ISSUES ON CRUDE OIL PRICE VOLATILITY:

DETERMINANTS AND IMPACT OF FUTURES TRADING

İSTEMİ BERK

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ISSUES ON CRUDE OIL PRICE VOLATILITY:

DETERMINANTS AND IMPACT OF FUTURES TRADING

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Approval of the Graduate School of Social Sciences

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ABSTRACT

ISSUES ON CRUDE OIL PRICE VOLATILITY:

DETERMINANTS AND IMPACT OF FUTURES TRADING

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This thesis analyzes the impacts of futures trading activity on crude oil spot market volatility. GARCH-type volatility modeling along with causality and cointegration analyses has been conducted to model the interrelationship between variance of both spot and futures markets. Moreover, with using ICSS algorithm structural breaks in spot market is captured and, then, used as variables with futures trading volume in variance equation of spot market. Results of this thesis imply that there exists a strong bidirectional short-term lead-lag relationship and long-term co-movement between WTI spot and futures crude oil markets. In addition to that, futures trading volume is found to have a significant and positive impact on Brent spot crude oil market volatility. These results suggest that futures prices have a considerable impact on spot price regimes. This suggestion obviously, challenging the basic idea that futures exchange increase market efficiency.

Keywords: Crude Oil, Volatility, Futures Trading, GARCH

ÖZET

PETROL FİYAT VOLATİLİTESİ; BELİRLEYİCİ ETKENLER VE VADELİ İŞLEMLERİN ETKİLERİ

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Bu çalışma vadeli işlemlerin petrol spot piyasası volatilitesi üzerindeki etkilerini incelemektedir. Spot ve vadeli işlemler piyasalarının varyansları arasındaki ilişki nedensellik ve kointegrasyon analizleri ile beraber GARCH volatilite modellemesi ile analiz edilmiştir. Bunun dışında ICSS algoritması spot piyasa varyansındaki yapısal kırılmaları bulmak için kullanılmış, bu yapısal kırılmalar ile beraber vadeli işlemler kontrat hacmi spot piyasa varyans denklemi içinde değişken olarak kullanılmıştır. Bu çalışmanın sonuçları göstermektedir ki, WTI petrol vadeli işlemler ve spot piyasaları arasında kısa dönem nedensellik ve uzun dönem kointegrasyon mevcuttur. Bununla beraber, vadeli işlem hacminin spot volatilite üzerinde istatistiksel olarak anlamlı ve pozitif etkisi bulunmaktadır. Bu sonuçlar vadeli işlem piyasasında oluşan fiyatların spot piyasa fiyat rejimleri üzerinde etkili olduğunu önermektedir. Bu önerme, açıkça, vadeli işlemlerin piyasa verimliliğini arttırdığı fikrine karşı gelmektedir.

Anahtar Kelimeler: Petrol, Volatilite, Vadeli İşlemler, GARCH

To My Parents

ACKNOWLEDGMENTS

I express sincere appreciation to Assoc. Prof. Dr. Adnan Kasman for his guidance and insight throughout the research. Thanks go to the other faculty members, Berna Okan Aydoğan and Gökçe Aksoy, for their suggestions and comments. The technical assistance of Özgül Bilici is also gratefully acknowledged.

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1 Introduction

Energy has been one of the most important factors of production since the Industrial Revolution, which has started in the 18th Century in United Kingdom and spread trough all Europe and North America. Steam powered engines in the 18th Century and internal combustion engines in the 19th Century have triggered an alteration in the production process. Since than labor power has substituted with machinery equipments, working with energy sources, in major sectors such as; manufacturing, transportation, and agriculture. During the mentioned period coal was the primary energy source.

With the beginning of the 20th Century because of its chemical structure including more hydrogen bounds and revealing higher energy in combustion period, crude oil has become the dominant among other energy sources. The gradual increase in the share of crude oil, as the dominant fuel, in production function in overall economic activity and uneven distribution of global crude oil reserves, has emerged the concept of energy security especially during healing the damage on economies caused by the Second World War. Issues such as, supply security and efficient pricing mechanism has made crude oil both political and economic commodity which the countries try to manage for their development process.

After the first oil crisis in 1973[1] most of the economists, policy makers and academicians have started to discuss the consequences of domination of OPEC in the market and effects of OPEC administrated oil prices on macroeconomic activity. Most of the studies conducted on this sense, have found significant and negative

[1] Before 1973 crude oil reserves in Middle East are mainly managed by the International Oil Companies. States of Middle Eastern countries were receiving a royalty ratio from the producing companies on which the debates emerged, resulted with the nationalistic political movements and foundation of Oil Producing and Exporting Countries, OPEC in 1960. In 1973 certain OPEC members have decreased crude oil production due to Yom-Kippur War which led to a recession in Western, developed countries.

correlation between energy, especially oil, shocks and macroeconomic activity. Therefore, increasing concerns on the domination of OPEC in the crude oil market has revealed an alternative mechanism in determination of worldwide crude oil prices; namely futures exchanges. In 1983 first crude oil financial contract has been offered by New York Mercantile Exchange (NYMEX), since then, the volume of transactions being held in futures exchanges have increased gradually leading futures exchanges be dominant in crude oil markets. The basic aim for Western, oil importing and developed countries in forming an artificial/financial market for crude oil was to avoid direct effects of OPEC's monopolistic behavior on prices and to minimize short-term fluctuations, volatility. The common view of crude oil market executives was stating that futures exchange would diminish price volatility of oil and at the same time "invisible hand" would lead a fair equilibrium of price. On the other hand, as it will be mentioned later, the price fluctuations in crude oil market still have a considerable impact on macroeconomic indicators. Therefore, modeling crude oil price volatility and analyzing the factors of short term fluctuations in crude oil price have emerged as important topics among the researchers.

This thesis will focus on one of the factors lying behind the crude oil price volatility, futures trading activity and will try to model the impacts of crude oil futures activity on spot market. The primary suggestion of this study is that futures prices have a considerable impact on spot price regimes. This suggestion obviously, challenging the basic idea that futures exchange increase market efficiency. If, any, significant effect of futures trading on spot market volatility is captured, it would be quite possible to conclude that futures exchange has failed the primary mission of increasing market efficiency.

The main contribution of this thesis to the related literature is that after analyzing the fundamentals of crude oil industry and microeconomic structure of crude oil market in historical contex, impacts of futures trading on spot crude oil market will be investigated using both West Texas Intermediate (WTI) and Brent crude oil markets data for the periods between 1986 to 2010 and from 2008 to 2010, respectively.

The remainder of this thesis is organized as follows. Chapter 2 will handle the basic fundamentals of crude oil market from both economic and technical perspective and Chapter 3 will analyze the structure of financial derivatives market. In Chapter 4, empirical relationship between financial derivatives market and crude oil prices will be investigated and finally chapter 5 will conclude with policy implications.

2 Crude Oil Market

This section will handle the essentials of crude oil market with giving brief information about the formation and history of crude oil, fundamentals of crude oil industry, and microeconomic structure of crude oil market in an historical perspective.

2.1 Crude Oil as a World Commodity

Among other commodities crude oil has been treated as it has the dominant role in the sustainable development process of world economies since the beginning of the 20th Century. Ediger (2005) concludes that domination of crude oil in worldwide energy system has named the 20th and 21st Centuries as “Oil Era”. The importance of crude oil in human daily life and industrial activity has been stated by many authors. Maugeri (2006) states “No other raw material has been so critical in shaping the destiny of nations, the development of military and global trade strategies, and relationships between countries" and according to Yergin (1991) "As we look towards the twenty-first century, it is clear that mastery will certainly come as much from a computer chip as from a barrel of oil." Orwel (2006) discusses the role of crude oil in modern economies with stating the fact that crude oil literally drives the whole production functions in our planet apart from the apparent function of fuelling world transportation system. Rubin (2009) states that less and expensive crude oil means higher transportation costs leading to a localized and a smaller world for all of human being. Moreover, while Venn (2002) emphasize the role of crude oil on conducting foreign policies apart from on macroeconomics, Maass (2009) describes the political power asymmetries that crude oil can create. On the other hand, book of Leeb and Leeb (2004) was the first study which has mentioned to the relationship between crude oil prices and individual portfolio management within the context of behavioral finance.

As all of these studies conclude, crude oil differs from other commodities because of its uneven distribution geographically, its share in primary energy demand, and high gains comprised by crude oil trading and end-user marketing of products. Moreover, those reasons have lead crude oil to one of the major determinants in countries policies in the context of political economy. The production of crude oil, so far, have been very close to global demand but as production peak approaches the divergence between two indicators will make it clear that there will arise a constraint of scarcity which has been first introduced by Hotelling (1931). Furthermore, it has become a common sense that the period during which world economies has faced fairly low price of crude oil, has ended. New era of expensive crude oil has started due to supply-demand disequilibrium and speculative behavior in crude oil trading.

With the late 1900's crude oil has started to be traded in financial markets, which will be discussed later in this chapter, merging a new concept for industry; non-commercial trading, i.e. transactions held by investors and speculators who have nothing to do with physical crude oil. Therefore, in the 21st Century crude oil has become a political, economic and financial commodity creating a new market which the energy analysts have to analyze in a wider perspective.

