAE's economy is also petroleum-based but recently, the government's efforts at diversifying the economy have reduced the portion of GDP that is based on oil and gas output to 25%. The UAE has undergone a profound transformation over the last three decades, from an impoverished region of small desert principalities to a modern state with a high standard of living since the discovery of oil in the country (TWF, 2011). In a bid to consolidate on its recent developmental strides, the UAE government has renewed its interest on job creation and infrastructure expansion which will open up utilities for more participation of the private sector. To further enhance the private sector involvement in the country's economy, the government signed a Trade and Investment Framework Agreement (TIFA) and agreed to undertake negotiations toward a Free Trade Agreement (FTA) with Washington. In the same vein, the country's Free Trade Zones (FTZ) offer 100% foreign ownership and zero taxes as a means to help attract foreign investors (TWF, 2013).

The country witnessed some financial challenges during the global financial crisis due to tight international credit and deflated asset prices. The global financial crisis led to a contracted economic growth in 2009 and 2010. However, since late 2010 and early 2011, the UAE economy began a gradual rebound as a result of the financial boost that the Dubai Investment firm (a real estate interest) received from the Abu Dhabi emirate and the rising crude oil prices.

The economy's slow rebound is expected to continue but would face some structural challenges. These structural challenges are continuous dependence on oil, dominance of the labour force by expatriates and growing inflation rates. According to TWF (2011), the UAE's government is expected to focus on the diversification of the economy and creating jobs and more opportunities for its citizenry through increased private sector employment and improved education system.

(xii) Venezuela

The petroleum sector accounts for about 95% of export earnings, 55% of the government's budget revenues, and around 30% of GDP in Venezuela (TWF, 2011). The country is highly dependent on crude oil revenues and has been recovering from a contraction in economic growth due to the sharp declines in oil prices in 2009. Apart from the decline in oil prices in 2009, the strong government control of the system has some economic consequences.

The rising crude oil prices in recent years combining with the increase in minimum wage and improved access to domestic credit led to a consumption boom, especially national imports in Venezuela. The consumption boom triggered off high rates of inflation, rising to 32% in 2008 and dropped to 30% in 2010, 26% in 2011 and 21% in 2012 (TWF, 2013). Recently, Venezuela's attempt to increase the government's control of the economy by nationalizing firms in the different sectors of the economy has affected the private investment environment, reduced productive capacity, and slowed non-petroleum exports. In January 2011, the government devalued the country's currency – the Bolivar, after twelve months of an earlier devaluation and introduction of a parallel foreign exchange rate market. The socialist state has continued to witness different level of intervention and full participation by the government in the different sectors of the economy. There are various laws passed recently by the Legislature before the death of the country's socialist leader, Hugo Chavez, to enforce some unorthodox economic policies. The country is currently grappling with the challenges of macroeconomic imbalances and varying sectoral crisis as a result of the prevailing economic policies. These economic crisis have led to a budget deficit of 17% of the GDP in 2012 and a public debt that has risen to 49% of the GDP in 2012 as well (TWF, 2013).

2.1.1 OPEC'S Crude Oil Exports and Economic Dependence

OPEC members' exports are dominated by oil and gas. The share of crude oil in OPEC's total exports has been massive since the 1970s as compared to natural gas, which became a significant OPEC export in the late 1990s. Table 1 below shows OPEC's total exports and petroleum exports values in 2010. Among the OPEC member states, Iraq has the highest share of petroleum exports in its total export value at 98% followed by Angola at 96% and the least is UAE at 37%.

Table 1: OPEC's Crude Oil Exports (Source: OPEC Annual Statistics Bulletin 2011)

OPEC Countries	**Value of Crude Oil Exports (Bn$)**	**Value of Exports (Bn$)**	**Share of Crude Oil exports in OPEC's total Export value (%)**
ALGERIA	38.30	57.8	66
ANGOLA	47.24	49.2	96
ECUADOR	9.65	17.37	56
IRAN	71.57	83.79	85
IRAQ	51.15	52.08	98
KUWAIT	61.67	65.98	93
LIBYA	41.87	46.31	90
NIGERIA	61.80	70.58	88
QATAR	29.28	72.05	40
SAUDI ARABIA	196.19	253.34	77
UAE	74.03	198.36	37
VENEZUELA	62.32	65.79	95

The revenues of OPEC member states are majorly from crude oil exports' income. Although, it varies, crude oil exports' income accounts for over 95% of the government revenues of most OPEC members. In 2010, the shares of energy exports' revenue in the country-level GDP for OPEC members are shown below:

Table 2: OPEC's Crude Oil exports share in the GDP (Source: OPEC Annual Statistics Bulletin 2011)

OPEC Members	**Value of Oil Exports (Bn$)**	**GDP (Bn$)**	**Share of Oil Exports in OPEC's GDP (%)**
ALGERIA	38.30	162.92	24
ANGOLA	47.24	85.31	55
ECUADOR	9.65	57.00	17
IRAN	71.57	357.22	20
IRAQ	51.15	125.90	41
KUWAIT	61.67	131.32	47
LIBYA	41.87	74.23	56
NIGERIA	61.80	193.67	32
QATAR	29.28	128.59	23
SAUDI ARABIA	196.19	443.69	44
UAE	74.03	269.10	28
VENEZUELA	62.32	295.96	21

From table 2 above, the contribution of crude oil exports to the OPEC GDP at country-level varies. Libya has the highest level of dependence at 56% while Ecuador has the least level of dependence at 17%.

The share of crude oil exports in the total OPEC exports and the crude oil export revenue per country as well as the contribution to the GDP indicate that OPEC member states are significantly dependent on crude oil exports. Therefore, these countries are expected to be vulnerable to fall in GDP, revenues and per capita income when the incomes from crude oil exports decline. With OPEC's dependence on crude oil exports and the envisaged vulnerability to the global crude oil price shocks, it becomes expedient for OPEC to be considered in developing, designing and implementing global climate change mitigation policies and measures. It is expected that the existing climate change mitigation policies and measures would further undermine the ability of OPEC to influence the global energy market as OPEC market share in the global supply of crude oil is expected to decline as well.

2.2Climate Change Mitigation and Crude Oil Importing Countries

The countries listed in the UNFCCC Annex 1 document represent about 24 countries that are members of the Organisation for Economic Cooperation and Development (OECD), therefore, this paper focuses on OECD countries in describing the crude oil importing countries or Annex 1 countries.

OECD countries account for about 60% of the global crude oil consumptions and are major players in the international oil market. With consumption in other parts of the world like China and India growing, this figure may drop but OECD member states would still be the major importers of crude oil. Table 3 below shows the share of OPEC's crude oil supplies in the world crude oil imports by OECD countries.

Table 3: OPEC's Crude Oil supplies share in OECD countries (Source: OPEC Annual Statistics Bulletin 2011; EIA, 2012)

Countries	2010 OPEC Crude Oil Supplies(1,000 b/d)	2010 Total World Crude Oil Imports	Share of OPEC's Exports (%)
North America	5,100	9,953.4	51.2
Europe	3,068	11,718.6	26.2
Asia and Pacific	11,546	17,163.0	67.3*
Latin America	661	2,166.1	30.5
Africa and Middle East	694	1,473.1	47.1
Total World	**23,112**	**42,474.2**	**54.4**

*including Japan which is an OECD country

With these figures in table 3 above and the significant stake these OECD countries control on the demand side of the global crude oil market, a reduction in consumption of and demand for crude oil by OECD countries will have significant economic impacts on the crude oil exporting countries.

Since crude oil consumption has been universally recognised as one of the most significant sources of carbon emissions in the world, various policies and measures are adopted to curb crude oil related carbon emissions. Among these measures, adoption of technologies to enhance energy efficiency has been most popular and could be more effective. The application of energy efficiency oriented technologies that enhance switching from crude oil consumption to natural gas or to other low emission sources and renewable energy sources are currently in use in

OECD countries while advanced technologies such as the carbon capture and storage (CCS) are being considered as well. According to the EU in a European Commission's communication titled 'Winning the battle against Climate Change', the importance of a country-level portfolio of climate change policies and energy efficiency related technologies is emphasized. Apart from climate change mitigation, security of energy supply is also as a chief concern in OECD energy equation as presently demonstrated by the OECD countries' energy policies. In the long term, fossil energy depletion based on the oil peak theory and the concentration of the reserves and production of fossil energy resources in politically unstable regions of the world (TWF, 2010) are expected to affect the security of energy supply. While the quota of fossil fuels in the energy supply portfolio may affect the possibilities of carbon emissions in the short term, policies for long term supply security will however seek to reduce the consumption of imported crude oil and encourage low carbon energy sources in the OECD countries.

Several studies have listed some energy efficiency technologies that will simultaneously contribute to curbing greenhouse gas emissions (Berk et al 2006, Bardley and Lefevre 2006). According to the IEA (2006), these adopted technologies and their contribution to the global greenhouse gases emissions reduction by 2050 are as follows;

Improved energy efficiency measures will account for about 31-53% greenhouse gases emissions reduction, while carbon capture and storage will account for about 20-28% of greenhouse gases emissions reduction, fuel switching will account for about 11-16% greenhouse gases emissions reduction, renewable energy sources will account for about 16% greenhouse gases emissions reduction, nuclear energy will account for about 2-10% greenhouse gases emissions reduction and biofuels in the transportation sector will account for about 6% greenhouse gases emissions reduction.

With a massive crude oil demand portfolio by OECD members as shown above, the OECD countries, are keen to implement their climate change mitigation policies like the Kyoto Protocol greenhouse gases emissions reduction targets with some countries raising the bar above the original Kyoto Protocol's allocated targets.

2.2.1 Climate Change Mitigation: the Kyoto Protocol's Influence

At the third session of the Conference of Parties (COP) to the UNFCCC in 1997 at Kyoto – Japan, greenhouse gases emissions reduction targets were agreed for OECD member states (i.e. the annex 1 countries) from 2008 – 2012 as the first commitment period (Kyoto Protocol's targets have been extended to a second commitment period, 2013 – 2020, while efforts are made to achieve a universal and all inclusive climate change mitigation agreement). Based on the reference year – 1990, it was agreed that the US reduction target would be 7%, the EU reduction target would be 8% and Japan's reduction target would be 6%. Hence, the Kyoto Protocol established these mandatory and enforceable targets for greenhouse gases emissions reduction. The general emissions target for the participating countries range from –8% to +10% of 1990 levels and the overall reduction goal is 5% below the 1990 level from 2008 to 2012 (UNFCCC, 2013a). The Kyoto Protocol is hinged on three greenhouse gases emissions reduction mechanisms**.** These mechanisms are the joint implementation mechanism, clean development mechanism and emissions trading mechanism. The joint implementation mechanism involves one country receiving emissions reduction credits for implementing projects that reduce emissions or sequester carbon in another country that has an emission limit. For example, The Netherlands is implementing carbon (CH4) capture projects in Germany (UNFCCC, 2013b). The clean development mechanism allows countries with emission limits (majorly Annex 1 countries) to receive greenhouse gases emissions reduction credits for implementing projects that reduce emissions or sequester carbon in another country that does not have an emission limit. For example, Finland is receiving credits for developing biomass-based power plants in India and Italy is receiving credits for developing a natural gas based Independent Power Plant (IPP) project in Nigeria (UNFCCC, 2013c). The emissions trading mechanism distributes permits equal to an allowed level of emissions to each country. The countries or parties with emissions level below their specified allowances are expected to dispose off their excess permits through sales to other countries or parties that are emitting above or exceeded their emissions allowance (UNFCCC, 2013d).

2.2.2 Climate Change Mitigation Strategies

In OECD countries, especially the major crude oil consumers, there are strategic plans and policies to mitigate climate change and chief among these plans is the reduction of fossil energy consumption. While it is expected that this strategy - reduction of fossil fuel consumption, will lead to a significant fall in demand for OPEC crude oil exports, there are other strategies that may not affect the demand for petroleum products. Some of the strategies adopted by the OECD to reduce greenhouse gases emissions are the Market-Based Strategies and the regulatory strategies. The market-based strategies or instruments include tradable carbon permits, emissions taxes and subsidies for renewable fuels. Most OECD countries have adopted the tradable carbon permit system as a means to achieve their greenhouse gases emissions reduction targets. The tradable carbon permits system earlier mentioned as one the Kyoto Protocol's mechanisms, allows a country or party to continue with some level of emissions which are specifically distributed by the country or party. Tradable emissions permits are presently traded on the Chicago and European Climate Exchanges and have the potential to reduce emissions in a cost-effective way. Tradable permits system emphasises on energy efficiency and eventual decline in fossil energy consumption levels in the OECD countries. Emissions taxes are introduced in different sectors of the economy for the emissions of greenhouse gases above certain atmospheric level. The most effective sector has been the transportation sector. This approach has a multiplier effect which lead to the reduction of fossil energy consumption.

Subsidies on the production of renewable energy are used to reduce the impacts of the costs of renewable energy on the consumers while encouraging them to reduce their consumption of fossil energy.

The regulatory strategies are the non-market approaches adopted by some OECD countries in order to achieve their greenhouse gases emissions reduction targets. They include technology and performance standards, direct government investments, product bans, and non-tradable permits. For instance, in the US, the household appliance performance standards and the corporate average fuel economy (CAFE) standards for vehicles, administered by the National Highway Traffic Safety Administration (NHTSA) fall into this category. Recently, the US environmental protection agency (EPA) and the NHTSA proposed a joint rule to combine the EPA's greenhouse gases emissions standards and CAFE's standards that require vehicles to reduce their average carbon dioxide (CO2) emissions level to 250 grams of CO2 per mile or 35.5 miles per gallon. This proposal was sequel to 2007 ruling by the US Supreme Court, that the environmental protection agency (EPA) can regulate CO2 emissions from mobile sources under the clean air act. As a major importer of oil and gas among the OECD member states, it is important to understand the US government's approach to reducing greenhouse gases emissions.

3. OPEC and the Kyoto Protocol Debate

The debates and deliberations for the measures and policies with which to achieve the greenhouse gases reduction targets agreed in Kyoto and the self-imposed targets have been going on over the years. The fossil based energy exporters have been sticking to Article 4.8 of the UNFCCC in their quest to mitigate or alleviate the impact of the climate change mitigation on their economies. Among these countries, OPEC, comprising of twelve crude oil exporting countries, has been leading this debate. Though OPEC was not chosen to lead this group but its organised nature, history and the economic dependence of its member states on fossil energy exports have made their voice louder than non-OPEC exporting countries (Barnett et al 2004).

OPEC has been very influential in this regard. The UNFCCC article 4.8 states that; in the implementation of policies (and measures) aiming at a reduction of greenhouse gases emissions, the Parties shall give full considerations to actions that are necessary under the Convention, including actions related to funding, insurance and the transfer of technology, to meet the specific needs and concerns of developing country Parties arising from the adverse effects of climate change and/or the impact of the implementation of the response measures, especially on small island countries; countries with low-lying coastal areas; countries with arid and semi-arid areas, forested areas, and areas liable to forest decay; countries with areas prone to natural disasters; countries with areas liable to drought and desertification; countries with areas of high urban atmospheric pollution; countries with areas with fragile ecosystem, including mountainous ecosystems; countries whose economies are highly dependent on income generated from the production, processing and export and/or on consumption of fossil fuels and associated energy-intensively products; and land-locked and transit countries

OPEC members have continuously emphasised with reference to Article 4.8 that countries implementing their greenhouse gases emission reduction policies, especially OECD countries, should take note of the adverse impacts of their actions on the oil and gas revenues of its member states. This has made OPEC members to be cautious about the global efforts to implement climate change mitigation policies especially the Kyoto Protocol’s emissions reduction targets.

However, some non-Annex 1 countries in the same category with OPEC have embraced the efforts towards the implementation of climate change mitigation policies. This group of non-Annex 1 countries see the efforts to mitigate climate change as an opportunity to enhance the efficiency of their energy sectors and enhance positive economic growth. Because of this hindsight, they have adopted a more positive attitude and approach towards climate change mitigation measures. With some countries having a different interest from OPEC, the non-Annex 1 countries as a whole have not been able to form a coherent group on climate negotiations.

4. Conclusions

This section reviewed the motivation for the study, the structures of OPEC's economies with reference to their dependence on fossil energy exports revenues, climate change mitigation strategies and why the OECD countries that are Annex 1 countries are keen on reducing their fossil fuel consumptions as a means to reducing greenhouse gases emissions. The Kyoto Protocol's influence as a supplement to the UNFCCC and major driver of global climate change mitigation has made it the basis of all climate negotiations. While OPEC members seek to continue to legitimately make a case for the economies of the fossil energy exporting countries, the OECD countries have developed strategies to meet their greenhouse gases emissions reduction targets in line with the Kyoto Protocol.

This section has also shown the relationship between OPEC and climate change mitigations on the one hand and OECD and climate change mitigations on the other hand. However, this section is based on qualitative analysis and it is recommended that a quantitative analysis be carried out to determine the impacts of climate change mitigation strategies on OPEC economies.

5. Structure of the Thesis

This thesis is a four section study that covers the scope of work and attempts to answer the research questions raised above. Following the motivation for the thesis and structures of OPEC economies in this section is the paper on “the impacts of climate change mitigation on crude oil prices” in section two, while the paper on “the impacts of crude oil prices on OPEC economies” comes up in section three and finally, the paper on “the analysis of the measure of OPEC’s oil and gas demand security risk” is presented in section four.