2.1.1 Fossil Fuels

Fossil fuels, which include high percentage of hydrocarbon compounds in their chemical structure, are fuels that are generated by sedimentation of dead organisms under proper pressure and temperature conditions. Fossil fuels are known as nonrenewable sources because their formation takes millions of years. Therefore, depletion of fossil reserves is much faster than formation of new reserves. Coal and petroleum are known as the basic types of fossil fuels. The physical structure, i.e. solid, liquid and gas phase, of fossil fuels depends heavily on the chemical structure and the corresponding reserve's pressure and temperature levels. Petroleum is exactly the combination of crude oil and natural gas.

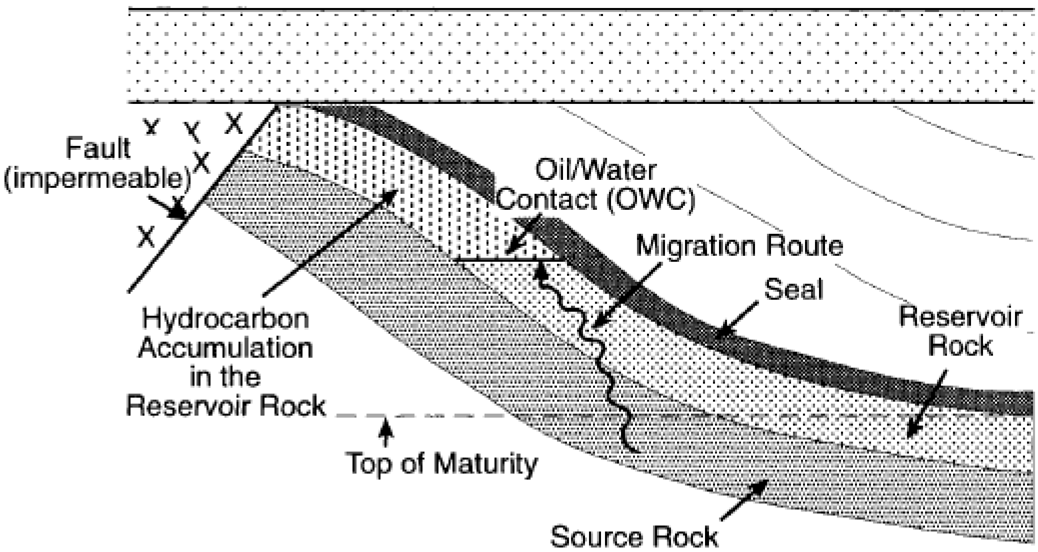
Coal was the first fossil source that is used for the purpose of maintaining energy for industrial activities, transportation, and heating. Although the evidence of coal usage goes back to Roman Empire period, it was not until Industrial Revolution in the 18th Century that coal has largely used for mentioned purposes. From this perspective it is acceptable to start the history of usage of fossil fuels with the

Industrial Revolution period. Since than fossil fuels have become the major energy sources of mankind in daily life.

2.1.2 Formation of Fossil Fuels/Petroleum; Resource/Reserve Dilemma

Formation of petroleum can be mainly analyzed in three processes; generation, migration and accumulation. The generation process takes place in the permeable rock called source rock. In this geologic sediment petroleum maturates under proper conditions of temperature and pressure. Once the maturation happens petroleum migrates from the source rock to reservoir rock. The most two important properties of reservoir rock are porosity and permeability. Besides the common idea about the underground petroleum reserves that they are like a lake, petroleum is deposited in the porous media of reservoir rock. The production takes place from this media. The most primary factor of the reservoir rock is that above this rock there must lay a non-permeable cap rock. Furthermore, the fault between cap rock and reservoir rock must be convenient for petroleum accumulation.

Figure 2.1 Petroleum Generation, Migration and Accumulation



Source: Frank et. al. (1998)

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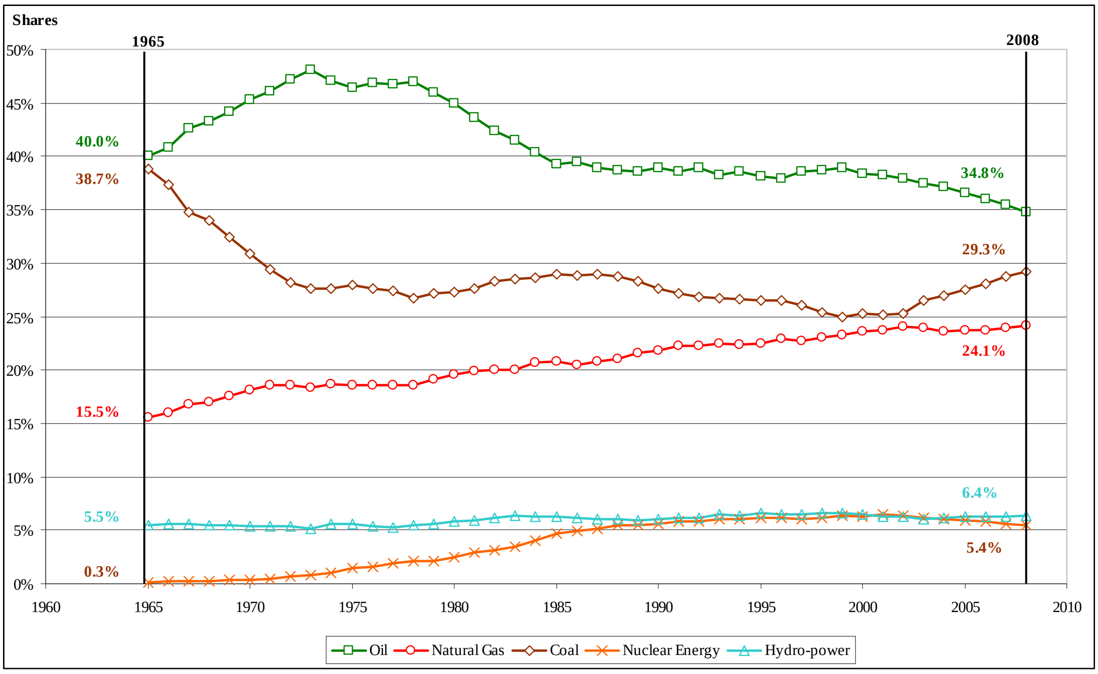
One other confusing issue among petroleum industry is resource-reserve definitions. According to the report of "Petroleum Resources Management"[2] resource is defined as all the "all quantities of petroleum naturally occurring on or within Earth's crust, discovered or undiscovered (recoverable and unrecoverable) plus those quantities already produced. Whereas, reserves are defined as the resources, that are proved, ready to produce, economically viable and technically possible.

2.1.3 World Crude Oil Facts

Share of fuels in world primary energy demand is shown in Figure 2.2. In 1965 shares of crude oil, coal, natural gas, hydro-power and nuclear in primary energy demand were 40%, 38.7%, 15.5%, 5.5%, and 0.3%, respectively. In 2008, moreover, the order did not change while shares of natural gas and coal have converged. In historical perspective crude oil has always been the dominant fuel in primary energy demand.

[2] Report by SPE, AAPG, WPC and SPEE

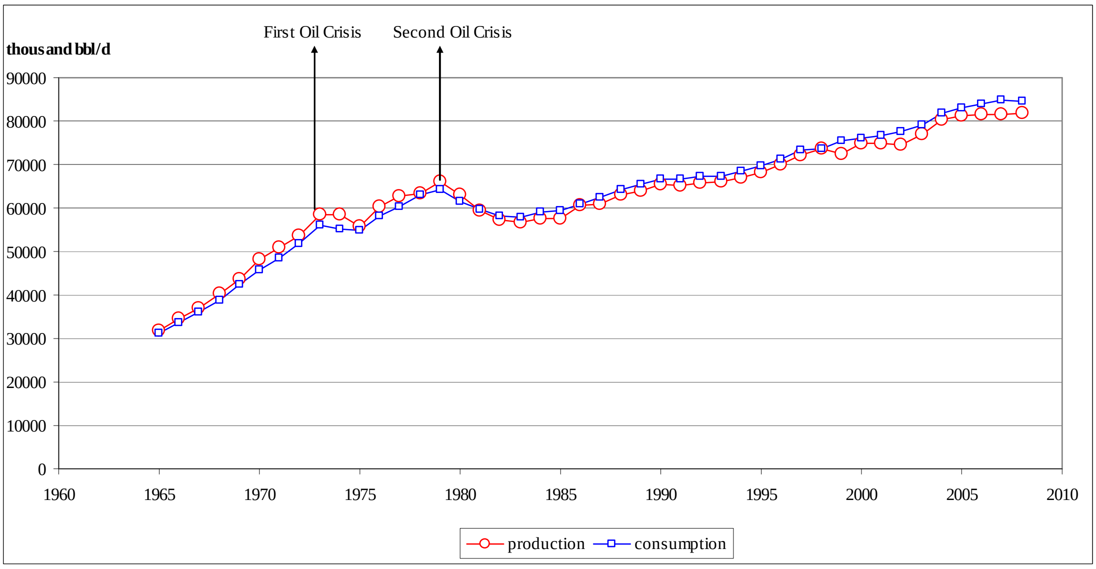
Figure 2.2 Shares of Fuels in World Total Primary Energy Consumption



Source: BP Statistical Review of World Energy 2009 Report

Figure 2.3 represents production and consumption of crude oil globally. Apart from the high correlation between two trends, it is obvious that both trends have a gradual increase since 1965. Two trends have deteriorated two times in history in 1973 and 1979 because of first and second oil shocks, respectively. One other deduction from the graph is that after 1983 both crude oil production and consumption has increased from nearly 57 Mbbl/day to 82 Mbbl/day in 2008.

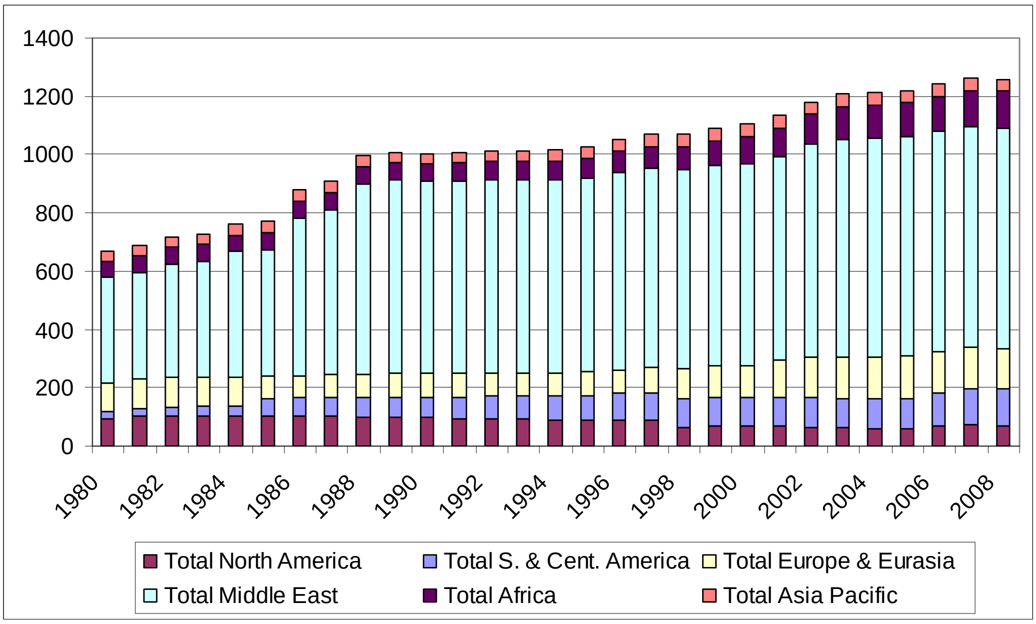
Figure 2.3 World Crude Oil Production and Consumption, 1965–2008.



Source: BP Statistical Review of World Energy 2009

Another issue, regarding the world energy facts, is the heterogeneous distribution of world crude oil reserves among the globe. As stated in Figure 2.4, Middle East region, as commonly known, is leading in world crude oil reserves. Moreover, this creates a challenge that the major importing countries' would face because of crude oil demand of their economies.

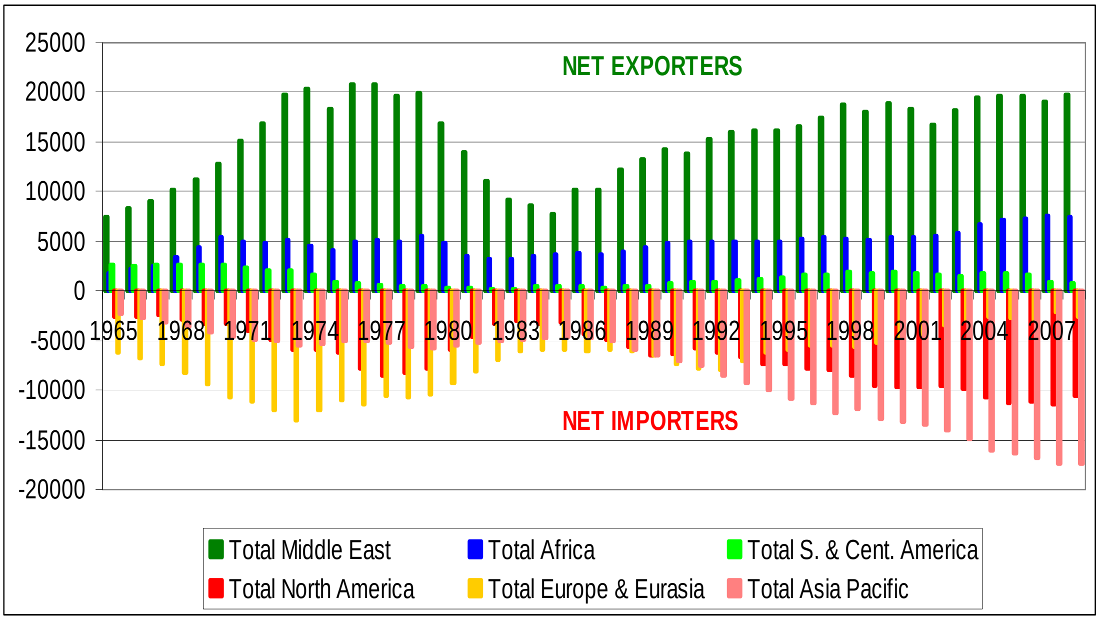
Figure 2.4 World Crude Oil Reserves; 1980 – 2008 (in billion barrels)



Source: BP Statistical Review of World Energy 2009 Report

Mentioned challenge rising above the distribution of crude oil reserves among earth crust, represented by the Figure 2.5, whose data is derived as difference between crude oil production and consumption by regions. According to the Figure 2.5, the regions that have positive production minus consumption values, i.e. net exporters, are Middle East, Central and South America and Africa, whereas net importer regions are North America, Europe and Asia-Pacific Region. One derivation from the figure is that mentioned net importers are, by social and economic means, more developed than the exporters, therefore crude oil consumption are directly related to development levels of countries.

Figure 2.5 Differences between Crude Oil Production and Consumption by Regions (in million barrels daily)



Source: BP Statistical Review of World Energy 2009 Report

This section has provided evidence that crude oil, as the dominant fuel in global energy demand, creates major challenges that the world has faced since 1965 and will continue to face in coming years. With this respect, in order to define the recent challenges properly, world crude oil history must be analyzed.

2.1.4 History of World Crude Oil

Although there are different ideas about the beginning of history of crude oil, it is known that human being has met this crucial commodity thousands of years before today. It has been even proved that Chinese people has drilled the first crude oil well in the 4th Century with bamboos[3]. They had used crude oil to provide energy for sugar production. On the other hand, first technical crude oil well was drilled in 1859 by Edwin L. Drake in Pennsylvania, the USA. Crude oil industry accepts the date of Drake's well as the beginning of modern crude oil era, after which crude oil production and local crude oil transactions gradually increased till the peak of crude oil production in the USA. In the 1870's Standard Oil Company has established and

[3] Parlaktuna et. al. (2007)

become the world's largest oil refining and marketing group. During the mentioned years crude oil demand of Europe has been supplied by Standard Oil's refineries in USA, with crude oil tankers passing the ocean. First Ocean passing crude oil tanker was built by Shell Transportation and Trade Company which has later merged with Royal Dutch Company forming modern Royal Dutch Shell Group.

With the transoceanic trade of crude oil, explorations of reserves in Russia in 1876 and Iran (by William Darcy) in 1908, crude oil has become a global commodity which was the most important determinants of the results of world two motorized wars World War I and World War II. According to Yergin (1991) ally forces has bombed the Romanian oil fields and forcing Germans heavily depend on the synthetic oil[4] production which was obviously not sufficient for demand of German Army. As the World War II gets over, need for a sustainable, secure and more organized system for crude oil supply, which was essential for transportation, energy generation and petrochemical industry, lead European countries and the USA struggle for reserves in Middle East region.

Actually this was bidirectional dependence since, while western developed countries needed Middle Eastern crude oil, Arabian countries needed western counterparties for the capital, expertise and technology to develop their crude oil reserves and gain profit from this essential natural source. Mentioned dependence caused American originated International Oil Companies, i.e. Seven Sisters, arising as the dominant players in crude oil industry.

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[4] Synthetic Oil is a lubricant consisting of chemical compounds which are artificially made by compounds other than crude oil.

The vertically integrated structure[5] of companies and long-term contracts were two reasons of comparably stable crude oil market. As it will be mentioned later in this chapter, companies set the price, which was called posted price, with calculating major costs such as share of host countries, lifting and transportation costs. The price was not tested by supply-demand equilibrium.

The dominancy of international companies on crude oil market has continued till late 1950's. As the initial stage of development of crude oil reserves completed, host countries started to discuss oil companies' control on their natural sources. The first world-wide dispute over the reserves has actually started in Latin America in 1920s and spread over Middle East in 1930s. Whereas, it was not until 1960s that Arabian countries started to take actions on this issue. In September 1960 Organization of the Petroleum Exporting Countries, OPEC, has been formed in Baghdad conference with the participation of Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela[6]. With respect to the foundation objective aiming coordination and unifying the petroleum policies among members, organization has tried to secure fair and stable prices. The formation of OPEC was the most elementary consequence of crude oil reserve nationalism in Middle East.