The paper on the impacts of climate change mitigation on crude oil prices empirically investigates how climate change mitigation affects crude oil prices while using carbon intensity as the indicator for climate change mitigation. The relationship between crude oil prices and carbon intensity is estimated using an Arellano and Bond GMM dynamic panel model. This study undertakes a regional-level analysis because of the geographical similarities among the countries in a region. Regions considered for the study are Africa, Asia and Oceania, Central and South America, the EU, the Middle East and North America. Results show that there is a positive relationship between crude oil prices and carbon intensity, and a 1% change in carbon intensity is expected to cause about 1.6% change in crude oil prices in the short run and 8.416% change in crude oil prices in the long run while the speed of adjustment is 19%.

The paper on the impacts of crude oil prices on OPEC economies investigates the relationship between OPEC's economic growth and crude oil prices. The relationship between economic growth and crude oil prices has received enormous attention in the literature. However, there are diverse views about the causality and nature of this relationship. The purpose of this paper is to investigate how economic growths in crude oil exporting countries are affected by changes in global crude oil prices using a panel vector auto regression (VAR) approach. This paper examines the response of economic growths in the Organisation of Petroleum Exporting Countries (OPEC) member states to changes in crude oil prices. Findings in this paper show that changes in crude oil prices in the period under considerations positively and significantly affect economic growths in OPEC member states. The findings emphasise the role of economic policies in insulating OPEC economies and other oil exporting countries from changes in crude oil prices.

With the establishment of empirical evidence that climate change mitigation affects crude oil price and that there is a transmission of this effect on OPEC economies, the last paper on "the analysis of the measure of OPEC's oil and gas demand security risk" determines the risk index of OPEC members as a result of decline in crude oil and gas demand. One of the policy objectives of the Organisation of Petroleum Exporting Countries (OPEC) is the security of the crude oil exports of its members. Achieving this objective has become imperative with the projected decline in the global crude oil demand as a result of the looming global warming concerns. This paper focuses on determining the external crude oil demand risk of OPEC member states. The study introduces two indexes designed to evaluate the short term risks associated with the external demand of OPEC crude oil and gas exports and the contribution of the member states to the OPEC risk exposure. The first index, Risky External Energy Demand (REED), indicates the level of energy export demand risk for the OPEC member states. It combines measures of export dependence, economic dependence, monopsony risk and transportation risk. The second index, Contribution to OPEC Risks Exposure (CORE), indicates the individual contribution of the OPEC members to the OPEC energy export demand risk exposure. This study utilises the disaggregated approach to measuring energy security risks for crude oil and gas and involves a country level analysis. With the disaggregated approach, the study shows that OPEC's energy export demand security risk exposures differ across energy types.

6. References

Barnett, J., Dessai, S. and Webber, M., 2004. Will OPEC lose from the Kyoto Protocol? Energy Policy 32, 2077-2088.

BP (British Petroleum), 2011. Statistical Review of World Energy, 2011.

Barnett, J. and Dessai, S., 2002. Articles 4.8/4.9 of the UNFCCC: the adverse effects and the impacts of response measures. Climate Policy 2 (3), 231–239

Berk, M.M., van Minnen, J.G., Metz, B., Moomaw, W., van Elzen, M.G.J., van Vuuren, D.P., Berk J., M.M., Bollen, J.C., Eerens, H.C., Manders, A.J.G. and van Vuuren, D.P., 2006. Sustainable Energy: trade-offs and synergies between energy security, competitiveness, and environment. Netherlands Environmental Assessment Agency, Bilthoven

Blyth, W. and Lefevre, N., 2004. Energy Security and Climate Change. International Energy Agency Information Paper Interactions, International Energy Agency, Paris.

Bradley, R. and Lefevre N., 2006. Assessing Energy Security and Climate Change Policy.

Centre for Climate and Energy Solutions, 2011. Climate Action Plans.

CSS, 2012. Climate Change: Policy and Mitigation.

Darby, M.R., 1982. The price of oil and world inflation and recession. *American Economic Review, 72*, 738–751.

Database of State Incentives for Renewables and Efficiency (DSIRE), 2012. RPS Standards.

De Vlieger, I., De Keukeleere, D. and Kretzschmar, J.G., 2000. Environmental effects of driving behaviour and congestions related to passenger cars. Atmospheric Environment, Vol. 34, 4649-4655.

Dolsak, M., 2001. Mitigating Global Climate Change: Why are some Countries more committed than others? *Political Studies Journal*, 29(3)

EC (European Commission), 2003. World Energy, Technology and Climate Policy Outlook

Federal Register, 2011. Proposed Rules, Vol. 76, No. 231, Thursday, December 1, 2011

Fenhann, J., 2005. Capacity Development for the Clean Development Mechanism Pipeline Overview. UNEP Risø Centre.

Ghalayini, L., 2011. The Interaction between Oil Price and Economic Growth. Middle Eastern Finance and Economics Journal 13.

Ghanem, S., Lounnas, R. and Brennand, G., 1999. The impact of emissions trading on OPEC, OPEC Review June, 23 (2), 79–112

Gupta, J., 1997. The climate change convention and developing countries: from conflict to consensus? Dordrecht, The Netherlands: Kluwer Academic Publishers.

Gupta, S., Tirpak, D. A., Burger, N., Gupta, J., Höhne, N., Boncheva, A. I., Kanoan, G. M., Kolstad, C. , Kruger, J. A., Michaelowa, A., Murase, S., Pershing, J., Saijo, T. and Sari, A., 2007. Policies, Instruments and Co-operative Arrangements. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Hamilton, J. D., 1983. Oil and the macroeconomy since World War II. Journal of Political Economy 91: 228–248.

H.R. 2454--111th Congress, 2009. American Clean Energy and Security Act of 2009. In www.GovTrack.us. Retrieved April 17, 2013, from http://www.govtrack.us/congress/bills/111/hr2454

IEA (International Energy Agency), 2002. *Beyond Kyoto: Energy Dynamics and Climate Stabilization*. France.

IEA (International Energy Agency) , 2006a: Energy Technology Perspectives. Scenarios and Strategies to 2050. OECD/IEA, Paris

IEA (International Energy Agency), 2006b. *CO2 Emissions from Fuel Combustion 1971–2004* (2006 edition). Paris.

IPCC (Intergovernmental Panel on Climate Change), 2001. *Climate Change 2001: Mitigation*. Ed. Bert Metz et al.; Cambridge University Press. Cambridge, United Kingdom.

IPCC (Intergovernmental Panel on Climate Change), 2001. *Climate Change 2001: The Scientific Basis*. Intergovernmental Panel on Climate Change; Ed. J.T. Houghton et al.; Cambridge University Press. Cambridge, United Kingdom.

IPCC (Intergovernmental Panel on Climate Change), 2007. *Climate Change 2007: Mitigation*. Intergovernmental Panel on Climate Change; B. Metz et al.; Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Linden N. H van der, Linde C. Van der, Lako, P. and van Rooijen, S. N. M., 2000. Analysis of the Impacts of the Kyoto Protocol on the Export Revenues of OPEC member states and on the Oil Import Requirements of Non-Annex 1 countries. Dutch National Research Programme on Global Air Pollution and Climate Change. Bilthoven. The Netherlands

Mahmud, S., 2009. The Impacts of Oil Prices on Economic Growth of Developing Countries: A Panel Approach. Working Paper, University of Surrey

Matsumoto, K., Voudouris, V., Stasinopoulos, D., Rigby, R. and Di Maio, C., 2012. Exploring crude oil production and export capacity of the OPEC Middle East countries. Energy Policy (2012), http://dx.doi.org/10.1016/j.enpol.2012.06.027

OPEC (Organisation of Petroleum Exporting Countries), 2010. OPEC Annual Statistics Bulletin

OPEC (Organisation of Petroleum Exporting Countries), 2011. OPEC Annual Statistics Bulletin

OPEC (Organisation of Petroleum Exporting Countries), 2012a. OPEC Annual Statistics Bulletin

OPEC (Organisation of Petroleum Exporting Countries), 2012b. OPEC Statement to the United Nations Climate Change Conference (COP18). Doha, Qatar.

Pacala, S. and Socolow, R., 2004. Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies. *Science.* vol. 305, p. 968-972.

Pew Centre on Global Climate Change, 2007. States with Renewable Energy Standards and Emissions Targets: United States and Regional.

Roubini, N. and Setser, B., 2004. The Effects of the Recent Oil Price Shock on the U.S. and Global Economy (www.stern.nyu.edu/globalmacro/OilShockRoubiniSetser.pdf).

Stevens, P. and Hulbert, M., 2012. Oil Prices: Energy Investment, Political Stability in the Exporting Countries and OPEC's Dilemma. EEDP Programme Paper 2012/03

Stevens, P., 2012. The Arab uprisings and the international oil markets. Chatham House Briefing Paper, EERG2012/03

Statoil (2007) *Carbon Dioxide Storage Prized.*

TWF (The World Fact book), 2007. CIA

TWF (The World Fact book), 2008. CIA

TWF (The World Fact book), 2009. CIA

TWF (The World Fact book), 2010. CIA

TWF (The World Fact book), 2011. CIA

TWF (The World Fact book), 2012. CIA

TWF (The World Fact book), 2013. CIA https://www.cia.gov/library/publications/the-world-factbook/geos/sa.html (as at 31 May, 2013).

UNFCCC (United Nations Framework Convention on Climate Change), 2012. Durban: Towards full implementation of the UN Climate Change Convention. http://unfccc.int/key_steps/durban_outcomes/items/6825.php

UNFCCC (United Nations Framework Convention on Climate Change), 2013a. The Kyoto Protocol. http://unfccc.int/kyoto_protocol/items/2830.php

UNFCCC (United Nations Framework Convention on Climate Change), 2013b. Joint Implementation. http://unfccc.int/kyoto_protocol/mechanisms/joint_implementation/items/1674.php

UNFCCC (United Nations Framework Convention on Climate Change), 2013c. CDM's CER Issued. http://cdm.unfccc.int/Issuance/cers_iss.html

UNFCCC (United Nations Framework Convention on Climate Change), 2013d. Emissions Trading.

http://unfccc.int/kyoto_protocol/mechanisms/emissions_trading/items/2731.php

US EPA (Environmental Protection Agency), 2004. *Climate Leaders Success Stories: Innovative Approaches to Reducing Greenhouse Gas Emissions.*

US EPA (Environmental Protection Agency), 2007. Lighting - Compact Fluorescent Light Bulbs

US EPA (Environmental Protection Agency), 2007. Voluntary Programs

US EPA (Environmental Protection Agency), 2008. Quantifying Greenhouse Gas Emissions: from Key Industrial Sectors in the United States.

US EPA(Environmental Protection Agency), 2012. Greenhouse Gas Reporting Program
http://www.epa.gov/climatechange/emissions/ghgrulemaking.html

US EPA (Environmental Protection Agency), 2012. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2010.

Wiser, R., Barbosa, G. and Holt, E., 2010. Supporting Solar Power in Renewables Portfolio Standards: Experience from the United States.

Does Climate Change Mitigation Activity Affect Crude Oil Prices? Evidence from Dynamic Panel Model

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Abstract

This paper empirically investigates how climate change mitigation affects crude oil prices while using carbon intensity as the indicator for climate change mitigation. The relationship between crude oil prices and carbon intensity is estimated using an Arellano and Bond GMM dynamic panel model. This study undertakes a regional-level analysis because of the geographical similarities among the countries in a region. Regions considered for the study are Africa, Asia and Oceania, Central and South America, the EU, the Middle East and North America. Results show that there is a positive relationship between crude oil prices and carbon intensity, and a1% change in carbon intensity is expected to cause about 1.6% change in crude oil prices in the short run and 8.4% change in crude oil prices in the long run while the speed of adjustment is 19%.

Key words: Climate Change Mitigation, Carbon Intensity, Crude Oil Prices, Dynamic Panel

1. Introduction

Many factors influence the prices of crude oil globally and among these factors are supply and demand activities (Bacon, 1991; Dees et al., 2007; Mitchell, 2006), market speculations (Haigh et al. 2005 and Kogan et al. 2003), taxes (OPEC, 2012), war and political instability (Stevens and Hulbert, 2012). These factors have been empirically shown to have significant effects on crude oil prices (Fattouh, 2007; King et al, 2012). The Organisation of Petroleum Exporting Countries (OPEC) as the major global crude oil producers and suppliers, has been concerned about these factors especially the ones, which from their point of view have adverse effects on the prices of crude oil (OPEC, 2010).

Recently, the global energy industry’s focus has shifted to the concern about the carbon contents of fossil based energy sources especially with the global spotlight on carbon emissions reduction (IPIECA, 2007). This concern and the extension of Kyoto Protocol’s commitment period to 2020 (i.e. the second commitment period 2013 – 2020) have thrown up a major economic challenge for countries that are dependent on crude oil export revenues especially OPEC (OPEC, 2010). One of the issues related to this new economic threat perceived by OPEC is the pricing of crude oil under the new climate regime(s). To shed more light on this issue, this paper attempts to determine the relationship between crude oil prices and climate change mitigation activity.

To carry out the required investigation in this paper, climate change mitigation activity is represented by a proxy indicator. This study opts for a proxy indicator in order to capture the climate change mitigation activities that have the tendency to impact on crude oil consumption and/or production. The proxy indicator for climate change mitigation chosen for this study is carbon intensity which shows the level of carbon utilisation in the economy (Kaya, 1990, Rogner et al, 2007; UN, 2008). Carbon intensity is also preferred as a proxy indicator because it is derived from all sectors of the economy and captures all carbon-related climate mitigation effects whether in the short term or long term and there are data on carbon intensity levels that cover the period under consideration (Sun, 1998; Sun and Ang, 2000; Helme and Leining, 2003). The carbon intensity values are derived at consumption level instead of production level because of the different regions/countries considered by the model. Measurement of carbon intensity at production levels may lead to double counting as some intermediate products exported to other countries will be taken into account in both the exporting and importing countries. However, measurement of carbon intensity at consumption level encourages the transfer of emission from country or region of production to the country or region of consumption where inter-country or inter-regional trades exist. Other indicators considered initially are greenhouse gases emissions and per capita emissions (WRI, 2013) but carbon intensity is more compatible to the model used for this study. While greenhouse gases emissions indicator considers all the gases emitted, carbon intensity considers only CO_2 related emissions. On the other hand, per capita emissions indicator considers total emissions per person while carbon intensity considers total emissions per economic output. The a priori and theoretical assumption is that, crude oil consumption is affected when carbon reduction strategies such as carbon taxes are introduced to reduce carbon dioxide (CO_2) emissions (IPCC, 2007; Barnett et al 2004). This paper also addresses how fast, crude oil prices change when carbon intensity changes.

To estimate the relationship between crude oil prices and carbon intensity levels including the short and long run effects, and the speed of adjustment, this paper explores the Arellano-Bond (AB) dynamic panel model (Arellano and Bond, 1991).The results of this study show a positive relationship between crude oil prices and carbon intensity suggesting that there is a relationship between crude oil prices and climate change mitigation activity in the regions under consideration in the short run and long run respectively.

This paper is presented in five sections. The following section looks at the structure of the crude oil market, related studies in the literature and the sources and nature of the data used for the study. Section three explores the methodology of the study and section four addresses the presentation and discussion of the results. Section five covers the conclusion and policy implications of the study's outcome.

2. Literature Review and Background to the Study

2.1The Structure of the Crude Oil Market

The global crude oil market has been described theoretically as an oligopolistic market (Mileva and Siegfried, 2007). It is said that the long term marginal cost of oil is a small fraction of oil price (Adelman, 1993), therefore, the prices are driven by the restriction of excess supply by the market supply leader. Such scenario describes the OPEC monopolistic theory, where higher cost producers sell all they can produce and the low cost producers satisfy the market supply shortage or excess demand at current prices and could as well restrict production (Mileva and Siegfried, 2007). There is econometric evidence that confirms this position about Saudi Arabia, which plays the role of a “swing” producer (Mileva and Siegfried, 2007). Other studies also support the oligopolistic nature of the oil market and the market dominance by Saudi Arabia and OPEC (Griffin, 1985; Alhajji and Huettner, 2000; Dees et al, 2003).

On the other hand, the demand for crude oil is driven by the choices of individual households/firms as well as other private interest groups such as refineries because of the economic and national security importance of oil (Mileva and Siegfried, 2007). The dependence of the economy and national security on oil makes it inevitable for oil importing countries to influence oil demand (just like oil exporting countries influence the supply). Therefore, the oil market is also influenced by the oil importing countries. These influences could be in the form of investing public funds in the development of alternative energy sources (in order to create substitutes), explorations based on advanced technology, fiscal instruments, environmental regulations, political interventions, strategic oil reserves, etc. (Energy Intelligence, 2004; Barbosa and Sorkin, 2005; Mileva and Siegfried, 2007).

However, it has been shown also that the crude oil market is competitive especially on determination of prices, where the forces of supply and demand determine the spot market prices (Grant et al, 2006; Mileva and Siegfried, 2007; Hamilton, 2009). According to Hamilton (2008) there are three separate conditions that hold in equilibrium in the dynamic crude oil market and these conditions are storage/inventory, futures markets and scarcity rent factors.

In the competitive oil market, spot prices are the market prices against the official prices (OPEC or major Oil companies determined) that were in place in the '70s and '80s because the petroleum industry has become increasingly dependent on the spot prices which also determine the term and futures prices (Energy Intelligence, 2004).

The major factors that affect crude oil demand and supply are therefore expected to affect crude oil prices as well. In as much as the global oil market is seen as competitive, there are situations where market failure occurs which makes it imperfectly competitive. When a market failure occurs, the price of crude oil would be affected.