Two of the most important actions of OPEC members were the production cut and putting quota on exports to the western countries in 1973 because of the support they gave to Israel in Yom Kippur, Arabian-Israeli, War. The mentioned actions has concluded with the first oil crisis of 1973-1974. Venn (2002) separates crisis in four parts; independent decisions of major oil exporters through the control of oil prices, long-standing Arab-Israeli dispute, imposing of oil boycott and implementing cuts in

[5] Integrated strcuture means that company holds all the actions of exploration, production, transportation, refining and marketing actions.
[6] Source: official website of OPEC; http://www.opec.org

production. In 1979, as a consequence of Iranian Revolution world crude oil market has faced the second oil crisis. Most of the researchers have agreed that this crisis was originated by the rising tension of Cold War period. In 1980, the war between Iran and Iraq has broken; forcing two of the founding members of OPEC cut production levels.

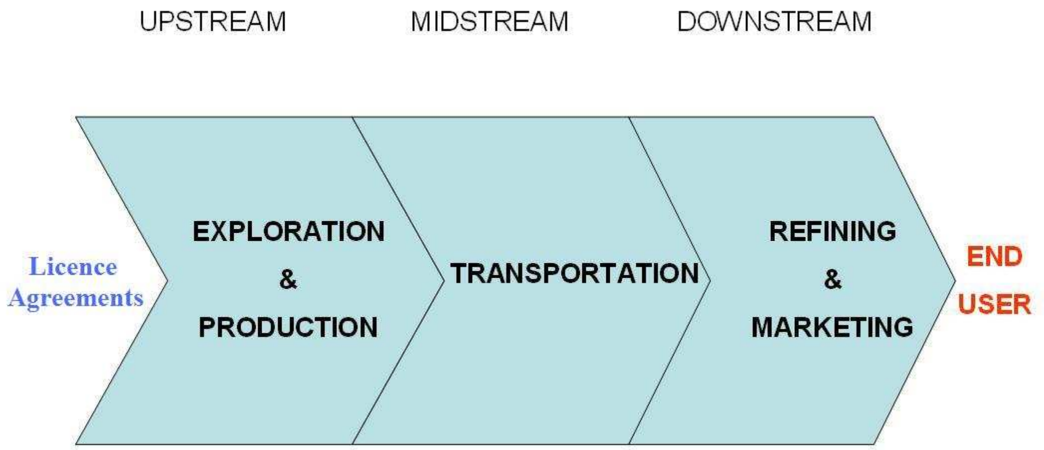
Due to the political uncertainties over production and supply of Middle Eastern crude oil, the issue of dependence on this region has begun to be discussed by major importing countries. In 1980s alternative crude oil reserves; such as North Sea and Central Asia, have attracted the attention of oil companies who seek an alternative for OPEC oil. Moreover, the worries of developed western countries towards the Arabian domination of the market emerged a new concept in 1980's; futures exchange in which like other commodities crude oil would be priced by free market conditions. First crude oil futures contracts have been introduced by New York Mercantile Exchange, NYMEX, in 1983. In a very short time futures exchanges has started to dominate the crude oil market. Since 1986, price has been determined in a manner which considers parameters such as physical supply and demand of crude oil, news about economics, politics, technology etc., trading volume in both spot and futures markets, and decisions of large investor groups.

Also in 1990s crude oil market has witnessed regional political and economic transformations such as fall of Soviet Union and opening of new markets, gulf crisis and American intervention in Middle East. Among all, maybe the most important transformation was inside the microeconomic structure of crude oil market. Beginning with 1998 most of the major oil companies has merged forming recent international companies such as; Exxon-Mobil, Total-Petrofina-Elf, BP-Amaco, Chevron-Texaco, Conoco-Phillips. This transformation in the market was because of slowing demand and low prices. Moreover, national oil companies of OPEC and Non-OPEC countries has started to arise as the opponents of international oil companies with the enhanced support of governments.

2.2 Fundamentals of Crude Oil Industry

For those who try to model the crude oil prices and determine factors affecting price dynamics, understanding the fundamentals of crude oil industry is essential. Associations in energy industry such as Society of Petroleum Engineers and American Petroleum Institute divide petroleum business into three sub-sections according to operations; upstream, i.e. exploration and production of petroleum, midstream, i.e. transportation of petroleum, downstream; refining and marketing of refined products.

Figure 2.6 Petroleum Value Chain



Source: Author

The Figure 2.6 represents the petroleum value chain. In this value chain all three steps require financing. On the other hand, within the context of risk and return analysis, upstream operations are riskier than other sections. Moreover, most of the returns gained in petroleum industry are in downstream operations. The risk associated in the upstream operations is due to a number of factors such as, insufficient information about the reserves while exploration and production processes geological structure of reserves etc. The financing is more required in upstream operations when compared to other two sections.

Therefore, the oil companies who are vertically integrated; working in all three branches of industry, are comparably more profitable. These integrated companies are dominating the industry with higher rate of returns and higher availability for financing the upstream investments. This part of the thesis will try to analyze the basic mechanisms of upstream, midstream and downstream operations.

2.2.1 Upstream

Upstream operations in the crude oil industry consist of exploration of crude oil reserves and production from wells drilled into these reserves. This section will analyze the fundamentals of upstream operations.

2.2.1.1 Exploration

Exploration process carried by geologists are mainly focusing on evaluation of formations and finding recoverable reserves underground. For this purpose according to Grace (2006) seismic surveys are the basic tools. The working principle of seismic surveys consists of sending an artificial shock in to the ground and receiving the shock waves which are reflected by the sediments. Although the technical process of gathering data with seismic surveying is simple, the evaluation of these data is not. The recent developments in seismic surveying technology enabled 3D and 4D analyses to find proposed formations, which would later be evaluated with exploratory drilling. Other survey methodoligies done on geological formations are gravity and magnetic surveys (Jahn et. al. 1998). The former methodology measures the small variations of the Earth's gravity while the latter detects the changes in magnetic field of the Earth.

Once the possible hydrocarbon bearing formations are drilled, structural maps and well logs would give better and more accurate information about the underground geological structure. Well logs of formations are evaluated according to some factors like, gamma radiation, density, electrical resistivity and transitivity of sound waves. All these surveys and evaluations are done to characterize the objected formation in order to find hydrocarbon accumulation. Well logs are accepted as the most important tests for evidence of hydrocarbon accumulations and further development of formations are processed according to the well logs.

2.2.1.2 Production and Reserve Management

The exploration of crude oil under the ground is the basic starting point of petroleum value chain. The second step is the production of hydrocarbon from reserves. Drilling is the basic process of producing crude oil from well bores. Drilling rigs are necessary systems which provide the support for raising and lowering drill string. Drill string is the combination of equipments and drill pipes, which are connected to the drill bits to produce the weight on it. Drilling bit makes rotational movement to cut the subsurface formations. When the hydrocarbon bearing zones are met the drilling procedures end to continue with production process.

The reservoir management is crucial for sustainable production from wells. There exist two types of production from reservoirs. When the production takes place by the natural energy of the reserve than this type of the production is called primary recovery. The energy of the system can be created by many different factors, varying according to the type of the reservoir such as gas drive or water drive (aquifier) in which the required energy is created by the pressure of gas and water respectively (Lyons, 1996).

If the energy of the reservoir system is not sufficient for lifting the crude oil to subsurface or if the pressure declines gradually during production, artificial energy is installed by production equipments such as; pumps. With the help of this artificial energy, secondary recovery takes place from the reservoir. Reservoir management is important during secondary recovery phase. Main purpose of reservoir management is obtaining the efficiency in production from the reservoir. The optimization of reservoir must be conducted with considering the optimal production rate since when the production rate rises above a critical value, formations can be damaged. In a damaged system, accumulated hydrocarbons can escape from fractured formations.

Obtaining the optimal production rate, on the other side, is a complicated issue. While determining the optimal production reservoir managers and engineers have to consider technical and economical constraints. Determination of amount of producible hydrocarbon depends heavily on the technological opportunities that the field engineers can use. In this respect, the geological subsurface formation and geographical location, onshore or offshore, of the reserve are vitally important. Moreover, the price of crude oil, economic costs and distance of the reserve from market are the main indicators of determination of economic value of future production.

With this perspective Banks (2008) explains the methodology of sustaining optimal crude oil production level. The main determinant of this methodology is determining the life of the reserve; reserve to production (R/P) ratio, where R is the reserves in terms of barrels and P is the production ratio in terms of barrels per year. Once the critical R/P ratio is determined the reservoir management would be done in order to maintain this ratio by decreasing production ratio gradually.

R/P ratios of worldwide reserves are important indicators for crude oil market since it gives an insight of world production peak and depletion time of the reserves. The current R/P ratio of the world crude oil reserves is 42,12 years[7]. As Maugari (2006) states the crude oil reserves are finite but no one knows the exact time of depletion which depends heavily on the determination of critical R/P ratio.

From reservoir management point of view the important thing is not the exact depletion of crude oil reserves but the date of production peak. According to geologists the technological innovation would enhance the reserve management techniques leading the peak be delayed. Economists, on the other hand, states that during rising trend of crude oil prices, the reserves would diminish in a higher rate leading to a quicker peak. Reserve management, within this context, rise as the vital phase of petroleum value chain.

2.2.2 Midstream

Midstream of petroleum industry mainly focuses on the transportation of crude oil. Transportation in the industry was born naturally due to the geographical distance between reserves and market. The early years of industry witnessed crude oil transportation with horse carts and trains. Because of increasing costs due to the cartelization of horse cart owners in 1860s, crude oil market experts have found an alternative way to carry the produced crude oil from fields to train stations; pipelines. Since than pipeline type of transportation has been the major methodology used in midstream operations in the industry. In the beginning of 1900s the need for American oil export in United Kingdom and other European countries lead a new concept to emerge; transoceanic transportation of crude oil. It is obvious that

[7] Source: BP Statistical Review of World Energy 2009 Report

pipelines were not adequate for this process therefore, tankers started to be used as an alternative transportation procedure.

Today two options for transferring the crude oil from resource regions to the markets are pipelines and tankers. Although the design of appropriate transportation system for crude oil is dependent up on trade transactions held by countries, there exist some other constraints such as; political, economical and technical.

2.2.2.1 Constraints in Transportation

The basic constraint of designing a proper transportation scheme for crude oil is the distance between the source and the market. As an example for Japan crude oil market the pipeline transportation is nearly impossible. On the other hand, transportation of crude oil within the land will obviously be with pipelines.

Moreover, the political aspect of transportation type choice suggests that the pipelines are the technical linkages between countries and may be used as political tools during debates. For the most of the cases when producing country tries to enhance its political power or increase its crude oil sales revenues with making higher price deals flow from pipelines would be cut. On the other side, consuming country would challenge the power of supplier and, after diversifying its sources of energy supply, would use pipeline to dictate its power on supplier. Therefore, pipelines are the basic element of energy interdependency game. Tankers, in this regard, provide a flexible option. In short term trade agreements tankers are more useful than pipelines.

Crude oil industry economists mainly consider the cost per kilometers that the crude oil will be carried when they design the transportation system. As the distance between the field and market increases, tankers economically become favorable when compared with pipelines.

2.2.2.2 International Trade of Crude Oil; Trade Paths

Table 2.1 represents the worldwide trade paths of crude oil. The most significant quantity of crude oil is traded from Eurasia and Middle East to Europe and North America, due to which the importance of modeling and finding the optimal transportation system for crude oil trading rises as a crucial issue within the industry.

Table 2.1 International Crude Oil Trading Paths for Year 2008 (in million tones)

	To										
From	US	Canada	South and Central America	Europe	Africa	Australia	China	India	Japan	Singapore	Other Asia Pacific
US	–	13,1	25,4	24,4	1,8	0,8	0,8	0,7	3,6	4,3	1,4
Canada	121,7	–	0,1	1,6	–	–	–	–	0,1	–	–
Mexico	64,7	1,4	4,3	7,7	–	–	–	1,9	–	0,1	–
S. & Cent. America	119,4	1,0	–	25,2	1,1	–	16,5	5,8	0,1	7,8	0,1
Europe	43,4	8,3	4,8	–	16,9	–	0,2	0,5	1,4	5,3	1,4
Former Soviet Union	23,8	1,6	3,0	318,5	1,1	0,6	22,4	2,0	8,2	5,0	6,6
Middle East	119,7	6,3	5,8	127,6	44,5	5,4	92,0	107,6	196,9	53,1	238,3
North Africa	32,6	8,9	5,1	101,3	1,0	0,3	4,2	4,3	0,4	0,1	3,1
West Africa	90,9	5,2	15,0	49,5	4,5	–	39,1	16,6	1,1	0,1	6,7
Australasia	1,8	–	–	–	–	–	0,9	0,2	2,6	3,5	6,6
China	0,8	–	4,0	0,3	0,4	0,2	–	0,1	1,3	2,1	9,2
India	0,3	–	1,6	3,3	–	–	0,2	–	1,4	6,8	20,0
Japan	–	–	0,1	1,2	–	2,6	4,9	0,6	–	4,6	2,4
Singapore	–	–	1,0	2,4	1,6	12,1	4,5	2,9	1,4	–	49,2
Other Asia Pacific	5,3	–	1,5	2,5	0,5	20,0	21,4	5,8	20,7	38,0	–
Total imports	**636,6**	**48,4**	**71,9**	**680,9**	**73,4**	**43,6**	**217,8**	**149,7**	**244,2**	**130,9**	**345,7**

Source: BP Statistical Review of World Energy

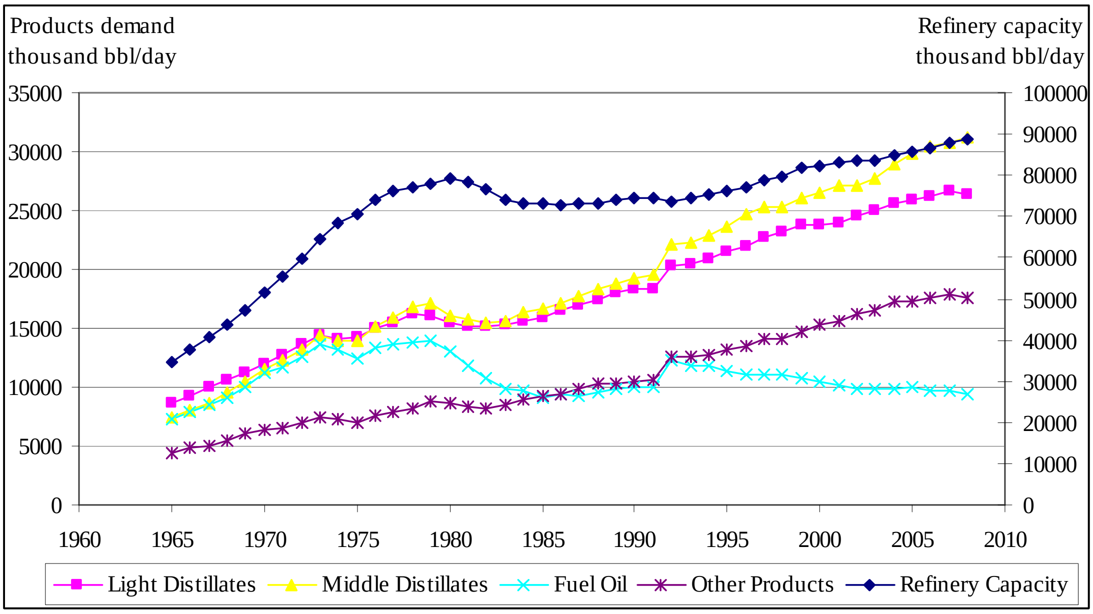
2.2.3 Downstream

Obtaining the end user products with processing crude oil and marketing of these products is named as downstream, the last but not the least sub-sector of the industry. The mechanism of downstream oil industry is much more complicated than the ones of upstream and midstream. This section of thesis will briefly describe how downstream petroleum industry works.

First action held in downstream industry is refining of crude oil. The primary goal of an oil refinery is to convert the crude oil to transportation fuels, which are economically more practical. Moreover, refineries also produce different products such as; asphalt, pharmaceuticals, plastics, and solvents. Although, the basic working mechanism of refineries is simple atmospheric distillation of crude oil, there exists some other and more technological operations, such as catalytic cracking. Atmospheric distillation is, basically, heating crude oil to separate the products with regard to their boiling temperatures. On the other hand, catalytic cracking is the chemical procedure that is used to convert heavy oil into economically more valuable products such as gasoline and lighter products (Gary and Handwerk, 2001).

Crude oil distillation capacity of global refining system and global demand for petroleum products, such as light distillates, medium distillates, fuel oil and others, are shown in Figure 2.8. As it can be clearly seen from the figure, world refining capacity has increased gradually from 1965 to 1980, than has been relatively stable during period between 1980 and 2000, which is followed by an increase again. It has reached to nearly 35 years’ peak in 1980, with a value of 79 Mbbl/day, when demand for petroleum products has declined as a result of skyrocketing prices with first and second oil shocks in 1973 and 1978 respectively.

Figure 2.7 World Refining System Distillation Capacity and Petroleum Products Demand, 1965-2008



Source: BP Statistical Review of World Energy 2009

As represented in the Figure 2.8 products demand and refining capacity have very strong co-movement except fuel oil. All trends increase gradually since the 1965 and show similar respond to oil shocks in 1980. Afterwards demand for fuel oil started to decline gradually while the other products increase. In 2008 while total distillation capacity was nearly 90 Mbbl/day, demands for light distillate, middle distillate, fuel oil and other products were 26 Mbbl/day, 31 Mbbl/day, 9 Mbbl/day, and 17 Mbbl/day, respectively.

The primary conclusion to be derived from the above analyses is that in order to meet increasing demand for crude oil products, world still needs crude oil. Moreover, Since the main input and outputs of downstream oil industry are crude oil and petroleum products, respectively, prices of those products are highly and directly related with crude oil prices. In this regard, what the end-user consumers will face at the pump stations will be the consequence of developments in crude oil market. Therefore analyzing crude oil pricing mechanism, or more generally microeconomic structure of crude oil, does gain importance as a crucial issue.

2.3 Microeconomic Structure of Crude Oil Market

"Today, the oil market is as good as it can be. With literally thousands of oil traders negotiating prices all over the world…" says Orwel (2006) and adds "from Economics 101 textbooks we remember that commodity prices are a function of demand and supply. But today's market is responding to additional pressures- geopolitical tensions as well as speculative activity". The importance of analyzing the crude oil market structure in historical context is crucial in terms of understanding the mechanism of crude oil prices today. This section will therefore try to explain how the microeconomic structure of crude oil market has changed since the beginning of the 20th Centruy. Most of economists know about OPEC but little knows what have been the drivers of crude oil prices during pre and post OPEC periods. This section is divided into three main parts including pre-1973; dominancy of international oil companies, 1973-1983; domination of OPEC and post 1983; free market regime.