This study assumes that while the market is competitive, it is dynamic and not fully transparent which bring about market failure. Theoretically, the introductions of climate change mitigation policies are expected to have major impacts on the oil market. Energy efficiency methods and subsidy on renewable energy sources are market driven climate change mitigation policies while carbon taxes are public/government driven policies that also distorts the market. When energy efficiency policies are introduced, the demand falls over time and such demand shocks are eventually transmitted to the market. When renewable energy sources are subsidised, the substitution effect comes into play and demand for oil also falls over time. However, when carbon taxes are introduced, it disrupts the competitive markets situation or equilibrium by driving up crude oil prices which leads to the increased move to discover adequate non-carbon/less-carbon substitutes for oil over time. Therefore, it is assumed that even when oil demand tend to be price inelastic or have low price elasticity (Hamilton, 2009), the combination of the energy efficiency driven demand shocks, renewable energy subsidy driven substitution effects and carbon tax driven market distortion may affect oil prices, if not in the short term then in the long term.

2.2 Related Studies in the Literature

Climate change mitigation activity entails any activity or policy related to the reduction of greenhouse gases emissions (IPCC, 2007). Among the greenhouse gases, CO_2 accounts for over fifty per cent (50%) of the sources of global warming (UNFCCC, 2009). It is also established by the UNFCCC (2009) that fossil fuels (coal, oil and gas) are the major sources of CO_2 emissions and are responsible for about fifty-six per cent (56%) of the total global CO_2 emission. So, it is assumed that major activities to reduce CO_2 emissions would take fossil fuel consumption into consideration.

The level of carbon intensity is defined as the standard or basis for measuring the utilisation of carbon emitting resources in the economy (EIA, 2012). In this paper, it is assumed in line with EIA (2012) that carbon intensity accounts for the economy wide carbon utilisation level which can also show the carbon reduction level.

Carbon intensity levels are not as flexible as crude oil prices. The volatility of carbon intensity levels is shown in the figure below. Figures 1 and 2 show the annual levels of carbon intensity and crude oil prices for a period of thirty-two (32) years (1980-2011). The carbon intensity levels follow a trend while crude oil prices are more volatile over the same period.

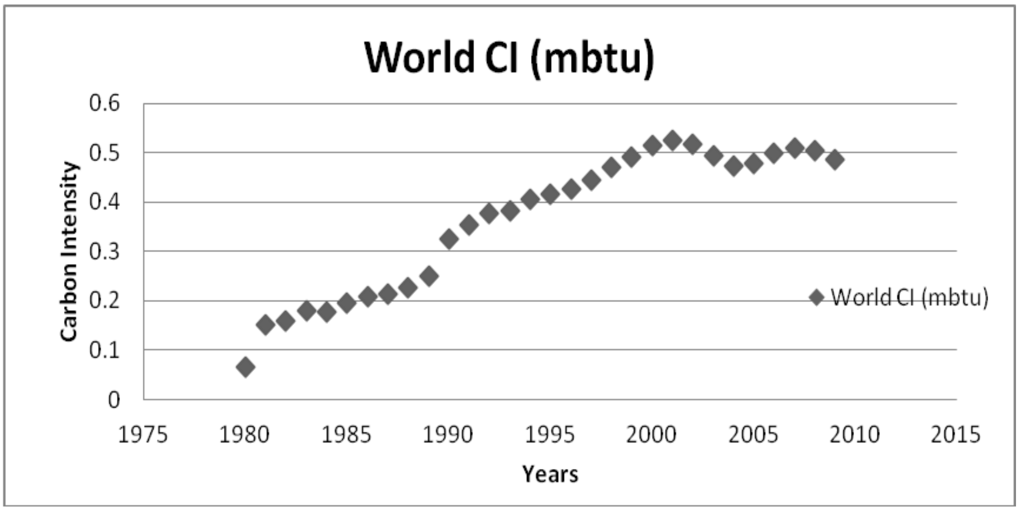

Figure 1: Annual Carbon Intensity Levels

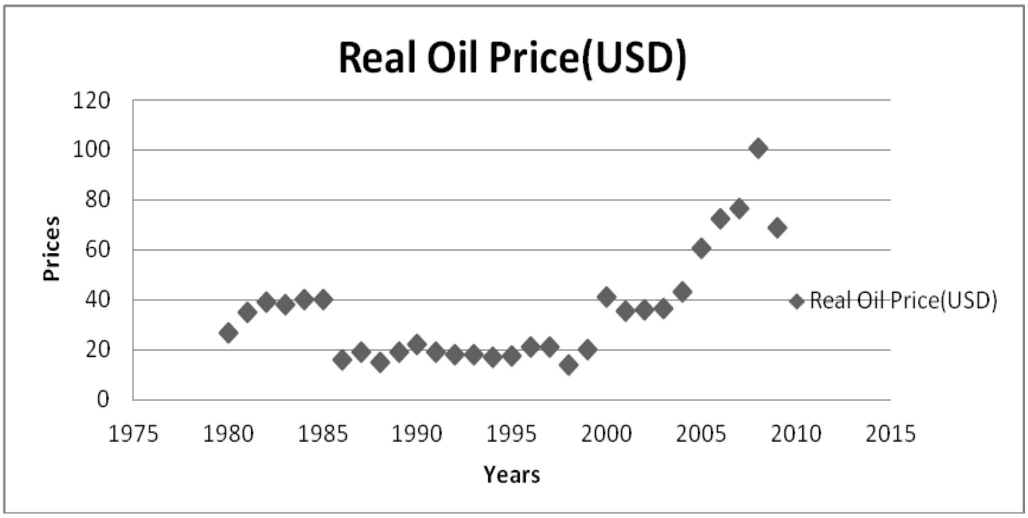

Figure 2: Annual Crude Oil Prices

Carbon intensity is also described as the carbon dioxide emissions per unit of total primary energy supply in the economy (IPCC, 2007; Kaya, 1990; EIA, 2012) or according to the EIA (2012), carbon intensity is an energy consumption weighted average of the emissions coefficients[2].

[2] Emissions coefficient is a unique value for scaling emissions to activity data in terms of a standard rate of emissions per unit of activity (e.g., weight of carbon emitted per Btu of fossil fuel consumed).

Kaya (1990) identifies carbon intensity, energy intensity, gross domestic product per capita and population as indicators for the level of energy related carbon emissions. Energy Modelling Forum (2011) indicates that climate change mitigation activity or policy such as carbon tax would likely reduce (affect) carbon intensity of an economy's total energy consumption. OECD (2008) also states that "on-going efficiency gains" (mitigation activity) are expected to contribute to the decline in carbon intensity levels. This position is supported by the IPCC (2007) which further states that the change in carbon intensity as a result of CO_2 reduction may affect oil prices and oil exporters' economy. According to IPCC (2007) and several studies in the literature, greenhouse gases emissions' mitigation is expected to affect oil price. Among these studies are Ghanem et al, (1999); Pershing, (2000); Barnett et al, (2004); and Awerbuch and Sauter (2006).

Barnett et al (2004) discuss the different global energy economy models which suggest that climate policies and measures supported by the Kyoto Protocol and subsequent negotiations would see a reduction in the consumption of crude oil products in developed countries thereby leading to a decline in global oil demand. According to Henman, (2002) these energy economy models have been influential in the political economy of climate change. In the short run, when climate change mitigation activity is introduced in developed countries or Annex 1 countries under the Kyoto Protocol, which account for 60% of world oil consumption (Barnet et al, 2004), oil prices would rise, thereby leading to a fall in oil demand. As a result of this reduction in oil demand, prices may decline in the long run. The effects of Annex 1 countries climate mitigation policies and measures on oil prices might occur through carbon taxes applied according to the carbon content of oil (Barnet et al, 2004; Lacasta et al, 2002).

In the different models used to estimate the impact of climate mitigation activity on oil exporting countries, G-cubed model - McKibbin et al (1999) , OPEC World Energy model (OWEM) - Ghanem et al (1999), MS-MRT model - Bernstein et al, (1999), CLIMOX model - Bartsch and Muller (2000), GREEN model - Pershing (2000) and GTEM model - Polidano et al (2000), it was found that climate change mitigation affects energy prices (including crude oil prices). Awerbuch and Sauter (2006) in their model found that a 10% increase in renewable energy sources especially in the electricity sector, would reduce CO_2 by 3% and global oil price reduction would be in the range of 3% - 10%. However, this study is different from the above models as it is based on a dynamic panel model which shows the short and long terms impacts and focuses on climate change mitigation activities in six regions, viz, Africa, Asia and Oceania, Central and South America, the EU, the Middle East and North America. This study undertakes a regional-level analysis because of the geographical similarities among the countries in a region.

Based on the existing studies, this paper assumes that causality runs from carbon intensity to crude oil prices. Although sudden changes in crude oil prices may affect some climate change mitigation policies and measures such as technological innovation in the long run, this study assumes that this effect may not be significant because of the growing consensus on the impacts of climate change and there are other factors that drive technological innovations other than crude oil prices (Grubbler et al, 1999; Weyant, 2000). However, in this study, there is a provision to take care of endogeneity by using the AB dynamic panel model, which uses lagged explanatory variables as instruments.

Apart from carbon intensity, other climate change mitigation related factors affect crude oil prices and they are covered by the stochastic term in the model. This study also makes provision for controls and some other deficiencies in the data by introducing some categorical variables to account for the outliers observed as possible structural breaks in the crude oil prices' data. Some other factors are not included because of lack of or insufficient data.

2.3 Data

The data used for the study covers from 1980 – 2011. The carbon intensity data are from the US Energy Information Administration (EIA) online database. The carbon intensity data for all the regions are derived using market exchange rates (metric tons of carbon dioxide per thousand year 2005 U.S. Dollars). This feature makes carbon intensity a good indicator because crude oil is priced in US Dollars as well. For the different regions, certain countries are considered due to the availability of data on carbon intensity for the period under consideration. The study focuses on regions because the country level data for some countries of interest are so small that they may lead to poor statistical results. The crude oil price data are collated from the International Energy Agency (IEA) database and OPEC annual statistical bulletin[3]. The OPEC prices are based on a weighted average index of currency exchange rates in the modified Geneva I Agreement. The crude oil prices data are diversified as follows; the prices from 1980 – 1981 are based on the posted prices of the Arab Light. The prices from 1982 – 2005 are based on the OPEC Reference Basket and from 2005 – 2009, the prices are based on OPEC's new Basket methodology. The US WTI prices are used for the North America region, UK Brent prices for the EU, Nigerian Light crude prices for Africa region, Saudi Arabian Light crude prices for Middle East region, Indonesia Minas crude prices for Asia/Oceania region and Venezuela Light crude prices for South/Central America region. These prices are reported in US dollars. The data are estimated in log forms.

3. Methodology and Modelling Framework

This study utilises the AB dynamic panel model because the regressor(s) may be correlated with the error term E_{it}. The AB dynamic panel model is also considered because of the time-invariant regional characteristics

[3] OPEC Statistical Bulletins (1980 – 2010)

(fixed effects) such as geographical and demographic factors which may be correlated with the explanatory variables. The AB dynamic panel model also takes care of the problems related to the presence of the lagged dependent variable P_{it-1} as a regressor.

The standard model for this dynamic panel study is specified below using the Arellano-Bond GMM approach[4]:

$P_{it} = \gamma P_{it-1} + \beta C_{it} + \rho Z_i + \alpha_i + \varepsilon_{it}$ ....(i)

Where P_{it} and C_{it} are the crude oil price in regions, i and periods t; and carbon intensity level in regions i and periods t, and where α_{i*} are the (unobserved) individual region effects, ρZ_{i*} are time-invariant explanatory variables and ε_{it} is the error term with

$E(\varepsilon_{it}) = 0$..............(ii)

It is assumed that;

$E(\alpha_i) = 0$ ....(iii), and

$E(\alpha_i C_{it}) = 0$..........(iv)

Introducing the GMM's first difference approach, the model takes care of the individual effects α_i and time-invariant explanatory variables Z_i

$(P_t - P_{t-1}) = \gamma(P_{t-1} - P_{t-2}) + \beta(C_{it} - C_{i,t-1}) + \varepsilon_{it} - \varepsilon_{it-1}$...........(v)

[4] Arellano and Bond, *op. cit*

For t = 2, …., T.

To overcome the problems of endogeneity in the model, Arellano and Bond (1991) recommend using instrumental variables. More specifically, they propose using lagged values of the explanatory variables as instruments.[5] It is also assumed that all time varying explanatory variables, in this case, carbon intensity levels are strictly exogenous, that is

$E(C'_{it}\, \varepsilon_{it}) = 0$………….(vi)

Letting $\Delta = (1\text{-}L)$ where L denotes the lag operator and

$Y_{it} = (p_{it0}, p_{it1}, ----, y_{i,t-2}, c_i')'\ (t\text{-}1 + TK_{1,}1)$ ……….(vii)

Where $c_i' = (c_{i1}', \ldots, c_{iT})$

And for each period, there is the existence of the following orthogonal conditions

$E\ (p_{it}\, \Delta\, \varepsilon_{it}) = 0$…………(viii)

t = 2,…, T

Introducing the stacked (T-1) first differenced equations in matrix form, gives the following

$\Delta P_{it} = \Delta P_{it-1}\gamma + \Delta C_{it}\beta + \Delta \varepsilon_{it}$ ……….(ix)

[5] Ibid

$i = 1, \ldots, N$

This study estimates the K_i+1 parameters of the $\Theta = (\gamma, \beta')'$ vector, where there is T(T-10 (K_1 +1/2) moment conditions (if C_{it} are strictly exogenous) that can be presented as

$$E(W_i \Delta\varepsilon_{it}) = E\left[W_i \left(\Delta P_{it} - \Delta P_{it-1}\gamma - \Delta C_{it}\beta\right)\right] = 0 \ldots\ldots\ldots\ldots\ldots\ldots (x)$$

However, the above model specifications can also be adjusted further conditional on or with reference to the available data in some regions or countries, this study estimates the relationship between crude oil prices and carbon intensity using the dynamic panel model in equation (ix) above.

3.1 Diagnostic Tests

The validity of the instruments specified in the estimation process using the AB GMM approach are tested using the Sargan test of over-identifying restrictions. The Sargan test is used to check whether the instruments are truly exogenous which is based on the assumption that the residuals are uncorrelated with the set of exogenous variables. It is asymptotically distributed as chi square (X^2) and tests the null hypothesis that the instruments are valid. The null hypothesis can only be rejected if the p-value of the chi-square is less than 0.1 or 0.05. Therefore, a model with valid or exogenous instruments would have a higher p-value of the Sargan statistic. Sargan test is preferred to other weak instruments tests such as Hansen test and F-test because it is the standard test for weak instruments under the AB dynamic panel model, less vulnerable to instrument proliferation and based on the optimal weighting matrix (MacDonald et al, 2010). It is pertinent to use Sargan test to confirm the validity of the instruments and indicate that the error term is uncorrelated with the instruments when the dynamic panel model is used (Bowsher, 2002).

Similarly, it is also vital to check for the nonexistence of serial correlation in the error term, as consistency of the estimates depends on it. This study carries out the first order (AR1) and second order (AR2) serial correlation tests to determine whether serial correlation exists or not. Based on a priori theoretical assumptions, the rejection of the null hypothesis for first order serial correlation (AR1) is expected by design or default but failure to reject the null hypothesis of the absence of second order serial correlation (AR2) leads to the decision that the original error terms are serially uncorrelated, while the test statistics are asymptotically distributed as standard normal variables. The dynamic panel model is correctly specified if the researcher fails to reject the null hypothesis based on the outcome of the second order (AR2) serial correlation test. This means that the estimated coefficients in the model are consistent and reliable.

The study also identified some outliers in the oil prices data which are tested for structural breaks. The structural breaks are controlled for, by introducing dummy variables accordingly. The dummy variables are Y1986, Y1990, Y1998, Y2000 and Y2008.

4. Empirical Results

The AB dynamic panel model results as shown in table 4.1 below, contain the estimates of the coefficients of the effects of carbon intensity on crude oil prices for the baseline or reference case (column 2), where the direct relationship between crude oil prices and carbon intensity is estimated, and the control(s) for the outliers/structural breaks identified in the crude oil price data are reported in column 3. The dummy variables serve as impulse and control variables to determine the effects of predetermined shocks as a result of rise and fall in oil prices. The deterministic variables are used to control for the outliers observed in the crude oil price data for 1986, 1990, 1998, 2000 and 2008. These variables capture the effects of identified events related to the oil price data and improve the robustness of the model.

Some of the outliers could be explained as a result of the gulf oil crisis in 1990, the new millennium related price shocks in 1999 and the price rise in 2008 respectively. The study focuses on the short run and long run carbon intensity effects on crude oil prices. The estimated panel results are presented below in table 4.1.

Model/panel 1 shows the panel result for the reference case. The result indicates that a 1% change in carbon intensity causes about 2.1% change in crude oil prices in the short run and 14% change in the long run. It shows a positive relationship between crude oil prices and carbon intensity and it is statistically significant at all levels. Column 3 shows the panel results when the control variables for the outliers are introduced. It indicates a statistically significant, positive relationship between oil prices and carbon intensity. The relationship estimates show that 1% change in carbon intensity causes 1.6% change in oil prices in the short run and about 8.4% in the long run. The speed of adjustment of crude oil prices to changes in carbon intensity in a period is about 15% in the reference case and 19% in the controlled model. Although, the methodology of this study is different from the existing studies in the literature, the estimates are similar. Awerbuch and Sauter (2006) found that the effect of carbon emissions reduction on oil prices is within the range of 3%-10% , while this study finds that the effect of carbon intensity on oil price is within the range of 1.6% - 2.1% in the short run and 8.4% - 14% in the long run. This study's results find a positive relationship between oil price and carbon intensity, which is also in line with McKibbin et al (1999), Ghanem et al (1999), Bernstein et al, (1999), Bartsch and Muller (2000), Pershing (2000) and Polidano et al (2000), all of which found that there is a relationship between oil prices and greenhouse gases emissions reduction activity.