2.3.1 Crude Oil Market before 1973

As Mabro (1984) states there has been different pricing regimes in different part of oil history. Before 1973 crude oil market was dominated by international oil companies. According to Fattouh (2007) host countries, in which crude oil was being produced, played no role in determining the quantity of production and hence in the determination process of prices.

During the subjected period the price, which was called "Posted Price", was determined with including lifting and intra-company transaction costs. The prices did not reflect and respond the physical market conditions such as demand and supply instead they reflected the terms of long-run agreements between oil companies and buyers. According to the report of Energy Charter Secretariat (2007), period between 1928 and 1971 witnessed oligopolistic cartel behavior of companies called seven sisters. On the other hand there was a competition in end-user consumer market. As Maugari (2006) mentions, the period has witnessed relatively stable price trend around 2 $/bbl.

Especially after World War II, during the period between 1950 and 1970, industrialized economies enjoyed stable and low prices. Stournaras (1985) explains the stable trend in oil prices with two factors; increasing returns to scale of upstream operations and the positive future expectations about crude oil market stability. Hence one can point out that relatively stable, i.e. low volatile and lower crude oil prices boost development process.

2.3.2 Crude Oil Market between 1973 and 1983

Increasing tension among Middle East countries, have emerged the formation of OPEC. The primary aim of the OPEC has been to increase the oil sales revenues of crude oil producing countries. On that sense, OPEC has affected microeconomic structure of crude oil market with controlling the crude oil production levels among member countries. The dominancy of OPEC in the market has started with the first oil crisis in the year of 1973. Since than there has been a plateau of studies investigating the role and behaviour of OPEC in the market[8]. Most of which has resulted with a significant impact of OPEC in worldwide crude oil markets.

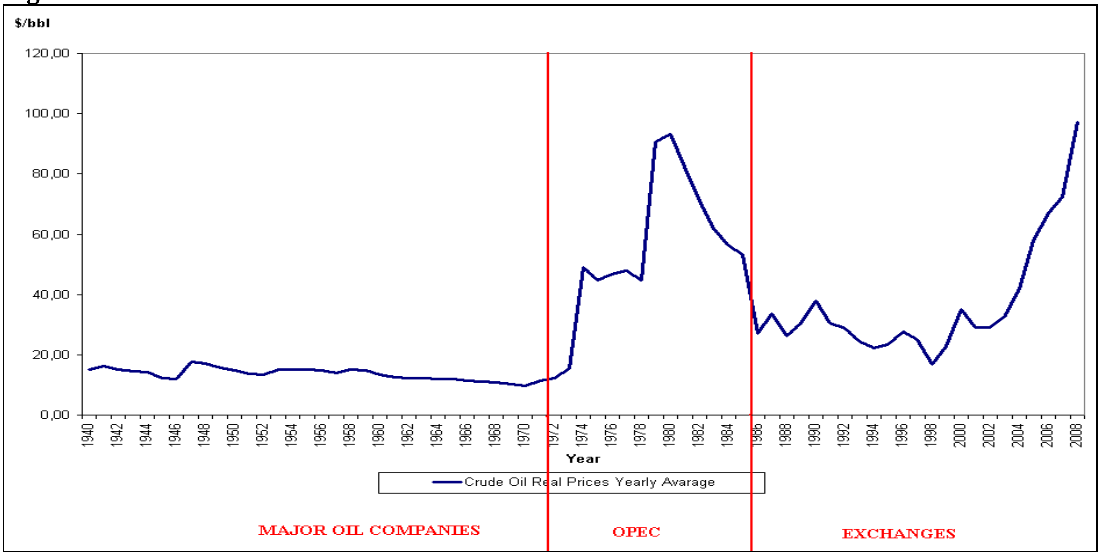
Behavior and the role of OPEC in world crude oil market may be analyzed by three of the market models; cartel model, Stackelberg dominant firm model and Arrow's general equilibrium model. In the cartel model, OPEC is assumed to behave as a unique monopolistic firm which determines the prices of crude oil in a manner

[8] Kennedy (1974), Gately (1984), Roberts (1984), Loderer (1984), Alhajji and Huettner (2000)

that it maximizes OPEC countries' total revenues. In Stackelberg model, Saudi Arabia is assumed to be the market leader among other countries. In addition, Arrow model assumes that all the producing countries will affect the prices equally with determining the production levels if disequilibrium exists in the market. On that sense, most of the experts conclude that during the 1973-1978, the period of oil crises, cartel model fits well to the market structure. Roberts (1984) founds that for the period of 1978-1979 the Arrow's and for 1979-1983 Stackelberg models are applicable to the market structure.

The selection of the appropriate model for the market microeconomic structure during 1973-1983 period is out of scope of this study, whereas the respond of prices to OPEC dominancy worth to be discussed for further analysis. Figure 2.9 represents the transformation of crude oil market dominancy and crude oil price trends.

Figure 2.8 Real Prices of Crude Oil since 1940 and Market Domination



Source: BP Statistical Review of World Energy 2009 Report

According to the Figure 2.9, one can obviously figure out that with the beginning of the dominancy of OPEC crude oil price trend has changed with a sudden increase and continued till 1980. Afterwards trend witnesses structural break resulting with a downward trend. The increase in the fluctuations, i.e. volatility, in crude oil prices were due to the political tensions created by the dominancy of OPEC. During the pre-1973 period, the period of companies, crude oil was a commercial commodity. On the other hand with the dominancy and supply cut decisions of OPEC in 1972, crude oil has become a political commodity used as a weapon by producing countries in order to protest the Yom-Kippur War.

As Mabro (1984) stated the major objective of the exporting country is to influence the prices because the price is the unit of revenue. During the dominancy of OPEC, with no doubt prices were administrated by members. The wealth created in the crude oil industry therefore, transferred from international oil companies to the member countries.

2.3.3 Crude Oil Market after 1983

In mid-1980s due to new oil field discoveries in non-OPEC countries and increasing liquidity conditions in worldwide crude oil market, OPEC administrated crude oil prices has become insufficient in determining worldwide price of crude oil as stated by Grace (2006) and Fattouh (2007). In addition to those, increasing concerns about the dominancy of OPEC has lead a new concept emerge in developing countries; futures exchanges trading. Trading in futures exchanges, as an alternative, has created an advantage for major crude oil importing countries. During the history of crude oil market since 1980s, the competitive structure was in the end-user market and prices were not reflecting the physical market conditions such as; demand and supply. Whereas, with the domination of futures exchanges, crude oil prices started to reflect all the relevant information about physical market fundamentals.

On the other hand, as Venn (2002) stated price determination process has become more complicated when compared with the OPEC and companies dominancy period. The reason lying below that was the increasing number of the market participants such as oil companies, refineries, individual investors, funds and speculators.

There has been a number of attempts to explain the microeconomic structure of crude oil market during period of futures exchange domination. Geroski et. al. (1987) mentions the structural change in crude oil market in 1980s. They found that market variables such as lifting costs, demand and supply significantly affect the prices in varying manner. Serletis and Hulleman (1994) confirm the theory of storage, which suggests decreasing rate in marginal convenience yield in futures market as inventory increases. The study of De Santis (2003) analyzes the determinants of price fluctuations during the period between 1985 and 2000. This study rejects the hypotheses of competitive market and cartel/monopolistic market structures of crude oil and finds that external shocks have a significant impact on variations of crude oil prices and supports the basic idea of pricing the information in futures market. The report of Energy Charter Secretariat (2007) suggests that prices, during this period, are being set by a competitive market structure in exchanges. Price volatility tends to increase and prices vary from 25 $/bbl to 150 $/bbl as shown in the Figure 3.

Moreover Mabro (1998) investigates the causes of individual 1998 oil price crisis and finds out that the contango structure[9] in oil futures contracts leading decrease in the futures expectation of oil prices. Killian (2006) and Segal (2007) investigates the structures and determinants of crude oil prices during the post-OPEC dominancy period. Both studies conclude with stating the oil crisis in post-OPEC

[9] The upward sloping forward curve where futures prices are greater than spot prices.

period differ those during OPEC dominancy because they are more subjected to the external shocks created by many participants in the market.

The study of Fattouh (2007,a) could be treated as the best of its kind in investigating the basic mechanism of crude oil market microeconomic structure and price determination. He tests the market for three models; the theory of exhaustible resources[10], conventional supply-demand framework and informal approach, which analyses the crude oil prices in both economic and political context. In the final approach, he suggests that the physical market conditions, i.e. supply disruptions, variations in demand, political crisis, etc., are all external shocks to the trend of crude oil prices. Since the crude oil prices are stochastic process, the external shocks seem to be permanent. In his other paper, Fattouh (2007,b) studies the pricing power of OPEC in crude oil markets and finds out that, the power of OPEC is not straight forward in 2000s due to the variable OPEC behavior, asymmetric influence of OPEC on prices and the number of participants in price determination procedure.