Table 4.1: Model Estimates

	Panel 1 - Baseline	Panel 2 – Structural breaks control
Oil Price (Lag)		
Estimate	0.85	0.81
Standard Error	(0.079)	(0.0430)
P-value	0.000	0.000
Carbon Intensity		
Short-run	2.1	1.6
Standard error	(0.8772)	(0.7436)
P-value	0.015	0.024
Long-run	14	8.4

4.1 Sargan and Serial Correlation Tests

The Sargan and second order serial correlation (AR 2) diagnostic tests shown in table 4.2 below indicate that the instruments are valid and there is no serial correlation. With the outcome of the Sargan test, the study failed to reject the null hypothesis of the Sargan test that the instruments are valid. For the serial correlation, the study also failed to reject the second order serial correlation null hypothesis that there is no autocorrelation. The outcome of the diagnostic tests shows that the results are robust, reliable, efficient and consistent for the models/panels reported in table 4.1 above.

Table 4.2: Diagnostic Tests

Diagnostics tests	Panel 1 - Baseline	Panel 2 – Structural breaks control
Sargan Test:		
chi2(156)	163.28	185.46
Prob > chi2	0.3286	0.335
Serial-Correlation Test:		
AR (1): z	-6.93	-3.02
Pr > z	(0.000)	(0.000)
AR(2): z	-1.49	-5.08
Pr > z	(0.137)	(0.160)

4.2 Discussion and Summary

From the study's results presented above in table 4.1, it is safe to state that carbon intensity affects crude oil prices, especially in the long run. This shows that a unit change in the level of carbon intensity has a significant effect on oil prices. However, the rate of effect or impact of this influence from the estimated "speed of adjustment" is low at 15% and 19%.

With reference to climate change mitigation activity, these empirical outcomes show that there is a relationship between crude oil prices and CO_2 emissions reduction.

5. Conclusion and Policy Implications

Although so many factors affect crude oil prices, this study has shown that there is a statistically significant relationship between crude oil prices and climate change mitigation activity using the AB dynamic panel model. Other factors that affect the prices of crude oil such as production, supply, demand and taxes may have more or larger effects but it is evident in this study that climate change mitigation activity also affects oil prices.

This study concludes from the empirical outcomes that significant changes in crude oil prices can be induced by changes in climate change mitigation activity in a country or region that is a net importer of crude oil, which are majorly the industrialised countries and Annex 1 countries under the Kyoto Protocol. The study outcomes show that it is safe to state that climate change mitigation activities especially CO_2 reductions using carbon intensity as indicator are expected to have effects on crude oil prices.

There are also some research implications from this study. The carbon intensity data used in this study covers the entire economy but further research can look into estimating a model of carbon intensity levels in transportation sector only using the utilisation of renewable energy sources like biofuel consumption. The reason for such model is to investigate the difference between carbon intensity levels in the economy as whole and the carbon intensity levels in the transportation sector which accounts for about 80% of crude oil consumptions. However, the insufficient data on biofuel consumption in all the regions made the estimation of this model difficult at this stage. Therefore, as data on biofuel consumption in these regions becomes available in the future, it may be necessary to also estimate the impacts of biofuel consumption induced carbon intensity levels or transportation sector based carbon intensity level on crude oil prices.

It can also be assumed that an increase in crude oil prices may have a reasonably significant effect on climate change mitigation policy measures through investments in climate change mitigation technologies. Investments in the technology required for climate change mitigation have become a burden on governments across the world. Private investors are yet to fully embrace green investments as expected due to the risk of negative returns on investment. In some countries or regions where there are growing interests in green investments, it is either because the government subsidises these private firms or they are enjoying some levels of tax waivers. Therefore, there is need for further investigation on the transmission of the impact of crude oil prices on climate change mitigation investments.

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7. **References**

Abraham, K.S., 2000. A revised global drilling outlook for 2000 and update on Iraq. Journal of Energy and Development 25, 203–215.

Adelman, M. A., 1993. Modelling world oil supply. The Energy Journal, 14 (1); 1-32.

Alhajji, A.F. and Huettner, D., 2000. OPEC and world crude oil markets from 1973 to 1994: cartel, oligopoly or competitive? Energy Journal 21 (3), 31–60.

Arellano, M. and Bond, S., 1991. Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations. Review of Economic Studies, 58, 277-297

Arellano, M. and Bover, O., 1995. Another Look at the Instrumental Variable Estimation of Error Components Models, Journal of econometrics 68, 29-52

Awerbuch, S., and R. Sauter, 2006. Exploiting the Oil-GDP effect to support renewables deployment. Energy Policy 34(17), pp. 2805-2819.

Bacon, R. 1991. Modelling the price of oil. Oxford Review of Economic Policy, 7, pp. 17–34.

Barboza, D. and Sorkin A. R., 2005. "Chinese oil giant in takeover bid for US corporation" in The New York Times, 23 June 2005.

Barnett, J., Dessai, S. and Webber, M., 2004. Will OPEC lose from the Kyoto Protocol? Energy Policy, 32(18), pp. 2077-2088

Bartsch, U. and Muller, B., 2000. Impacts of the Kyoto Protocol on fossil fuels. In: Bernstein, L., Pan, J. (Eds.), Sectoral and Economic Costs and Benefits of GHG Mitigation. Intergovernmental Panel on Climate Change, Bilthoven.

Baum, C. F., 2009. Instrumental Variables and Panel Data Methods in Economics and Finance. Boston College.

Bernstein, P., Montgomery, W.D. and Rutherford, T.F., 1999. Global impacts of the Kyoto agreement: Results from the MS-MRT model. Resource and Energy Economics, 21, pp. 375-413.

Binh, T.N. and McGillivray, M., 1993. Foreign Aid Tax and Public Investment: A Comment, Journal of Development Economics 41, 173-6

Blundell, R. and Bond, S., 1998. Initial Conditions and Moment Restrictions in Dynamic Panel Models, Journal of Econometrics 87, 115-143

Blundell, R., Bond, S. and Windmeijer, F., 2000. Estimation in dynamic panel data models: improving on the performance of the standard GMM estimator (Institute for Fiscal Studies, London)

Bond, S., Hoeffler. A. and Temple, J., 2001, GMM Estimation of Empirical Growth Models, Centre for Economic Policy Research Discussion Paper 01/525

Bowsher, C., 2002. On testing overidentifying restrictions in dynamic panel data models. Economics Letters 77 (2): 211–201

Dees, S., Karadeloglou, P., Kaufmann, R. and Sanchez, M. 2003. Does OPEC matter? An econometric analysis of oil prices. The Energy Journal, 25 (4)

Dees, S., Karadeloglou, P., Kaufmann, R.K. and Sanchez, M. 2007. Modelling the world oil market: Assessment of a quarterly econometric model. Energy Policy, 35(1), pp. 178–191.

Energy Information Administration (EIA), 2012. Energy intensity Data http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=91&pid=46&aid=31

Energy Intelligence, 2004. Understanding the oil and gas industries. Energy Intelligence: New York

Energy Modelling Forum (EMF), 2011. Energy Efficiency and Climate Change. EMF report 25, 1

Fattouh, B., 2007. Structural Model, the Demand – Supply Framework and Informal Approaches. CFMS, SOAS.

Finley, M., 2012. The Oil Market to 2030 – Implications for Investment and Policy, Economics of Energy and Environmental Policy, 1, 1.

Franzini, L. and Harvey, A.C., 1983. Testing for deterministic and seasonal components in time series models, Biometrika 70, 673–682

Ghanem, S., Lounnas, R. and Brennand, G., 1999. The impact of emissions trading on OPEC, OPEC Review June, 23 (2), 79–112

Grant, K., Ownby, D. and Peterson, S. R., 2006. Understanding today’s crude oil and product markets. A Policy Analysis Study by Lexecon undertaken for API.

Griffin, J.M., 1985. OPEC behaviour: a test of alternative hypotheses. American Economic Review 75, 954–963.

Grubler, A., Nakicenovic, N., Victor, D., 1999. Dynamics of energy technologies and global change. Energy Policy 27 (5), 247–280.

Haigh, M.S., Hranaiova, J. and Overdahl, J. 2005. Price volatility, liquidity provision and the role of managed money traders in energy futures markets. US Commodity Futures Trading Commission Working Paper.

Hamilton, J. D., 2009. "Understanding Crude Oil Prices," The Energy Journal, International Association for Energy Economics, vol. 0(Number 2), pages 179-206.

Hanley, N. and Owen, A. D., 2004. The Economics of Climate Change. Routledge, London

Harvey, A.C., 1989. Forecasting, Structural Time Series Models and the Kalman filter. Cambridge University Press, Cambridge.

Harvey, A.C. and Koopman, S.J., 1992. Diagnostic checking of unobserved-components time series models, Journal of Business and Economics Statistics 10, 377–389

Harvey, A.C., Henry, S.G.B., Peters, S. and Wren-Lewis, S., 1986. Stochastic trends in dynamic regression models: an application to the employment-output equation. Economic Journal 96, 975–985

Helme, N. and Leining, C., 2003. Designing Future International Actions on Climate Change – UNFCCC 18th session of the Subsidiary Bodies, Bonn, Germany

Henman, P., 2002. Computer modelling and the politics of greenhouse gas policy in Australia. Social Science Computer Review 20 (2), 161–173.

Hunt, L.C. and Ninomiya, Y., 2003. Unravelling trends and seasonality: a structural time series analysis of transport oil demand in the UK and Japan. Energy Journal 24 (3), 63–96

Hunt, L.C., Judge, G. and Ninomiya, Y., 2003a. Modelling underlying energy demand trends; In: Hunt, L.C. (Ed.), Energy in a Competitive Market: Essays in Honour of Colin Robinson. Edward Elgar, pp. 140–174. Chapter 9

Hunt, L.C., Judge, G. and Ninomiya, Y., 2003b. Underlying trends and seasonality in UK energy demand: a sectoral analysis. Energy Economics 25, 93–118

Intergovernmental Panel on Climate Change (IPCC), 2007. Contribution of Working Group III to the Fourth Assessment Report, B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

IPIECA, 2007. The Oil and Gas Industry and Climate Change. International Petroleum Industry Environmental Conservation Association’s Report.

King, K., Deng, A. and Metz, D., 2012. An Econometric Analysis of Oil Price Movements: The Role of Political Events and Economic News, Financial Trading and Market Fundamentals. Bates White Economic Report 2012/01.

Kaya, Y, 1990: Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios. Paper presented to the IPCC Energy and Industry Subgroup, Response Strategies Working Group, Paris.

Kogan, L., Ross, S.A, Wang, J. and. Westerfield, M.M. 2003. The price impact and survival of irrational traders. MIT Sloan Working Paper No. 4293–03.

Koopman, S.J., Harvey, A.C., Doornik, J.A. and Shephard, N., 1999. Stamp: Structural Time Series Analyser, Modeller and Predictor, 2nd Edition. Timberlake Consultants Ltd, London.

Lacasta, N., Dessai, S., Powroslo, E., 2002. Consensus among many voices: articulating the European Union’s position on climate change. Golden Gate University Law Review 32, 351–414.

MacDonald, R., Damasceno, A. and Vieira, F., 2010. “The role of institutions in cross-section income and panel data growth models: a deeper investigation on the weakness and proliferation of instruments.” Working Papers Department of Economics, University of Glasgow.

McKibbin, W.J. and Wilcoxen, P.J., 2004. Estimates of the costs of Kyoto: Marrakesh versus the McKibbin Wilcoxen blueprint. Energy Policy, 32(4), pp. 467-479.

Mileva, E. and Siegfried, N., 2007. Oil market structure, network effects and the choice of currency for oil invoicing. ECB occasional paper series no. 77

Mitchell, J. V., 2006. A New Era for Oil Prices, Chatham House Report, August 2006.

OECD, 1993. Taxation and the Environment: Complementary Policies. OECD, Washington, DC.

OECD, 2008. Climate Change mitigation: What do we Do? OECD report, 2008.

OPEC, Annual Statistical Bulletins (1980 – 2010): http://www.opec.org/opec_web/en/publications/202.htm

OPEC, 2010. OPEC Long Term Strategy. OPEC Report 2010/10.

OPEC, 2012. Who gets what from imported oil? OPEC report http://www.opec.org/opec_web/en/publications/341.htm

Pershing, J., 2000. Fossil fuel implications of climate change mitigation responses. In: Bernstein, L., Pan, J. (Eds.), Sectoral and Economic Costs and Benefits of GHG Mitigation. Intergovernmental Panel on Climate Change, Bilthoven

Pindyck, R.S., 2001. The dynamics of commodity spot and futures markets: a primer. Energy Journal 22 (3), 1–29.

Polidano, C., Jotzo, F., Heyhoe, E., Jakeman, G., Woffenden, K., Fisher, B., 2000. The Kyoto Protocol and developing countries: impacts and implications for mechanism design. ABARE Research Report - Australian Bureau of Agricultural and Research Economics, Canberra.

Ringlund, G. B., Rosendahl, K. E. and Skjerpen, T., 2008. Does Oilrig Activity react to Oil price change? An empirical investigation. Energy Economics 30 (2008) 371 – 396.

Rogner, H. H., Zhou, D., Bradley, R., Crabbé, P., Edenhofer, O., Hare, B., Kuijpers, L. and Yamaguchi, M., 2007. Introduction in Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Metz, B., Davidson, O.R., Bosch, P.R., Dave, R. and Meyer, L.A. (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Rowlands, I., 2000. Beauty and the Beast? BP’s and Exxon’s positions on global climate change. Environment and Planning C: Government and Policy 18 (3), 339–354.

Rutledge, I., 2003. Profitability and supply price in the US domestic oil industry: implications for the political economy of oil in the twenty-first century. Cambridge Journal of Economics 27, 1–23.

Stevens, P. and Hulbert, M., 2012. Oil Prices: Energy Investment, Political Stability in the Exporting Countries and OPEC's Dilemma. EEDP programme paper: 2012/03. Chatham House, London.

Sun, J.W., 1998: Changes in energy consumption and energy intensity: A complete decomposition model. Energy Economics 20(1), pp. 85- 100.

Sun, J.W. and Ang, B.W., 2000. Some properties of an exact energy decomposition model. Energy Economics 25(12), pp. 1177-1188.

UNFCCC (United Nation Framework Convention on Climate change), 2009. Fact Sheet: The need for Mitigation. UNFCCC Report, 2009/09.

United Nation Division for Sustainable Development (UN), 2008. Measuring Progress towards Sustainable Development and Climate Change –The potential of the CSD Indicators of Sustainable Development. Expert Group Meeting on Climate Change and Sustainable Development – The Role of Indicators' New York, 15-16 October 2008.

Weyant, J., 2000. An Introduction to the Economics of Climate Change Policy. Pew Centre on Global Climate Change, Arlington.

WRI (World Resource Institute), 2013. Climate Analysis Indicators Tool (CAIT) https://sites.google.com/site/climateanalysisindicatorstool/cait-international-8-0

Appendix A: Regions

In the North American region, the United States of America (USA), Canada, Mexico and Bermuda are the countries considered.

Table A1: Countries considered in the European region

1	Austria
2	Belgium
3	Cyprus
4	Denmark
5	Finland
6	France
7	Germany
8	Greece
9	Ireland
10	Italy
11	Luxembourg
12	Malta
13	Netherlands
14	Norway
15	Portugal
16	Romania
17	Spain
18	Sweden
19	Switzerland
20	Turkey
21	United Kingdom

Table A2: Countries considered in the Central and South American region

1	Antigua and Barbuda
2	Argentina
3	Bahamas, The
4	Barbados
5	Belize
6	Bolivia
7	Brazil
8	Cayman Islands
9	Chile
10	Colombia
11	Costa Rica
12	Cuba
13	Dominica
14	Dominican Republic

15	Ecuador
16	El Salvador
17	French Guiana
18	Grenada
19	Guatemala
20	Guyana
21	Haiti
22	Honduras
23	Jamaica
24	Martinique
25	Netherlands Antilles
26	Nicaragua
27	Panama
28	Peru
29	Puerto Rico
30	Saint Kitts and Nevis
31	Saint Lucia
32	Saint Vincent/Grenadines
33	Trinidad and Tobago
34	Uruguay
35	Venezuela
36	Virgin Islands, U.S.

Table A3: Countries considered in the Middle East region

1	Bahrain
2	Iran
3	Iraq
4	Israel
5	Jordan
6	Kuwait
7	Lebanon
8	Oman
9	Qatar
10	Saudi Arabia
11	Syria
12	United Arab Emirates
13	Yemen

Table A4: Countries considered in the African region

1	Algeria
2	Angola
3	Benin
4	Botswana
5	Burkina Faso
6	Burundi
7	Cameroon
8	Cape Verde
9	Central African Republic
10	Chad
11	Comoros
12	Congo (Brazzaville)
13	Congo (Kinshasa)
14	Cote d’ Ivoire (Ivory Coast)
15	Djibouti
16	Egypt
17	Equatorial Guinea
18	Ethiopia
19	Gabon
20	Gambia, The
21	Ghana
22	Guinea
23	Guinea-Bissau
24	Kenya
25	Lesotho
26	Liberia
27	Libya
28	Madagascar
29	Malawi
30	Mali
31	Mauritania
32	Mauritius
33	Morocco
34	Mozambique
35	Niger
36	Nigeria
37	Reunion
38	Rwanda
39	Sao Tome and

	Principe
40	Senegal
41	Seychelles
42	Sierra Leone
43	Somalia
44	South Africa
45	Sudan and South Sudan
46	Swaziland
47	Tanzania
48	Togo
49	Tunisia
50	Uganda
51	Zambia
52	Zimbabwe

Table A5: Countries considered in Asia and Oceania region

1	Afghanistan
2	American Samoa
3	Australia
4	Bangladesh
5	Bhutan
6	Brunei
7	Burma (Myanmar)
8	Cambodia
9	China
10	Fiji
11	Guam
12	Hong Kong
13	India
14	Indonesia
15	Japan
16	Kiribati
17	Korea, North
18	Korea, South
19	Laos
20	Malaysia
21	Maldives
22	Mongolia
23	Nepal
24	New Zealand
25	Pakistan
26	Papua New Guinea

27	Philippines
28	Samoa
29	Singapore
30	Solomon Islands
31	Sri Lanka
32	Taiwan
33	Thailand
34	Tonga
35	Vanuatu
36	Vietnam

The Impacts of Crude Oil Prices on OPEC Economies: Panel VAR Approach

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Abstract

The relationship between economic growth and crude oil prices has received enormous attention in the literature. However, there are diverse views about the causality and nature of this relationship. The purpose of this paper is to investigate how economic growths in crude oil exporting countries are affected by changes in global crude oil prices using a panel vector auto regression (VAR) approach. This paper examines the response of economic growths in the Organisation of Petroleum Exporting Countries (OPEC) member states to changes in crude oil prices. Findings in this paper show that changes in crude oil prices, for the period under consideration, positively and significantly affect economic growths in OPEC member states. The findings emphasise the role of economic policies in insulating OPEC economies and other oil exporting countries from changes in crude oil prices.

Keywords: oil prices and economic growth, Panel VAR, OPEC

1. Introduction

Changes in crude oil prices are expected to have macroeconomic consequences for both oil exporting and importing countries (Kireyev, 2000) because crude oil is a major production input for both industrialised and developing countries (Ghalayini, 2011; Mehrara and Mohaghegh, 2011). Although, the increasing concerns for global warming may have affected the consumption of crude oil in most countries, it is still influencing major economic decisions globally. It is generally assumed that an increase in oil prices has positive growth effects and a decrease in oil prices has negative growth effects on oil exporting countries (Hamilton, 1996; Pindyck and Rotemberg, 1983; Rosser and Sheehan, 1995).

Estimating the macroeconomic consequences of oil prices in crude oil exporting countries using the ordinary least square (OLS) method has serious specification concerns (Ghalayini, 2011; Adelman, 2004). The OLS estimated relationship between economic growth in oil exporting countries and oil prices is usually biased and inconsistent as they are based on assumptions that make both economic growth and oil prices endogenous. With this a priori knowledge about the OLS approach in mind, it becomes necessary to estimate the effects of crude oil prices on the economic growth of OPEC member states using another approach devoid of the perceived OLS bias and inconsistency.

Therefore, this paper attempts to provide consistent and unbiased estimates of the macroeconomic responses of OPEC member states to changes in crude oil prices. Although so many studies have estimated the impacts of oil prices on economic growth, only a few of them used an approach that could be said to be completely free from bias and inconsistency (Ghalayini, 2011; Adelman, 2004; Hamilton, 1996; Pindyck and Rotemberg, 1983; Rosser and Sheehan, 1995). Apart from addressing the biased and inconsistent nature of the OLS estimates caused by the endogeneity of crude oil prices, this paper also aims to determine the magnitude of the interactions of crude oil prices and economic growth in oil producing countries.

To determine whether oil prices affect economic growth in OPEC member states and the magnitude of this interaction, with unbiased and consistent models, this paper applies the panel vector auto regression (PVAR) method to national level data from nine (9) OPEC member states. This method exploits the standard VAR method (Sims, 1980) with the traditional panel data approach that allows for unobserved individual heterogeneity (Mehrara and Mohaghegh, 2011).

The findings of this study contribute to the debate about the general impacts of crude oil prices on economic growth especially in oil producing countries. The findings that a change in crude oil prices has a significant effect on economic growth are consistent with some works in the literature (Hamilton, 1983, 1988, 2003, 2008; Bernanke, 1983; Lee and Ni, 2005; Berument et al, 2010 and Mehrara and Mohaghegh, 2011). This study's results complement these studies by providing additional evidence on the effects of crude oil prices on economic growth. However, this study is different from the studies mentioned above because while these previous studies used dynamic regression or standard VAR techniques only to argue that there is relationship between economic growth and oil prices, this paper uses a panel VAR approach to provide new evidence in this area. Specifically, this study finds that the macroeconomic responses to oil price are positive and significant in OPEC member states as a group based on the structural similarities of their economies.

This paper is organised as follows; The following section discusses and reviews related studies in the literature. Section three describes the nature and sources of the data as well as the methodology used for the study. The results of this study are presented in section four while the conclusion and policy implications are covered in section five.

2. Theoretical Background and Literature Review

In order to measure the effects of crude oil prices on OPEC economies, it is pertinent to review the previous studies on crude oil prices and economic growth. Among the studies that show empirical evidence of the effects of crude oil prices on economic growth, a considerable number of studies indicate that while increase in crude oil prices has a negative effect on crude oil importing countries, it has a positive effect on crude oil exporting countries (Devlin and Lewin, 2004; Jimenez-Rodriguez and

Sanchez, 2005; Gisser and Godwin, 1986). According to Ghalayini (2011), a large number of technical papers on this issue exist in the literature but it is still not clear whether crude oil prices can be seen to have a robust effect on economic growth or changes in macroeconomic activities.

Leading the empirical papers on the response of economic growth to crude oil price shocks is Hamilton (1983). This paper entails an observed robust linear relationship between economic growth and crude oil prices in the US. The study finds that an increase in crude oil prices has a negative or adverse effect on the US economic output (that is, a rise in price leads to a negative economic growth). Roubini and Setser (2004) find that crude oil price shocks have a stagflationary effect on the macro-economy of oil importing countries. According to Roubini and Setser (2004), crude oil price shocks significantly contributed to all the US and global recessions of the last three decades. Other empirical papers based on linear relationship assumption between economic growth and crude oil prices are Rasche and Tatom (1981) and Gisser and Goodwin (1986) which estimate the crude oil price – gross domestic product (GDP) transmission effects in the US. Darby (1982) and Burbidge and Harrison (1984) estimate the relationship between GDP and crude oil prices in other developed countries[6].

[6] Darby (1982) – Japan, Germany, UK, Canada, France, Italy and the Netherlands); Burbidge and Harrison (1984) – Japan, Germany, UK and Canada)

Some empirical studies indicate a non-linear relationship and a lower macroeconomic effect than the empirical effects estimated by the above mentioned linearly estimated studies (Ghalayini, 2011). These non-linear methods are measures of indirect effects or transmission mechanisms of crude oil prices on real GDP growth. These indirect transmission mechanisms can be in the form of inflationary consequences (Mork, 1981; and Bruno and Sach, 1982) or investment level and uncertainty (Bernanke, 1983; and Dixit and Pindyck, 1994) or labour market reactions (Finn, 2000; and Davis and Haltiwanger, 2001).

Other major studies linking GDP to oil prices through diverse theoretical channels are Hamilton (1988) and Lee and Ni (2002) which apply consumption smoothing on industrial and durable goods as a linkage to determine the relationship between GDP and crude oil prices. These studies empirically indicate that the effects of crude oil prices on GDP can be determined using indirect transmission mechanisms. According to Mork (1989), the effects of oil price increases are different from the decreases using an asymmetric model to estimate the relationship.

In response to the growing non-linear models, Lee et al (1995) and Hamilton (1996) apply the scaled and net specification models respectively to estimate the relationship between GDP growth and crude oil prices. Other studies that show evidence of non-linear relationship between real GDP growth and crude oil prices are Jimenez-Rodriguez (2004), Hamilton (2003, 2008) and Ghalayini (2011). While using granger causality, Jimenez-

Rodriguez (2004) finds that there is a significant relationship between GDP growth and crude oil prices in oil importing countries with the exclusion of Japan; Hamilton (2008) finds that the relationship between economic growth and oil prices is hard to determine statistically as there might be other forces affecting both macroeconomic activities and GDP growth that cannot be detected.

Unlike the studies above, Ghalayini (2011) finds that there is no causal relationship between economic growth and crude oil prices in most regions or economic groups including OPEC, Indian, China, and Russia except for the G7[7] countries where there is empirical evidence that a significant relationship exists between economic growth and crude oil prices. There are other studies on the macroeconomic effects of crude oil price shocks in oil exporting countries but they are focused on individual countries. For instance, Olomola and Adejumo (2006) using VAR approach finds that oil price shocks significantly determine macroeconomic variables such as real exchange rate in Nigeria. Other studies that find a positive relationship between macroeconomic variables and crude oil price shocks in some OPEC member states are; Al-Mutairi (1993) – Kuwait, Eltony (2001) – Kuwait, Dibooglu and Aleisa (2004) – Saudi Arabia, Anshasy et al (2005) – Venezuela, Boye (2001) – Ecuador, and Farzanegan and Markwardt (2009) – Iran.

[7] Also known as G8 countries with the inclusion of Russia (joined the group in 2007).

Very few studies have considered an OPEC-wide estimation of the macroeconomic effects of crude oil prices. Mehrara and Mohaghegh (2011) find that there is a significant relationship between some macroeconomic variables and crude oil price shocks in OPEC member states. Berument et al (2010) estimate the effects of oil price shocks on economic output in Middle East and North America (MENA) countries with similar conclusion that oil shocks have significant impacts on economic outputs. Alotaibi (2006) investigates the interactions between oil price variation and some macroeconomic variables in the member states of the Persian Gulf Cooperation Council; Mehrara and Oskui (2007) find that oil shocks are the main source of output fluctuations in three OPEC member states and Indonesia – Iran, Kuwait and Saudi Arabia. Kireyev (2000) using a PVAR method, similar to this study's methodology, also investigates the macroeconomic dynamics in some OPEC member states classified as Arab countries. Finally, Lescaroux and Migno (2008) investigating OPEC and other countries, also find that there is a significant relationship between some macroeconomic variables and oil price shocks in the short run and long run respectively.

3. Data and Methodology

3.1 The Nature and Sources of Data

The data used for this empirical study are the real crude oil prices, real GDP, current accounts growth and money supply growth rate of OPEC member states. The available data are specifically for nine (9) OPEC member states (Algeria, Ecuador, Iran, Kuwait, Nigeria, Qatar, Saudi Arabia, United Arab Emirate (UAE) and Venezuela) excluding three other countries that complete OPEC's twelve-country membership (Angola, Iraq and Libya), because of insufficient data for these countries. Some of these data, especially crude oil prices, are available on weekly basis but were transformed to annual basis by calculating the average and annual differences where necessary. The sample frame for this study is from 1981 – 2011.

The annualised differences in real GDP represent economic growth (calculated as the year on year differences of the real GDP). The annualised differences in real crude oil price represent the crude oil price shocks (calculated as the year on year differences of the real crude oil prices). The other variables – current account growth and money supply growth, are introduced into the model in their given value as they are in percentages already.

The data on crude oil prices are from the OPEC annual statistical bulletin (2012) and the US Energy Information Administration (EIA) database, while the data on GDP, current accounts growth and money supply growth are from the World Development Indicators (World Bank) database. The real GDP values are deflated at 2000 constant US dollars.

In line with the a priori and theoretical assumptions, the study formulates a relationship between OPEC's economic growth and crude oil price by using the specified study's methodology. From a theoretical basis, it is safe to assume that causality also runs from crude oil prices to economic growth in OPEC member states for the sample period. However, the panel VAR technique takes care of the issue of reverse causality where it exists.

3.2 Methodology

The model estimation of the relationship between economic growth and crude oil prices is based on a panel VAR technique. The panel VAR is used because its VAR component treats all variables as jointly endogenous, thereby, reflecting the realities of interdependence, where it exists, without distinguishing between exogenous and endogenous variables. The traditional panel component allows for unobserved individual heterogeneity (Love and Zicchino, 2006) and also accommodates country-specific and OPEC-wide panel analyses allowing for comparative analysis of the different countries in the panel. These features make the panel VAR the ideal choice of methodology to analyse the macroeconomic responses in OPEC member states to crude oil price changes. The reduced form order of the panel VAR model is specified as:

$$Y_{it} = \Gamma(L)Y_{it-1} + U_i + \varepsilon_{it} \qquad \text{(i)}$$

Where Y_{it} is a vector of stationary variables {ΔGDP,CA, M2, ΔROP } with ΔGDP = economic growth (annualised changes in GDP); CA = current accounts growth (derived from Balance of Payment [BOP]); M2 = money supply growth rate; ΔROP = annualised changes in real oil prices or oil price shocks; U_i = vector of country specific effects and ε_t = vector of error terms. While the crude oil price shocks represent external shocks, the current accounts growth and the money supply growth rates are introduced into the model as well to determine the effects of internal shocks on economic growth, which also makes the model robust. Γ (L) is the matrix polynomial in the lag operator with $\Gamma(L) = \Gamma_1 L^1 + \Gamma_2 L^2 + \ldots + \Gamma_p L^p$ (ii).

In developing the panel VAR model, this study imposed the restriction that underlying structures are the same for each cross-sectional unit in line with Love and Zicchino (2006). This restriction or constraint on the parameters is expected to be different in practice, therefore, the panel VAR model allows for heterogeneity of the individual variables by introducing country fixed effects. Due to the endogenous variables lag, these country fixed effects are correlated with the regressors. This makes the elimination of the fixed effects necessary. The fixed effects can be eliminated by the mean-differencing procedure or the Helmert procedure also known as forward mean-differencing[8] (Arellano and Bover, 1995). However, using the mean differencing would create biased coefficients. Hence, the need for an alternative technique arises. Following Love and Zicchino (2006) and Boubtane et al (2012), the Helmert transformation (which allows for the orthogonality between transformed variables and lagged regressors, making it convenient to use lagged regressors as

[8] Forward mean-differencing is described as taking the mean of all the future observations available for each country-year

instruments and estimate the coefficients by system GMM[9]), is used in this study.[10]

The model also makes provisions for the error terms and shocks in order to calculate the impulse response functions (IRF) and the forecast error variance decompositions (FEVD). The IRF and the FEVD are required to show the dynamic responses and the magnitude of the total effect respectively. The estimation of the interaction between OPEC's economic growth and crude oil prices is based on the IRFs and the FEVDs after estimating the VAR model. The IRFs usually show the response of an endogenous variable to a shock in another variable in the model or system over time. The FEVD quantify the measure of contribution of the source of shocks to the variations in each endogenous variable in the model or system with reference to the specified forecast horizon.

The IRFs are based on the Cholesky decomposition approach. The Cholesky decomposition strategy entails a contemporaneous relationship among the variables. The first variable in the VAR system impacts the other variables contemporaneously, while the following variables in the VAR impacts the variables listed earlier only in their lag form. In the same vein, the variables listed earlier in the VAR are assumed to be more exogenous than the following variables. Considering that the variables of interest are GDP and Oil Price, GDP is placed first in the model while current account

[9] Generalised Method of Moments

[10] In this model, the number of regressors equals the number of instruments; therefore, the model is just identified.

growth follows before money supply growth rate and oil price. Therefore, the VAR model ordering is as follows:

Model: (GDP_{it}; $CURRENT\_ACCT_{it}$; $MONEY\_SUPPLY_{it}$; OIL_PRICE_{it})

The lags for the model are selected using the Akaike Information Criteria (AIC). Finally, this study also carried out the stationarity and cointegration tests for all the variables as well as granger causality tests.

3.3 Summary Statistics

Table 3.1 below shows the summary statistics of the variables:

Table 3.1: Summary Statistics

Variables	Mean	Std. Dev.	Min	Max	Observation
GDP*	4.03385	10.67596	-40.25348	80.36909	N = 279
					N = 9
					T = 31
Oil Price*	2.82166	12.21071	-32.07	29.94	N = 270
					N = 9
					T = 30
Current Account*	$1.42e^{+10}$	$2.68e^{+10}$	$-2.75e^{+10}$	$1.32e^{+11}$	N = 279
					N = 9
					T = 31
Money Supply*	17.1374	18.43988	-57.23532	153.6837	N = 279
					N = 9
					T = 31

*Note: GDP = annualised GDP differences; Oil Price = annualised real oil price differences; Current Accounts = current account growth rate; Money Supply = money supply growth rate

Given the summary statistics of the panel data above, the following diagnostic tests were carried out to analyse and understand the characteristics of the variables. First, this study carried out the lag selection. Second, the analyses of the stationarity properties of the variables are considered. Third, the cointegration properties of the variables are checked and fourth, the study shows the nature of causality for the variables of interest.

3.4 Lag Selection

The selection of the correct lag length is necessary for panel VAR. According to Kireyev (2001), excessively short lags may fail to capture the system's dynamics leading to omission of variables, coefficients' bias and serial correlation based errors while lag lengths that are too long causes rapid loss of degree of freedom and over parameterisation. Considering the time dimension of the data and the number of variables the system was tested for three to five lag lengths. The correct lag length of five (5) as indicated by the Akaike Information Criterion (AIC) and other information criteria is used for the panel VAR estimation. The lag-length selection table is presented in table 3.2 below.

Table 3.2: Lag selection

Lag	LL	LR	P	AIC	HQIC	SBIC
0	-872.363			70.1091	70.1632	70.3041
1	-838.382	67.963	0.000	68.6705	68.941	69.6456
2	-818.217	40.33	0.001	68.3373	68.8242	70.0925
3	-797.632	41.17	0.001	67.9705	68.6737	70.5058
4	-772.034	51.196	0.000	67.2027	68.1222	70.518
5	-718.615	106.84*	0.000	64.2092*	65.3451*	68.3046*

Endogenous: GDP; Current Account; Money Supply; Oil Price
Exogenous: constant

3.5 Stationarity Properties

Initial use of the autocorrelation function (ACF) and partial autocorrelation function (PACF) indicate that the variables – economic growth (GDP), crude oil price (ROP), current accounts and money supply growth are non-stationary. To confirm whether these observations are true or not, the study carried out formal stationarity tests using the panel unit root tests. The panel unit root tests included the constant, time trend and five lags in line with the general and specific stationarity analysis methodology. At the level forms, the null hypotheses that the variables are non-stationary are not rejected, indicating non-stationarity for all the variables. Most importantly, the variables of interest - economic growth and crude oil prices, are non-stationary respectively. The table showing the stationarity tests outcome is presented in table 3.3 below.