3 Futures Trading Activity

Because of the above mentioned transformation in oil price dominancy, it has become crucial for crude oil associates to investigate how the futures exchanges work. This section will try to give an insight on the mechanism of futures exchanges and basic trading fundamentals of commodities and crude oil in particular. The section will flow as follows; first the history and basic working principles of futures exchanges will be analyzed. Secondly, the commodities futures will be taken into consideration. Finally crude oil futures and efficiency of crude oil derivatives market will be investigated in detail.

[10] First introduced by Hotelling (1931)

3.1 Derivatives Markets and Futures Exchanges

As Andersen (2006) defines, derivatives have become an increasingly important element of global business with offering systematic alternatives to risk managers in different forms. Financial derivatives are financial instruments that are linked to other financial instruments and commodities, which are named as underlying items. They are generally in form of contracts. International Monetary Fund (IMF) states that a financial derivative contract is a financial instrument through which sort of financial risks, such as interest rate risk, foreign exchange risk, credit risk, can be traded in financial markets. Main objectives of financial derivatives can be counted as; risk management (hedging), arbitrage and speculation and major actors are hedgers, speculators and arbitragers. Moreover, according to the survey conducted by International Swaps and Derivatives Association (ISDA) in 2003 almost 90% of derivatives are used for risk management purposes. With this perspective derivatives are contracts between two parties used in order to reduce risk for one and to offer high return for the other. There are mainly three types of derivative contracts; futures (and forwards), options and swaps.

3.1.1 History and Mechanism of Futures Trading

As Hull (2005) states, a futures contract is an agreement to buy or sell an asset at certain time in the future for a certain price. In recent years, number of exchanges through the world is offering contracts. The biggest ones are; Chicago Mercantile Exchange, New York Mercantile Exchange, Intercontinental Exchange, and London International Financial Futures and Options Exchange. Future contracts enable people trade with each other by buying and selling contracts. The one who agrees to buy the asset has a long futures position, and one who agrees to sell has a short futures position. The price of the contract is named as futures price. The price is determined from underlying item. At the delivery date this price is called settlement price. Futures contracts are highly standardized in order to ensure their liquidity by specifying; the underlying asset or instrument, type of settlement, the currency in which futures contract is quoted and the delivery month.

Although roots of the futures trading go back to the ancient times, an organized and modern type has begun in United States in 1800s. In 1848 The Chicago Board of Trade was established in order to organize future dealings between farmers and merchants. The earliest forward contract recorded was for 3,000 bushels of corn. Forward contracts gain popularity among merchants and processors. In 1874 Chicago Produce Exchange was established for other products such as; butter, egg, poultry etc. In 1919 it was renamed as Chicago Mercantile Exchange as reorganized to provide futures trading. Since than futures exchanges have offered several derivatives for commercial and non-commercial traders.

Futures contracts are referred to by their delivery dates. For long position there is a period of time for delivery. Investors, taking long positions, usually refer contracts as the delivery month and name of the contract together such as November oil futures contract. Most of the time, delivery does not take place. Investor taking long position at some month before November could close his long position by selling the contract and opens a short position. New investor buying the contract, therefore, becomes an investor opening the long position. This process is called opening and closing futures positions.

When developing a new contract, the exchange must specify in some detail the exact nature of the agreement between two parties. It should specify the underlying asset, the contract size, the delivery date and the place of delivery. This process is named as standardization. Also the price of futures contract is determined by both underlying asset in stock market and by futures market. When delivery date approaches, future price converges to spot price of the underlying asset. At the delivery date both becomes equal.

One of the key roles of futures exchanges is to organize the trade. This is where margins come in. Investors deposit their funds in a margin account. At the beginning of a contract investor must deposit initial margin amount. At the end of each trading day future price of the contract is observed and earned or lost money is added or extracted to initial margin. Hypothetically, if a contract looses value that amount is extracted from initial margin, in addition to that extracted initial margin falls below an amount that investor could not continue his investment, then he receives a margin call saying that he must complete his deposit up to initial margin amount. The amount at which the call is received is called maintenance margin.

Although in most cases positions are closed and opened before delivery date, it would be useful to get over the delivery process. Delivery periods are determined by exchange and it varies between different contracts. Delivery decision is made by the party with the short position. And long position sides must accept delivery notices. First notice day is the time in which first notice of intention of delivery can be submitted to exchange and also last notice day is the time for last notice delivery. Last trading day is generally few days before the last notice day. Long position party must close the position after the first notice day in order to avoid the risk of taking a delivery.

3.2 Commodity Futures

As mentioned above, the main objective of using futures derivatives is hedging and because of their market structure, with high risk, commodity futures contracts constitute a major part of total futures trading. Geman (2005) describes the risks of commodity trading in four main parts; price risk, transportation risk, delivery risk and credit risk. The need for futures market in commodities trading has arisen from the importance of commodities in international trade between economies. With the introduction of futures contracts, standardization of price, delivery and quantity has been emerged. In the late 19th and early 20th Centuries, futures exchanges have been formed for the corresponding commodities such as; New York Cotton Exchange (NYCE), International Petroleum Exchange (IPE), London Metal Exchange (LME).

According to the Rational Expectations Hypothesis, first introduced by Ruth (1961), futures prices are exactly the expectation of spot price in the maturity date of the contract and can be written as;

$$F^T(t) = E[S(T)/f_t]$$

where, $F^T(t)$ is the price of the futures contract with maturity of T at date t, $E[S(T)/f_t]$ is the expected spot price at date T with the available information at date t. Moreover, futures price of a storable commodity will include costs of financing and storage and benefits of holding the commodity;

$$F^T(t) = S(t) \times [1 + r(T-t) + c(T-t) - y(T-t)]$$

where, $S(t)$ is the current spot price, $r(T-t)$ cost of financing the purchase of commodity, $c(T-t)$ is the cost of storing the commodity and $y(T-t)$ is the yield due to holding the commodity.

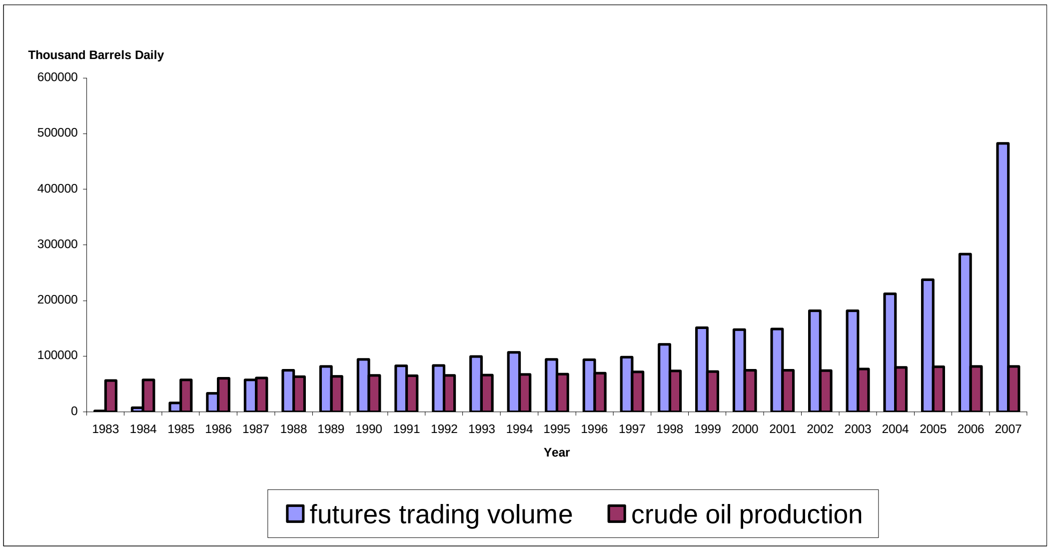
Although, the price determination in futures market is out of scope of this thesis, it would be convenient to mention to these equations in terms of analyzing the crude oil futures price mechanism since, apart from the factors mentioned over, scarcity, reserves and spot price volatility have the influence affecting the futures contracts prices.

3.3 Crude Oil Futures Trading; Exchanges and Benchmarks

As mentioned above, since 1983 crude oil futures have been traded internationally on exchanges. Introduction of financial derivative instruments into the oil market in 1983 with the first contract of NYMEX WTI futures, took place in the name of handling the risk of price volatility which has emerged in the presence of domination of OPEC in market. Although, the main purpose of agents futures exchanges has been hedging, speculators have taken a significant number of positions in order to benefit from arbitrage opportunities since mid-1980s. As represented in Figure 2.9 above, volatility of crude oil prices has increased during the period of futures exchange dominancy.

As it can be deduced from the Figure 3.1, the main reason lying behind the increase of volatility during post-futures era in crude oil market has been the increasing amount in futures trading volume. While the physical crude oil production has stayed in the same band during the period from 1983 to 2007, volume traded in the NYMEX futures exchange has gradually increased, showing that the market participants are not only commercial hedgers and traders but also investors and speculators. Therefore, crude oil markets have become an important issue for both commercial and non-commercial experts.

Figure 3.1: Volume of Transactions Held in Spot Crude Oil Market and Futures Exchanges (Representative: Nymex WTI Crude Oil Nearest Month Contract)



Source: NYMEX & BP Statistical Review of World Energy 2008 Report

The two most important world-wide markets are NYMEX in New York, the USA and ICE (formerly IPE) in London, the UK[11] (James; 2008). A common property of all commodity futures is the standardization process with specifying underlying commodity, size, delivery process, quality and grade. In crude oil case, underlying product, generally, is accepted as the benchmark of contract. While, for NYMEX futures contract the benchmark is West Texas Intermediate, WTI, crude oil, for ICE futures contracts the benchmark is Brent crude oil.