Table 3.3: Panel unit root test

Ho: Panels contain unit roots No. of Panels = 9

Ha: Panels are stationary No. of Periods = 31

ADF regressions: 5 lags

	GDP	Oil Price	Current Acct	Money Supply
Unadjusted t	-8.5086	-13.6573	4.0165	-9.3238
Adjusted t*	6.9359	33.6930	41.9000	9.0789
p-value	1.0000	1.0000	1.0000	1.0000

3.6 Cointegration Analysis

This study carried out the necessary cointegration analysis after the stationarity tests above. The outcome of the cointegration analysis shows that considering the long run relationship between economic growth and all the variables especially crude oil prices, the study rejects the null hypothesis of no cointegration in favour of the alternative hypothesis that at least there is one cointegration relationship at the five percent (5%) significance level. Given that the panel unit root test showed that the variables are non-stationary in their levels and differenced forms, the outcome of the cointegration tests satisfies the a priori assumptions of stationarity of the variables. The study allows all the variables to be included in the panel VAR model in their levels forms with the introduction of the lags where necessary. This approach prevents the loss of important information from the time-series co-movements of the variables (Kireyev, 2001). The outcome of the cointegration test is presented in table 3.4 below.

Table 3.4: Cointegration test

Trend: constant Lags = 5

Max rank	Parms	LL	Eigenvalue	Trace statistics	5% critical	1% critical
0	68	-802.9894		229.6854	47.21	54.46
1	75	-736.90312	0.99494	97.5128	29.68	35.65
2	80	-701.36357	0.94176	26.4337	15.41	20.04
3	83	-688.28806	0.64867	0.2827*1*5	3.76	6.65
4	84	-688.14671	0.01124			

*presence of cointegration relationship

4. Results

The panel VAR strategy for analysing the macroeconomic response to crude oil prices in OPEC economies follows Kireyev (2001), Love and Zicchino (2006) and Boubtano et al (2012) Panel VAR estimation strategies, which entail the model identification (using the stationarity test, lag selection, causal ordering and restrictions) and computing the impulse response functions and forecast error variance decomposition. Therefore, this section presents the impulse response function and variance decomposition from the panel VAR.

4.1 Impulse Response Functions

The IRF table presented in table 3.5 below shows that economic growth in OPEC member states respond positively and significantly to a 10% deviation in crude oil prices by 1.4% in the short run and 1.7% in the long run indicating that oil shocks among other variables affect OPEC's economic growth within the period under consideration. This means that economic growth in OPEC member states respond positively and significantly to crude oil price shocks.

This study's outcomes with regards to economic growth and crude oil prices are in line with the empirical studies of Mehrara and Oskoui (2007) as well as Dibooglu and Aleisa (2004), which independently found that world crude oil price shocks have positive impacts on domestic macroeconomic variables in Saudi Arabia and Kuwait.

However, these findings are not consistent with the findings of Ghalayini (2011) which suggest that oil price shocks do not affect economic growths in OPEC member states and Barsky and Kilian (2004) which suggest that domestic macroeconomic variables may cause global oil price movements. However, Barsky and Kilian (2004) investigate the relationship between domestic macroeconomic variables and oil prices with reference to the US, which is an oil importing country while this study is focused on OPEC, which is an oil exporting countries group.

Table 3.5: Impulse Response Function table

Step	GDP response to Oil Price impulse			Oil Price response to GDP impulse		
	IRF	Lower*	Upper*	IRF	Lower*	Upper*
0	0	0	0	0	0	0
1	.145746	-.06107	.352562	-.005226	-.736346	.725895
2	.156074	-.18673	.498878	-.16968	-1.1007	.761337
3	.070358	-.325702	.466417	-.244739	-1.3367	.847226
4	.193709	-.227489	.614907	-.106826	-1.40169	1.18804
5	.178355	-.287241	.64395	-.581195	-1.95579	.793401
6	.148765	-.290338	.587868	-.557313	-1.91065	.796027
7	.166651	-.229476	.562778	-.388438	-1.68177	.904891
8	.131392	-.264532	.527316	-.477324	-1.75617	.801525
9	.194861	-.22285	.612572	-.384212	-1.78209	1.01366
10	.173099	-.266198	.612397	-.484331	-1.90834	.939674

*95% lower and upper bounds

4.2 Variance Decomposition

The variance decomposition reports are presented in table 3.6 below. The variance decomposition shows that in the short term about 6% of the fluctuations in OPEC's economic growth(s) are explained by a 100% deviation in crude oil price shocks. In the long term, say ten (10) years, a 100% deviation in crude oil price shocks accounts for about 11% of the fluctuations in economic growth in OPEC economies.

From the above outcome, crude oil prices significantly affect economic growths in OPEC economies both in the short run and long run. However, economic growths in OPEC member states cannot significantly affect global oil prices within the period under consideration. This strand of the result is in line with the a priori expectations. This outcome is also consistent with the previous studies' findings for the relationship between oil exporting countries' economies and crude oil prices or crude oil price shocks. Some of these studies are Saptafora and Warner (1995); Dibooglu and Aleisa (2004); Mehrara and Oskui (2007); Farzanegan and Markwardt (2009) and Berument et al. (2010).

Generally, this study finds that barring any country level response, changes in oil prices are transmitted to OPEC economies. The study's outcome that macroeconomic activities respond to oil prices is further confirmed by the VAR granger causality test in table 3.7 which suggest that crude oil prices granger causes economic growth in OPEC member states.

This study's outcomes show that oil price increase or rise should translate to more revenue for the OPEC governments from crude oil exports. These revenues or oil windfalls are used to boost major development such as infrastructures and could also be used to finance the budgets of these countries. The level of these impacts in the different countries is also different as these countries respond differently to changes in crude oil prices (Lescaroux and Mignon, 2008 and Berument et al., 2010).

Governments' budget expenditures, exchange rates, money supply and imports among others are the expected transmission mechanisms for crude oil price shocks on OPEC economies. This assumption is explained by the positive relationship between current accounts balance and money supply growth, and crude oil prices in the this study's model. Although, the current accounts balance and money supply growth variables were included in the model to boost the robustness of the model, they also show that while they are affected by oil prices and economic growth, they affect economic growth but do not have any effect on oil price.

Table 3.6: Variance decomposition

Step	GDP response to Oil Price impulse			Oil Price response to GDP impulse		
	FEVD	Lower*	Upper*	FEVD	Lower*	Upper*
0	0	0	0	0	0	0
1	0	0	0	.051384	-.117198	.219966
2	.064642	-.114228	.243513	.051615	-.120534	.223764
3	.061811	-.112378	.236	.061313	-.125045	.24767
4	.076044	-.153395	.305483	.056431	-.124067	.23693
5	.111401	-.170578	.393381	.053266	-.116019	.222551
6	.107632	-.162985	.378249	.060707	-.091117	.21253
7	.108391	-.167238	.384021	.060437	-.090798	.211673
8	.108148	-.168382	.384678	.059353	-.090054	.208759
9	.107507	-.166639	.381653	.05437	-.087741	.196481
10	.115668	-.177431	.408767	.051659	-.088772	.192089
*95% lower and upper bounds						

Table 3.7: Granger Causality test

Granger Causality Wald tests			
Equation	Excluded	Chi2	Prob>Chi2
GDP	Oil Price	28.391	0.000
GDP	Current Account	-	-
GDP	Money Supply	7.5914	0.022
GDP	All	29.034	0.000
Oil Price	GDP	2.9645	0.227
Oil Price	Current Account	0.76322	0.683
Oil Price	Money Supply	0.80013	0.670
Oil Price	ALL	5.0997	0.405

5. **Conclusion**

This paper investigates the relationship and interaction between economic growths in OPEC member states and crude oil prices using a panel VAR approach. The study is conducted using the data of nine (9) OPEC member states from 1981 to 2011. This study finds that economic growths in OPEC economies have a positive relationship with crude oil price shocks. The study's results also show that while crude oil prices affect economic growths in OPEC member states, economic growths in OPEC member states do not affect crude oil prices.

This study adds to the works of Kireyev (2000), Devlin and Lewin (2004), Mehrara and Mohaghegh (2011) and Iwayemi and Fowowe (2011) among other previous studies that focused on the relationship between economic growth and crude oil prices. It also contributes to the literature on energy prices and macroeconomic responses by using the panel VAR approach to derive more consistent and reliable estimates on the magnitude and direction of the relationship between economic growth and crude oil prices.

5.1 Policy Implications

The policy implications of this study's findings are potentially important for OPEC member states and other crude oil exports' revenues dependent economies. With the expectation that short or long term changes in crude oil prices may have impacts on their economies, it is expected that they should introduce or enhance buffer policies that will insulate their economies from the volatility in global crude oil prices. Their energy and economic policies should focus on developing or increasing investments for future development purposes. Although, most crude oil exporting countries have "stabilisation funds" set aside to address any future shocks on their economies whether from crude oil price volatility or not, it is important to consider the effects of crude oil prices on their economies with reference to their annual budgets, fiscal and monetary policies. There is need for further diversification of the exports and trade components of these countries as well. For OPEC member states, it is expected that they further diversify their economies by developing other sectors of the economies such as agriculture and manufacturing sectors. These policy effects and recommendations are however country specific as the policy response to the risks of crude oil price fluctuations should be based on a cautionary diagnosis and analysis of the causal trends, transmission mechanisms and previous responses in the different OPEC member states.

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7. **References**

Adelman, A., 2004. The real Oil problem, *Regulation*, 27(1), 16-21

Al-Mutairi, N., 1993. Determinants of the sources of output fluctuations in Kuwait. Finance and Industry 11: 20-78.

Alotaibi, B., 2006. Oil Price Fluctuations and the Gulf Cooperation Council (GCC) Countries: 1960 -2004. Ph.D. dissertation, Southern Illinois University – Carbondale, USA

Anashasy, E. A., Bradly, D. B. and Joutz, F., 2005. Evidence on the Role of Oil Prices in Venezuela's Economic Performance: 1950-2001. Working Paper, George Washington University

Arellano, M. and Bover, O., 1995. Another look at the instrumental variable estimation of error component models. *Journal of Econometrics*, *68*, 29–51.

Barsky, R. B. and Kilian, L., 2004. Oil and the Macroeconomy since the 1970s, Journal of Economic Perspectives 18, 4, 115-134.

Bernanke, B., 1983. Irreversibility, Uncertainty, and Cyclical Investment, *Quarterly Journal of Economics* 98, 85-106.

Berument, H., Ceylan, N. B. and Dogan, N., 2010. The Impact of Oil Price Shocks on the Economic Growth of the Selected MENA Countries. The Energy Journal 31(1), 149-176.

Boubtane, E., Coulibaly, D. and Rault, C., 2012. Immigration, Growth and Unemployment: Panel VAR Evidence from OECD Countries. IZA Discussion Paper Series, 6966.

Bohi, D. R., 1991. On the Macroeconomic Effects of Energy Price Shocks. Resources and Energy, 13, 145–162.

Boye, F., 2001. Oil and macroeconomic fluctuations in Ecuador. OPEC Review 25: 145–172.

Bruno, M., and Sachs, J., 1982. Input Price Shocks and the Slowdown in Economic Growth: The Case of U.K. Manufacturing. Review of Economic Studies 49, 679–705.

Burbidge, J. and Harrison, A., 1984.Testing for the effects of oil-price rises using vector autoregressions. *International Economic Review, 25*, 459–484.

Darby, M.R., 1982. The price of oil and world inflation and recession. *American Economic Review, 72*, 738–751.

Davis, S. and Haltiwanger, J., 2001. Sectoral Job Creation and Destruction Responses to Oil Price Changes. *Journal of Monetary Economics,* 48, 465-512

Devlin, J. and Lewin, M., 2004. Managing Oil Booms and Busts in Developing Countries. Draft Chapter for Managing Volatility and Crises, a Practitioner's Guide

Dibooglu, S. and Aleisa, E., 2004. Oil Prices, Terms of Trade Shocks, and Macroeconomic Fluctuations in Saudi Arabia. Contemporary Economic Policy 22(1): 50-62.

Dixit, A.K. and Pindyck, R.S., 1994. *Investment under Uncertainty*, New Jersey: Princeton University Press.

Eltony, M. N., 2001. Oil Price fluctuations and their Impact on the Macroeconomic Variables of Kuwait: A Case Study Using VAR Model for Kuwait. Arab Planning Institute (API), Working Paper, 9908.

Farzanegan, M. and Markwardt, G., 2009. The Effect of Oil Price Shocks on Iranian Economy. Energy Economics 31: 134-151.

Ferderer, J.P., 1996. Oil Price Volatility and the Macroeconomy. Journal of Macroeconomics 18 (1): 1-26.

Finn, M. G., 2000. Perfect Competition and the Effects of Energy Price Increases on Economic Activity, Journal of Money, Credit and Banking, 32(3), 400-416.

Ghalayini, L., 2011. The Interaction between Oil Price and Economic Growth. Middle Eastern Finance and Economics Journal 13.

Ghanem, S., Lounnas, R. and Brennand, G., 1999. The impact of emissions trading on OPEC, OPEC Review June, 23 (2), 79–112

Gisser, M. and Goodwin, T., 1986, Crude Oil and Macroeconomy: Tests of Some Popular Notions. Journal of Money, Credit and Banking 18(1): 95-103.

Hamilton, J. D., 1983.Oil and the macroeconomy since World War II. Journal of Political Economy 91: 228–248.

Hamilton, J. D., 1988. A neoclassical Model of Unemployment and the Business Cycle. *Journal of Political Economy,* 96, 593-617

Hamilton, J. D., 1996. This Is What Happened to the Oil-Macroeconomy *Relationship. Journal of Monetary Economics, 38(2), 215–220.*

Hamilton, J. D., 2003. What is an Oil Shock? *Journal of Econometrics,* 113, 363-398.

Hamilton, J. D. and Herrera, A., 2004. Oil Shocks and Aggregate Macroeconomic Behaviour: The Role of Monetary Policy. Journal of Money, Credit and Banking, 36, 265–286.

Hamilton, J. D., 2008. Oil and the Macroeconomy. *The New Palgrave Dictionary of Economics,* Second Edition.

Iwayemi, A. and Fowowe, B., 2011. Impact of oil price shocks on selected macroeconomic variables in Nigeria. Energy Policy 39(2): 603-612.

Jimenez-Rodriguez, R., 2004. Oil Price Shocks: Testing for Non-linearity. Centre for Studies in Economics and Finance Working Paper, 115.

Jimenez-Rodriguez, R. and Sanchez, M., 2005. Oil price shocks and real GDP growth: empirical evidence for some OECD countries. Applied Economics 37: 201–228.

Kilian, L., 2005. The effects of exogenous oil supply shocks on output and inflation: evidence from the G7 countries. Centre for Economic Policy Research, Discussion Paper No. 5404.

Kireyev, A., 2000. Comparative Macroeconomic Dynamics in the Arab World: A Panel VAR Approach. IMF working paper, Middle Eastern Department, WP/00/54.

Lane, P. and Tornell, A., 1999. Voracity and Growth. American Economic Review 89, 1: 22 – 46.

Lee, K., Shawn, N. and Ratti, R., 1995. Oil Shocks and the Macroeconomy: The Role of Price Variability. *Energy Journal*, 16:39–56.

Lee, K., and Ni, S., 2002. On the Dynamic Effects of Oil Price Shocks: A Study Using Industry Level Data. Journal of Monetary Economics, 49(4), 823–852.

Lescaroux, F. and Mignon, V., 2008. On the influence of oil prices on economic activity and other macroeconomic and financial variables. OPEC Energy Review 32(4): 343-380.

Love, I. and Zicchino, L., 2006. Financial development and dynamic investment behaviour: Evidence from Panel VAR. Quarterly Review of Economics and Finance, 46(2), 190-210.

Mehrara, M. and Oskoui, N. K., 2007. The sources of macroeconomic fluctuations in oil exporting countries: A comparative study. Economic Modelling 24: 365–379

Mehrara, M. and Mohaghegh, M., 2011. Macroeconomic Dynamics in the Oil Exporting Countries: A Panel VAR study. International journal of Business and Social Science 2 (21)

Mork, K. A., 1989. Oil and the Macroeconomy when Prices Go Up and Down: An Extension of Hamilton's Results. Journal of Political Economy, 91, 740–744

Olomola, P. A. and Adejumo, A. V., 2006. Oil Price Shock and Macroeconomic Activities in Nigeria. International Research Journal of Finance and Economics 3: 28-34.

OPEC, 2012. Annual Statistical Bulletin

Pindyck, R. S. and Rotemberg, J. J., 1983. Dynamic factor demands and the effects of energy price shock American Economic Review 73: 1066–1079.

Rasche, R. H. and Tatom, J. A. , 1981. Energy Prices Shocks, Aggregate Supply and Monetary Policy: the Theory and International Evidence. Carnegie-Rochester Conference Series on Public Policy, Vol. 14, pp 9 – 83

Rosser, J. B. and Sheehan, G. R., 1995. A Vector Autoregressive Model for Saudi Arabian Economy. Journal of Economics and Business 47(1): 79-90.

Roubini, N. and Setser, B., 2004. The Effects of the Recent Oil Price Shock on the U.S. and Global Economy www.stern.nyu.edu/globalmacro/OilShockRoubiniSetser.pdf.

Saptafora, N. and Warner, A., 1995. Macroeconomic effects of terms-of-trade shocks: the case of oil-exporting countries. Policy Research Working Paper, World Bank.

8. Appendix A

Helmert Transformation – Boubtane et al (2012) and Love and Zicchino (2005)

"In this procedure, to remove the fixed effects, all variables in the model are transformed in deviations from forward means. Let
xmit = PTis=t+1 xmis/(Ti −t)
denote the means obtained from the future values of xmit, a variable in the vector
Xit = (x1it, x2it, . . . , xMit)',
where Ti denotes the last period of data available for a given country series.
Let ¯ϙmit denote the same transformation of ϙmit , where ϙit = (ϙ1it, ϙ2it, . . . , ϙMit)'.

Hence we get transformed variables:
˜xmit = δit(xmit− ¯xmit) (2)
and ˜ϙmit = δit(ϙmit− ¯ϙmit) (3)

where δit = p(Ti − t)/(Ti − t + 1).
For the last year of data this transformation cannot be calculated, since there are no future values for the construction of the forward means. The final transformed model is thus given by:
˜X it = ⍰(L) ˜Xit + ˜ϙit (4)

where ˜Xit = (˜x1it, ˜x2it, . . . , ˜xMit)' and ˜ϙit = (˜ϙ1it, ˜ϙ2it, . . . , ˜ϙMit)'

The first-difference procedure has the weakness of magnifying gaps in unbalanced panels (as in our case). The forward means differencing is an alternative to the first-difference procedure and has the virtue of preserving sample size in panels with gaps (Roodman, 2009). This transformation is an orthogonal deviation, in which each observation is expressed as a deviation from average future observations. Each observation is weighted so as to standardize the variance. If the original errors are not auto correlated and are characterized by a constant variance, the transformed errors should exhibit similar properties. Thus, this transformation preserves homoscedasticity and does not induce serial correlation (Arellano and Bover, 1995). Additionally, this technique allows use of the lagged values of regressors as instruments, and estimates the coefficients by the generalized method of moment (GMM)".

Measuring the Security of Energy Exports Demand in OPEC Economies

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Abstract

One of the objectives of OPEC is the security of demand for the crude oil exports of its members. Achieving this objective is imperative with the projected decline in OECD countries' crude oil demand among other crude oil demand shocks. This paper focuses on determining the external crude oil demand security risks of OPEC member states. In assessing these risks, this study introduces two indexes. The first index, Risky Energy Exports Demand (REED), indicates the level of energy export demand security risks for OPEC members. It combines measures of export dependence, economic dependence, monopsony risk and transportation risk. The second index, Contribution to OPEC Risk Exposure (CORE), indicates the individual contribution of the OPEC members to OPEC's risk exposure. This study utilises the disaggregated index approach in measuring energy demand security risks for crude oil and natural gas and involves a country level analysis. With the disaggregated approach, the study shows that OPEC's energy export demand security risks differ across countries and energy types.

Key words – Energy exports, Security of demand, OPEC, Index

1. **Introduction**

Securing the demand for crude oil exports is a primary concern for the Organisation of Petroleum Exporting Countries (OPEC), especially with the projected decline in the Organisation for Economic Cooperation and Development (OECD) countries' crude oil demand (OPEC, 2012a) and other factors that affect global crude oil demand (OPEC, 2013a). OECD countries are the major consumers of crude oil globally even with the recent increase in China's consumption (OPEC, 2012b). Although, there have always been competitive demands for OPEC crude oil exports, the global demand for crude oil has not always been at the expected market prices because of the volatile nature of crude oil prices. Therefore, one of the objectives of OPEC is to empower its members, who, collectively, are the major oil exporters in the world, to have control of their crude oil production, supply and market prices (OPEC, 2013b). In order to achieve this objective, OPEC is faced with the challenges of securing energy demand. Energy demand security can be defined as the availability of a steady or regular demand for the energy exports (e.g. crude oil or gas) at competitive market prices (i.e. prices that can at least cover the production and transaction costs).

In 1973, OPEC resolved to be practically involved in the production, supply and pricing of its members' energy exports, especially crude oil. This decision also affected their economies significantly as most of these economies became heavily dependent on crude oil export revenues over time. In 2008, crude oil and gas contributed about 75% of OPEC economies' total exports and 35% of the Gross Domestic Product (GDP) respectively as shown in figures 1 and 2 below:

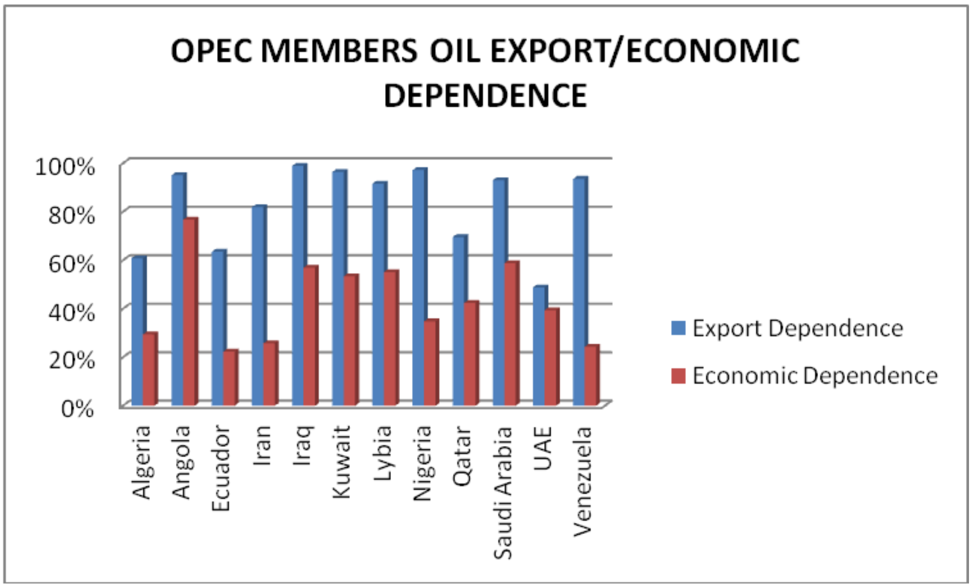

Fig. 1: OPEC member states' oil/economic dependence (Source of data: OPEC, 2009).

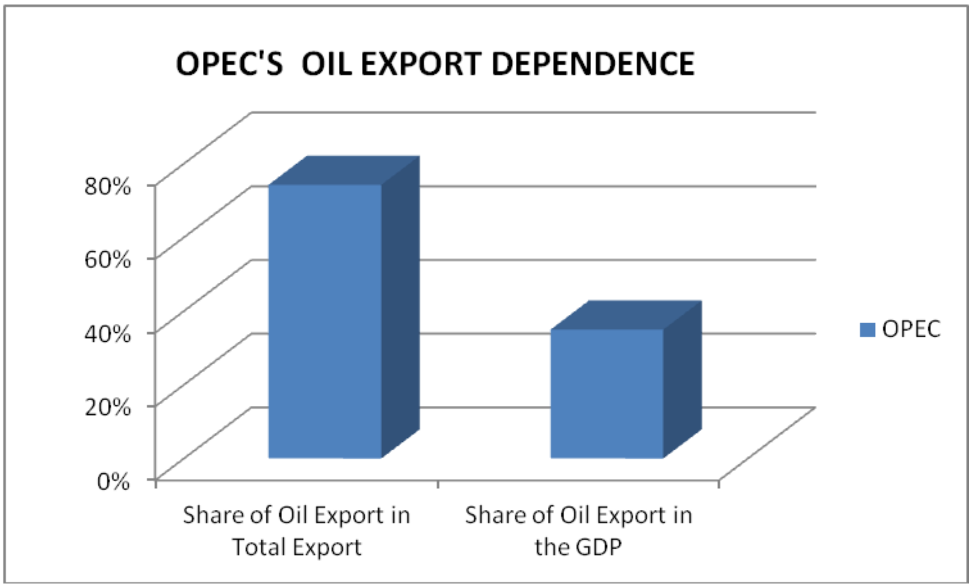

Fig. 2: OPEC's oil export dependence (Source of data: OPEC, 2009).

Recent trends in the global energy industry and the economic reliance of OPEC members on crude oil exports have increased their concern for the security of energy demand. Apart from the decline in crude oil reserves and production based on the peak oil assumptions, OPEC is concerned about other factors outside its control that may disrupt the stability of the global crude oil market such as imbalances of demand, falling rates of investment, speculative activities, exchange rate fluctuations and taxation on oil products (OPEC, 2013a; 2013c).

This paper focuses on the investigation of the level of energy demand security risks for the different economies under OPEC's umbrella. The paper addresses the external energy demand security risks dwelling on the problems associated with crude oil and natural gas exports. This is because the internal crude oil and gas consumptions in most OPEC member states are subsidised which leads to net loss at competitive market conditions (Oil and Gas Journal, 2010).

Just like energy supply security, energy demand security is not affected by economic rationales only but a retinue of other factors. Among these factors is the political rationale. The major crude oil and gas importing countries may act as monopsonists by determining the quantity of demand and market prices for economic and/or political reasons. When such monopsonists' interruptions occur, market prices are bound to be affected which would either reduce crude oil and gas consumptions or require OPEC to reduce output to maintain the existing price levels or incur losses.

These factors and others discussed in details later are the building blocks of the methodology used for this study.

Apart from the major conventional market factors that drive the consumption of crude oil in OECD countries, another factor that may affect their crude oil consumption is their responses and policy measures to international conventions on climate change mitigation (CCM) such as the Kyoto Protocol. For instance, OECD countries make up the majority of the United Nation Framework Convention on Climate Change (UNFCCC) Annex 1 countries. They have agreed under the UNFCCC's Kyoto Protocol targets to reduce their CO_2 emissions levels using CCM policies such as carbon taxes or energy efficiency strategies or the introduction of subsidies on renewable energy sources, thereby, reducing fossil energy consumptions which may reduce imports as well (Barnett et al 2004).

OPEC (2012a) projects reduction in crude oil demand in OECD countries by 5.7mb/d from 2016 to 2035 in its 2012 World Oil Outlook. According to Ghanem et al (1999) the imposition of a carbon tax in the OECD regions or Annex 1 countries that is sufficient to meet the country-level Kyoto and post-Kyoto CO2 emissions targets, would result in a fall in OECD oil demand by 6.5million barrels of crude oil per day, and this translates to a loss in annual OPEC oil export revenue by US$23 billion.

In order to develop policies to address the expected impacts of these external demand shocks on OPEC economies, there is need to understand the crude oil exports demand security risks facing OPEC member states respectively. While the crude oil index is the subject of interest, the gas index is introduced to show that energy exports demand security risks differ under different energy types. Furthermore, the indexes designed in this study do not show the actual impact of energy exports demand shocks on OPEC economies as they are specifically developed to show comparison between OPEC member states energy export demand security risks. The structure of the paper is as follows. After this section is the literature review in section two while the methodology comes up in section three. The data are discussed briefly in section four while the results are presented in section five. The conclusion and policy implications come up in section six.

2. Literature Review

In the energy economics literature, very little contributions exist in this area of study as regards energy exports demand security risks. However, there are numerous contributions in the literature on the external energy supply security risks. On the energy supply security side, Le Coq and Paltseva (2009), Gupta (2008), Frondel (2008), Neumann (2007, 2004), De Jong et al (2007), Roller et al (2007), and Blyth and Lefevre (2004) developed indexes to measure the risk exposure level of major energy importing countries and regions. Le Coq and Paltseva (2009) proposed a set of indexes to evaluate the external energy security risks facing the EU countries. This set of indexes focused on the disaggregated energy types by measuring the risks related to the external supply of oil, gas and coal.

They also covered the contribution of each member country to the EU energy security risk exposure. In designing these indexes, Le Coq and Paltseva (2009) used the Herfindahl-Hirschmann (HH) index to capture the concept of energy supply diversity. Gupta (2008) also used an adjusted HH index to measure the risks related to the diversity of external supply of crude oil but differs from Le Coq and Paltseva (2009) by considering a single energy type – crude oil. Frondel (2008) applied the HH index as well in measuring the diversity of energy supply but did not take into account the transaction risk factors. Neumann (2007) considered a disaggregated external energy supply security risk index comparable with Le Coq and Paltseva (2009) but different in some areas due to the composition of items in the measure of the index. While Neumann (2004; 2007) used the Shannon-Wiener index in measuring diversity, Le Coq and Paltseva (2009) used the HH index. The Neumann (2004; 2007) indexes did not consider the transaction risks as provided in the Le Coq and Paltseva (2009) indexes. Roller et al (2007) and De Jong et al (2007) also proposed a set of indexes but their studies were based on the aggregate measure of the energy types.

This study develops two major indexes similar to Le Coq's and Paltseva's (2009) Risky External Energy Security (REES) and Contribution to EU[11] Risk Exposure (CERE) indexes because of the clarity and systematic considerations of the individual country's risk share vis-à-vis the

[11] European Union

contribution to the regional or group's common risk. Although, this study is tailored after the works of Le Coq and Paltseva (2009) and Neumann (2004; 2007), they are different in so many ways. In this study, the focus is on OPEC and energy exports demand security risks, while the works of Le Coq and Paltseva (2009), Neumann (2004; 2007), Roller et al (2007) and De Jong et al (2007) are focused on the energy importing countries and energy supply security risks. Roller et al (2007) and De Jong et al (2007) specifically differ from this study in the aspect of the energy types measured. In their measurement of the energy supply security risks, they aggregated the energy types, while this study disaggregated the energy types into crude oil and gas just like Le Coq and Paltseva (2009) and Neumann (2004; 2007).

On the energy demand security side, Ghanem et al (1999) and Van der Linden et al (2000) focused on quantifying the impacts of decline in crude oil demand, as a result of the implementations of the Kyoto Protocol targets, on OPEC economies. Ghanem et al (1999) considered the cost implications of OECD carbon taxes for OPEC member states. They measured how the reduction in crude oil demand by OECD regions (in order to achieve the Kyoto targets through responses and policy measures in the form of carbon taxes) is expected to reduce OPEC's oil export revenue. The work of Ghanem et al (1999) is scientific like this study but differs in many ways. Ghanem et al (1999) do not show a disaggregated country level risk analysis like this study. Their work also focus on a single energy type – crude oil while this study focuses on two energy types – crude oil and gas, which are the major fossil energy exports of OPEC member states. Van der Linden et al (2000) developed different scenarios to determine how the Kyoto Protocol's policy responses of the oil importing countries (OECD) would affect OPEC economies. Although, Van der Linden et al (2000) measured the risks arising from the impacts of implementing Kyoto targets on OPEC economies, which is similar to this study's measurement of the crude oil and gas exports demand security risks, their approach is totally different from the approach used in this study. While they developed scenarios based on market situations, this study develops indexes based on major indicators that affect the crude oil exports demand for OPEC member states. This study is also different from Ghanem et al (1999) and Van der Linden et al (2000) because they show the actual impacts of demand shocks on OPEC economies while this study's indexes do not show such actual impacts but relative risks level with a view to compare the country-level risks exposures of OPEC members to energy exports demand shocks. The non-availability of a demand side driven energy security risks index in the energy economics literature makes the REED and CORE indexes original, unique and distinctive.

3. Methodology

In assessing the comparative vulnerabilities of OPEC economies to energy exports demand shocks, this study develops indexes that combine diverse factors to measure these risks which makes it possible for the model to accommodate as many factors as possible to enhance the robustness of the model. The index method is considered appropriate for this study because proxies can be used for the factors that do not have sufficient data and it also suits the multidimensional nature of the factors that affect OPEC's crude oil and gas exports.

The first index developed in this study, the Risky Energy Exports Demand (REED) index, combines measures of export dependency, monopsony risk, transaction cost risk and the economic importance of each energy types for the countries' energy exports bundle respectively. The REED index is uniquely designed and it covers the twelve (12) OPEC member states and their crude oil and gas exports. This study ranks the OPEC member states according to each country's index while comparing them and also compares the crude oil indexes with the natural gas indexes respectively.

The REED index is a multiplicative index because of the relationship between the various factors that affect OPEC's crude oil and gas exports. This is based on the assumption that each of the factors or indicators would contribute more to OPEC external energy demand security risks when the other factors or indicators exist. Using any other mathematical operation like addition or sum of the indicators would undermine the degree of in-exclusivity of this interdependent relationship. However, if the value of any of the indicators is equal to zero the REED value tends to be zero. This possibility is taken care of in the REED index by the assumptions and a priori characteristics of OPEC member states. These assumptions are that the country or group of countries must: (a) be a producer of crude oil and natural gas or the commodity in question (b) be an exporter of crude oil and natural gas or the commodity in question (c) be exporting crude oil and gas or the commodity in question to three or more countries (d) have a heterogeneous energy bundle or a heterogeneous bundle of the commodity in question. Therefore, these a priori assumptions must be satisfied before applying the REED index as a measure of energy demand security risks for any country or group of countries.

This index is designed to measure the present and potential risks related to the demand security of OPEC's energy exports. It measures the short term risks related to the security of demand for energy exports considering cases of either sudden or gradual discontinuation of demand for crude oil and gas from the importing countries.

3.1Composition of the REED Index

As mentioned above, the REED index combines measures of energy exports dependency (X), monopsony risk (M), transaction cost risk (D) and the economic importance (E) of both crude oil and natural gas.

3.1.1 Export Dependence

The measure of energy export dependence (X) matters a lot in this estimation and forms the foundation for the REED index. The energy export dependence is calculated as the ratio of the value of crude oil and gas exports to the total export value. The larger the quantity of crude oil and gas exports in a country's total export value, the higher the energy exports demand risks.

Export dependence (X) = Energy Exports (EE)/Total Exports (tot_exports).. (i)

3.1.2 Monopsony Factor

The size of the share of imports of an importing country in a country's crude oil and gas exports is also considered in designing the REED index. The larger the size of a country's import share of OPEC members' exports, the higher the country's monopsony power on OPEC member states. Similarly, with the increase in the monopsony power of any individual importing country, the higher the risk exposure of OPEC member states. The diversification of the size of the importing country's share of OPEC's energy exports is calculated using the HH index approach which entails the sum of squares of the different importer's share in the total average daily exports. The HH index model emphasises more on the larger market concentration which satisfies the study's assumption that all things being equal, the consumption and import decisions of the country with the a major chunk of OPEC's daily exports affect the crude oil and gas export demand security .

$$\text{Monopsony Factor (M)} = \sum \left[\frac{\text{imp\_country}_{(a,b,\ldots z)}}{\text{tot\_exports}} \right]^2 \quad \ldots\ldots\ldots\ldots \quad \text{(ii)}$$

(Where imp_country = country a, b, ... z imports from OPEC's crude oil /gas and tot_exports = total exports of OPEC's crude oil/ gas)

In measuring the diversity of import share of OPEC's energy importers, other alternative means considered are the Shanon-Wiener index, Gini index and Weitzman index (Stirling, 2010). However, these approaches do not meet the market concentration requirement for the diversification of the crude oil and gas import share. While the Shanon-Wiener and Gini indexes put more weight on the impact of smaller market participants and the Weitzman index emphasises on the number of categories of the participants, the HH index places more emphasis on larger market participants.

3.1.3 Transaction Costs

Another factor considered in designing the REED index is the transaction cost (D) as a result of the transportation and infrastructural disruptions. The distance between the capitals of the exporting and importing countries is used as proxy for the different causes of transportation and infrastructural disruptions and the size of the transaction costs. The distance between OPEC member states and their respective major importers are classified into three groups with the following thresholds. The countries with a distance of less than 1500km have a transaction cost index of 1; while the countries with a distance of 1501km to 4000km have a transaction cost index of 2; and the countries with a distance of 4001km and above have a transaction cost index of 3. The longer the distance between these countries, the higher the risk of crude oil and gas exports demand security because in the event of a fall in prices due to external shocks or otherwise, the value of the transaction costs may be considered in determining the profit or loss from the crude oil and gas exports as this study assumes that, with external demand shocks, the crude oil transaction system may change from FOB[12] (which is mostly in vogue now) to CIF[13] where the sellers bear the burden of the transportation, insurance and other transaction costs when vessels are used for the transportation of crude oil exports. In the case where pipelines are used for the transportation of crude oil exports, this study assumes also that, when the distance of the pipeline is longer, it would traverse more countries and the risks of disruption which falls under transaction costs as well, will be higher. Examples of such pipelines are the Iraq – Turkey crude oil pipelines and the Algeria – Europe gas pipelines.

$$D = \left\{ \begin{array}{l} 1, \text{ if dist\_btw\_capitals} \leq 1{,}500 \text{ km} \\ 2, \text{ if } 1{,}500 \text{ km} < \text{dist\_btw\_capitals} \leq 4000 \text{ km} \\ 3, \text{ if dist\_btw\_capitals} > 4000 \text{ km} \end{array} \right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{(iii)}$$

[12] Free on Board

[13] Costs, Insurance and Freight

3.1.4 Economic Dependence

The economic impact (E) of the crude oil and gas exports on OPEC member states is also considered in the REED index by estimating the ratio of the export value of the crude oil and gas respectively to the economic output. This entails the contribution of the crude oil and gas exports to the OPEC member states' gross domestic product (GDP). The more dependent the economy is on crude oil and/or gas exports, the higher the security of demand risks.

E = exp_val /GDP... (iv)

(where exp_val = value of OPEC's energy export and GDP = Gross Domestic Product value [all in billions of US Dollar])

Therefore, the REED index for each OPEC member state and the different energy types of crude oil and gas is defined by the following equation which encapsulates all the factors described above:

REED = X*M*D*E... (v)

The higher the countries index the more risky the energy export demand security.

3.2 The CORE Index

The impact of the respective countries risks to the entire OPEC risk exposure is also estimated as the second index. This is the contribution to the OPEC risk exposure (CORE). Theoretically, the country with more risk exposure individually would contribute more to the group's total risk exposure (Le Coq and Paltseva, 2009), i.e., a country with a high REED index will contribute more to OPEC's group risk to the security of demand. The country with a large share in OPEC's quota of crude oil and gas exports will also contribute more to OPEC's group risk.

CORE = REED * S/ ∑ (REED*S).. (vi)

Where, S is the share of the individual country in total OPEC crude oil and gas exports.

4. Data

In computing the REED indexes for crude oil and gas, and the CORE index, this study relies on the data on crude oil and gas exports, imports and consumption from the OPEC Annual Statistical Bulletins, the US Energy Information Administration (EIA) database and international trades' data of OPEC member states. The indexes are specifically based on the 2009 data for the twelve (12) OPEC member states (OPEC, 2010). The data on natural gas exports are adjusted in line with the model specification. The data sets are available in Appendix A.

5. **Results**

The results of the study showing the REED index and CORE index respectively are presented below in tables 1 and 2.

Table 1: The REED Index

OPEC Member States	Crude Oil REED Index	Gas REED Index
Algeria	0.07	1.21
Angola	0.58	0.00
Ecuador	0.06	0.00
Iran	0.08	0.00
Iraq	0.26	0.00
Kuwait	0.36	0.00
Libya	0.14	0.06
Nigeria	0.17	0.12
Qatar	0.08	4.98
Saudi Arabia	0.17	0.00
United Arab Emirates	0.05	0.02
Venezuela	0.07	0.00
Average	0.18	0.53
Standard Deviation	0.16	1.44

Table 2: CORE Index

OPEC Member States	Crude Oil (%)	Gas (%)
Algeria	2.1	16
Angola	22	0
Ecuador	0.4	0
Iran	4	0
Iraq	10	0
Kuwait	16	0
Libya	5	0
Nigeria	7	1
Qatar	1.5	83
Saudi Arabia	25	0
United Arab Emirates	3	0
Venezuela	4	0
Total	100	100

5.1. Crude Oil Indexes

The differences in exports, distance(s) of the exports destination, diversification of importing countries and economic outputs determine the difference in the indexes of the respective OPEC members. For instance, a country with a high crude oil export value in its total exports is expected to have a high index, hence a high risk level. The same applies for the other indicators.

For the purpose of this study, the index is calibrated under three categories. The countries with indexes that are above 0.20 are high risk countries while the ones with indexes between 0.10 and 0.20 are the medium risk countries and the ones below 0.10 are low risk countries. The crude oil REED index in table 1 shows that Angola, Iraq, and Kuwait have high crude oil demand security risks. This is explained by their heavy crude oil exports dependence, as crude oil accounts for over 90% of their total exports and over 40% of their GDP except Iraq which has 38% economic dependence level but has a high transaction risk. Some of these countries are in this category because of their high monopsony risks or high transaction risks due to the long distance from their major crude oil trade partners or countries.

The next category is the medium crude oil demand security risk countries such as Nigeria, Saudi Arabia and Libya. Although, these countries have a high crude oil exports dependence level, their economic dependence level are lower compared to the high level crude oil demand security risk countries except Libya which has 59% economic dependence level. They also have low monopsony risks and moderate transaction risks. Libya has high energy export dependence as about 99% of total exports in 2009 were energy based but has low monopsony and transaction risks.

The third category is the low level crude oil demand security risk countries. These countries are Algeria, Ecuador, Iran, Qatar, UAE and Venezuela. Some of these countries also have high crude oil exports dependence level but very low economic dependence level and low monopsony risks. Countries like Ecuador and Venezuela have low transaction risks as they are very close to their major crude oil trade partners or countries.

The contributions to OPEC's risk exposure follow a similar pattern but with respect to a country's share of OPEC's total energy exports as well. The countries with high crude oil demand security risks and/or large share of OPEC's total energy exports contribute more, while countries with medium demand security risks and/or moderate share of OPEC's total energy exports contribute moderately and the countries with low demand security risks and/or small share of OPEC's total energy exports contribute less to OPEC's risk exposure.

5.2. Gas Indexes

The gas REED index follows the same calibration categories like the crude oil index but shows a distinct pattern in values. The OPEC member states exporting natural gas in 2009 are few and their export demand security risks are analysed below. The countries with high gas demand security risk are Qatar and Algeria with high export and economic dependence levels. The other countries do not show significant gas demand security risks as they are either non-exporters of gas or their exports are insignificant compared to Algeria's and Qatar's gas exports. Countries, such as Nigeria, Libya, Iran and UAE fall under the latter category and have low export and economic dependence levels. The other countries, Angola, Ecuador, Iraq, Kuwait, Saudi Arabia and Venezuela did not export gas during the period under review, hence no risk identified.

The contributions to OPEC's gas demand security risk exposure follow the same trend. The high demand security risk countries contribute more to OPEC's risk exposure with Qatar responsible for 83% of the OPEC's risk exposure while Algeria accounts for 16% and Nigeria contributes approximately 1%. The contributions of other countries to OPEC's gas demand security risk exposure are not significant.

6. Conclusion and Policy Implications

This study designs a set of indexes to measure the crude oil and gas exports' demand security risks facing OPEC members. The study's focus is on the impacts of the externally induced crude oil and gas demand shocks on OPEC member states.

The indexes designed in this study take into account the crude oil and gas exports profile of OPEC members, economic output levels, risks associated with the size and destination of exports and transportation and disruption related factors. By calculating the indexes for two energy types, crude oil and gas, the study finds that the level of risks differ across energy types and the different OPEC member states.

The outcome of this study may have implications for the design, implementation and sustainability of a common energy policy for OPEC members. The security of demand for OPEC's crude oil has become paramount, considering the crude oil exports dependence of these OPEC member states and the risks associated with such dependence. OPEC as an organisation may opt for common strategies that would protect its members' economies from any adverse effect related to external demand shocks. However, the differences in energy export demand security risks across these countries may be a barrier to OPEC's common energy policy as the preferences over such policy may also differ among OPEC member states. The geographical spread of OPEC member states may also be an obstacle to a common energy policy as the membership of OPEC cuts across three continents with different geo-political realities.

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8. References

Barnett, J., Dessai, S. and Webber, M., 2004. Will OPEC lose from the Kyoto Protocol? Energy Policy 32, 2077-2088.

Blyth, W. and Lefevre, N., 2004. Energy Security and Climate Change. International Energy Agency Information Paper

De Jong, J., Maters, H., Scheepers, M. and Seebregts, A., 2007. EU Standards for Energy Security of Supply. ECN-E-07-004/CIEP

El Badri, A. S., 2010. Supporting stability, fuelling prosperity, OPEC Secretary General marks 50th anniversary. Petroleum World News, http://www.petroleumworld.com/ed10091501.htm

Frondel, M. and Schmidt, M., 2008. Measuring Energy Security: A Conceptual Note, Ruhr Economics Papers, 52, RWI, Essen

Ghanem, S., Lounnas, R. and Brennand, G., 1999. The Impacts of Emissions Trading on OPEC, OPEC Review, 23/2, 79-112

Gupta, E., 2008. Oil vulnerability index of oil-importing countries. Energy Policy 36 (3), 1195–1211.

Halsnæs, K.,1996. The Economics of Climate Change Mitigation in Developing Countries, Energy Policy, 24, 10-11

Le Coq, C. and Paltseva, E., 2009. Measuring the security of external energy supply in the European Union, Energy Policy, 37, 4474-4481

Linden, NH van der, Linden C. Van der, Lako P. and Rooljen, SNM van, 2000. Analysis of the Impact of Kyoto Protocol on the Export Revenues of OPEC , PBL Netherlands Environmental Assessment Agency Report, 115

Neumann, A., 2004. Security of Supply in Liberalised European Gas Markets Diploma Thesis, European University, Viadrina, Germany

Neumann, A., 2007. How to measure Security of Supply? Mimeo, Dresden University of Technology, Dresden, Germany

Oil and Gas Journal, 2010. Subsidies seen endangering OPEC prosperity. http://www.ogj.com/articles/2010/10/subsidies-seen-endangering.html

OPEC, 2009. OPEC Annual Statistical Bulletin 2009, http://www.opec.org/opec_web/static_files_project/media/downloads/publications/ASB2009.pdf

OPEC, 2010. OPEC Annual Statistical Bulletin 2010

OPEC, 2012a. OPEC's World Oil Outlook, 2012. http://www.opec.org/opec_web/static_files_project/media/downloads/publications/WOO2012.pdf (as at 31/05/2013)

OPEC, 2012b. OPEC Annual Statistical Bulletin 2012. http://www.opec.org/opec_web/static_files_project/media/downloads/publications/ASB2012.pdf (as at 31/05/2013)

OPEC, 2013a. What Causes High Oil Prices http://www.opec.org/opec_web/static_files_project/media/downloads/publications/FAQ.pdf (as at 31/05/2013)

OPEC, 2013b. Is there any need for Security of Oil Demand? http://www.opec.org/opec_web/en/press_room/178.htm (as at 31/05/2013)

OPEC, 2013c. The Oil Industry – What Impact can OPEC have on Industry? http://www.opec.org/opec_web/en/press_room/179.htm (as at 31/05/2013)

Roberts, J. T., 2001. Global Inequality and Climate Change, S&NR, 14/6, 501-509

Roller, L. H., Delgado, J. and Friederiszick, H. W., 2007. Energy: Choices for Europe, Bruegel Blueprint Series

Stirling, A., 2010. Multi-criteria Diversity Analysis, a Novel Heuristic Framework for Appraising Energy Portfolios, Energy Policy 38 (4), 1622-1634

The World Bank, 2009. The World Bank's global study on adaptation costs —Economics of Adaptation to Climate Change (EACC)

Tompkins, E. L. and Adger, W. N., 2005. Defining Response Capacity to enhance Climate Change Policy, Environmental Science and Policy, 8 (6), 562-571

9. **Appendix A**

Table A1: Primary Data for Crude oil (Source OPEC 2012 Annual Statistical Bulletin)

OPEC Members	Oil Export ($B)	Total Export ($B)	GDP($B)	Exp. Dep. (X)	Economic Dep. (E)	Monopsony (M)	D
Algeria	30.58	48.52	138.15	0.630256	0.221354	0.266592	2
Angola	39.8	40.83	75.51	0.974773	0.527083	0.378577	3
Ecuador	6.97	13.79	52.02	0.505439	0.133987	0.936437	1
Iran	55.75	87.53	360.63	0.636924	0.154591	0.265159	3
Iraq	41.67	42.41	110.97	0.982551	0.375507	0.231042	3
Kuwait	48.91	53.97	105.93	0.906244	0.46172	0.285279	3
Libya	36.97	37.06	62.96	0.997572	0.587198	0.246223	1
Nigeria	44.73	52.66	165.76	0.849411	0.269848	0.381284	2
Qatar	19.13	48.31	97.8	0.395984	0.195603	0.53202	2
Saudi Arabia	161.91	192.3	376.69	0.841966	0.429823	0.229366	2
UAE	52.87	191.78	270.34	0.27568	0.195569	0.461844	2
Venezuela	54.2	57.6	329.79	0.940972	0.164347	0.451485	1
OPEC total Oil export	593.49						

Table A2: Primary Data for Gas (Source OPEC 2012 Annual Statistical Bulletin)

OPEC Members	Gas Exports($B)	X	E	M	D
Algeria	123.2478	2.540144	0.89213	0.266592	2
Angola	0	0	0	0	3
Ecuador	0	0	0	0	1
Iran	13.2678	0.15158	0.036791	0.265159	3
Iraq	0	0	0	0	3
Kuwait	0	0	0	0	3
Libya	23.1426	0.624463	0.367576	0.246223	1
Nigeria	37.4166	0.710532	0.225728	0.381284	2
Qatar	148.6602	3.077214	1.520043	0.53202	2
Saudi Arabia	0	0	0	0	2
UAE	35.5914	0.185585	0.131654	0.461844	2
Venezuela	0	0	0	0	1
	381.3264				

Table A3: Computation Output for the CORE Index

OPEC Members	CRUDE OIL				GAS			
	Crude Oil REED Index	Share(S) of OPEC Exports	REED*S	CORE	Gas REED Index	Share (S) of OPEC Exports	REED *S	CORE
Algeria	0.07438403	0.0515	0.003833	0.021358	1.208267501	0.323208	0.390522	0.16628468
Angola	0.583522624	0.0671	0.039132	0.218062	0	0	0	0
Ecuador	0.063417535	0.0117	0.000745	0.00415	0	0	0	0
Iran	0.078324807	0.0939	0.007358	0.041	0.004436162	0.034794	0.000154	6.57228E-05
Iraq	0.255732438	0.0702	0.017955	0.100057	0	0	0	0
Kuwait	0.358109376	0.0824	0.029512	0.164457	0	0	0	0
Libya	0.144230768	0.0623	0.008985	0.050066	0.056517548	0.06069	0.00343	0.001460513
Nigeria	0.174789819	0.0754	0.013174	0.07341	0.122305779	0.098122	0.012001	0.005110004
Qatar	0.082416021	0.0322	0.002657	0.014804	4.97703995	0.38985	1.9403	0.826182153
Saudi Arabia	0.166013391	0.2728	0.04529	0.252381	0	0	0	0
UAE	0.049800132	0.0891	0.004436	0.024722	0.022568465	0.093336	0.002106	0.000896927
Venezuela	0.069820277	0.0913	0.006376	0.035532	0	0	0	0
	Avg = 0.175046768		∑ = 0.179451	∑= 1	Avg = 0.532594617		∑ = 2.348514	∑= 1
	STDEV= 0.158169907				STDEV= 1.441137009			