Prices of these mentioned benchmarks are, moreover, accepted world-wide as the crude oil prices. The two most important prices quoted daily in these exchanges are spot prices and nearest month contract prices. As it has been explained in the section 2.3.3. daily crude oil spot prices are determined according to the physical market conditions and the news created world-wide. Whereas, nearest month contracts are priced in a manner of supply and demand equilibrium created in the futures exchanges by market participants. Each participant, with the assumption of

[11] First crude oil contract was established by New York Mercantile Exchange in March 1983 with the name of West Texas Intermediate WTI crude oil futures contract. Then, in November 1983 International Petroleum Exchange, today known as InterContinental Exchange (ICE), London, established Brent crude oil contract which was revised in 1985

rational behaviour, considers and evaulates the information created by news in the physical crude oil market and takes positions. Therefore, the expectation is that futures contract prices are directly related to the spot prices. On the other hand, since the volume of the futures trading activity in crude oil market has so far been much more than physical transactions, the primary suggestion of this study is that futures prices have a considerable impact on spot price regimes. This suggestion is challenging the common view of executives of crude oil derivatives market stating that futures exchange would diminish price volatility of oil and at the same time "invisible hand" would lead a fair equilibrium of price.

It is a crucial issue because, as the most important input for all the industries, crude oil has been a term of foreign trade for developed countries. Therefore, for a sustainable development policy, oil price volaitility had to be controlled. The main objective of this study is to analyse empirically whether the financial market transactions has reduced oil price volatility or not.

4 Empirical Analysis

4.1 Literature Review

In the financial literature relationship between volatility, an indicator of risk, and return has been studied as a rising issue by number of studies[12]. The major outcome of all of these studies is that volatility and expected return is highly interdependent. While, Backus and Gregory (1993) have studied the relationship between risk premiums and conditional variance, the study of Fan et. al. (2008) points out the importance of capturing volatility for measuring 'Value at Risk'. Combes and Guillaumont (2002), on the other hand, examine the vulnerability of developing economies on commodity price volatility and concluding with the necessity for management of risk created by commodity price volatility. As Yang et. al. (2002) states price fluctuations in price of crude oil as the most important input commodity for economies result with a high vulnerability in developing countries. Moreover, Regnier (2007) states that crude oil prices are more volatile than other commodities, produced and sold domestically. Therefore, measuring the crude oil price volatility is crucially important.

Although there has been a plateau of studies examining the oil prices and macroeconomy interconnections[13] there have been very few papers investigating the impacts of crude oil price volatility to macroeconomy. The of Ferderer (1996), which conducts the empirical model between oil price volatility and macroeconomic indicators with considering the asymmetric structures, concludes that oil price volatility has negative and significant impact on output growth rate. While, Guo and

[12] Black (1976), Pindyck (1984), Poterba and Summers (1986), French et. al. (1987), Chou (1988), Bollerslev et. al. (1988), Baillie and DeGennaro (1990), Theodossiou and Lee (1995).

[13] Mork (1989), Kahn and Hampton (1990), Huntington (1998), Brown and Yucel (1999, 2002), Gao and Madlener (1999), Hamilton (2003), Dickman and Holloway (2004), Guo and Kliesen (2005), Rogoff (2006), Sill (2007), Kilian (2008) and Oladosu (2009).

Kliesen (2005) investigates the relationship between US output growth rate and oil price volatility and Rafiq et. al. (2009) uses Thailand macroeconomic indicators, such as GDP growth rate, investment, unemployment, inflation etc. Both studies found significant impact of oil price volatility on macroeconomic indicators.

Oil price volatility not only affects macroeconomic indicators but also has a significant impact on end-user petroleum related products, this situation is increasing the vulnerability of economies. Gjolberg and Johnsen (1999) founds the evidence of long-run co-movement between oil and refined products prices. Radchenko (2005) concludes with asymmetric[14] and negative relation between oil price volatility and gasoline prices.

With regard to all the importance of modeling volatility, as stated by Aydemir (2002), studies have so far developed three major empirical methodologies; ARCH type, stochastic and regime switching volatility models. While the stochastic volatility modeling, proposed by Harvey (1981), is known to be the leading methodology, the primary ARCH type conditional volatility model; Autoregressive Conditional Heteroskedasticity, ARCH is developed by Engle (1982). Bollerslev (1986) has extended ARCH model by involving the impact of lagged terms of conditional variance series by developing Generalized Autoregressive Conditional Heteroskedasticty, GARCH. Nelson (1991) has developed Exponential GARCH, EGARCH model to handle with the constraint of non-negativity. The study of Bollerslev et. al. (1994) defines the technical and empirical properties, with giving detailed information about issues such as volatility clustering, thick tails, leverage effect, model selection, of ARCH type models very well. Furthermore, Pagan and Schwert (1990) and Higgins and Bera (1992) defines the nonlinearity concept in

[14] Asymmetric relation means positive price shocks have greater impact than negative ones.

ARCH type variance modeling. As an extension in volatility modeling literature Hamilton (1988,1989) proposed Markov regime switching methodology for capturing the effects of sudden changes in trend due to external shocks. Study of Dacco and Satchell (1995) tests the forecasting performance of regime switching models and concludes that these are not as efficient as GARCH type models.

There have been a number of extensions in the volatility models including transformation of original volatility models. Ling and Li (1997) has combined ARFIMA and GARCH models to model fractural integrated autoregressive moving average time series with conditional heteroskedasticity. Tse and Tsui (2002) has proposed new GARCH model in a multivariate context with time varying correlations. Moreover, while Hamilton and Susmel (1994) and Cai (1994) combines the approaches regime switching and ARCH methodology to explain and capture the variance, Liu (2000) studies regime switching stochastic volatility modeling.

The other extensions done on the volatility modeling are measuring persistency and capturing structural breaks in variance series. Nelson (1990) and Bollerslev and Engle (1993) conducts Integrated GARCH (IGARCH) model, Engle (1993) on the other hand, uses EGARCH model to capture the persistency. Moreover, Fernandez (2004) and Malik (2005) uses Iterative Cumulative Sums of Squares (ICSS) algorithm to test the variance series for presence of structural breaks.

There has been a plateau of studies conducted to model the volatility in stock markets, interest rate, inflation, foreign exchange market and commodities. Study of Fama (1968), which analyzes the behavior of stock market prices, has become a seminal paper. While, French (1980) conducts a random walk model on Standard and Poor's composite portfolio to test the weekend effect on fluctuations in stock returns, Gibbons and Hess (1981) investigates the day of the week effect[15] on asset returns. Besides the so far mentioned studies, the paper of Poterba and Summers (1986) was the first of its kind, which models, directly, the volatility of stock returns with a stationary AR(1) process conducted on monthly return of S&P 500 index and found out that volatility is temporary. Chou (1988) challenges the finding of the latter study by investigating the volatility persistence using GARCH modeling on weekly returns of NYSE value-weighted index and finding persistence in variance.

Akgiray (1989) models the volatility of the daily return of CRSP value-weighted index for the period from January 1963 to December 1986, with using GARCH(1,1) model. Akgiray states that GARCH model fits to the data and out-of-sample forecasting based on GARCH model statistically performs well. Schwert (1990a) also examines the stock market volatility with considering specifically the stock market crash in October 1987. The study of Lamoureux and Lastrapes (1990) investigates the structural changes and persistence in volatility of daily returns of selected stocks from CRSP for the period between January 1963 and November 1979 and points the performance of GARCH model in capturing the persistence in variance. The study of Chen et. al (2006) also captures the persistence in volatility with using GARCH type model for different futures contracts; S&P 500 and NASDAQ 100 indices, Japanese Yen, British pound, Australian Dollars and some commodities. Chen et. al. found the stock index futures to be most persistent.

As an extension in studies of volatility modeling of stock markets, Hamilton and Lin (1996) conduct a bivariate model to measure the interrelations between stock market volatility and industrial activity. They found out that the primary

[15] Measuring the day of the week effect has also been a rising issue in volatility models; Balaban (1994), Alexakis and Xanthakis (1995), Berument and Kiymaz (2001)

determinants of fluctuations in stock market volatility are the economic recessions. In the means of extending the analysis on volatility of stock markets Martens et. al. (2004) and Kasman and Torun (2007) have used GARCH type models to investigate the long run memory in volatility structures of S&P 500 and Turkish Stock Indices respectively.

Besides the studies conducted to capture the volatility in interest rate[16] and foreign exchange rate[17], since the main investigation area of this thesis is volatility structure of crude oil, a commodity, volatility models conducted on commodities markets are more important. Seminal study of Samuelson (1965) proves that fluctuations in commodity prices are random. Kawai (1983) analyzes the behavior of variance of commodity prices with rational expectations theory under special cases; existence of risk neutral producers and dealers, infinitely risk averse dealers and infinitely large marginal cost of inventory holding. Ng and Pirrong (1994) employ bivariate GARCH model specification on returns of 3-month forward prices for copper, lead, silver and zinc for the period between September 1, 1986 and September 15, 1992 and for aluminum prices for the period between August 27, 1987 and September 15, 1992. They test the significance of theory of storage and find consistency of correlation between spot and forward prices with the theory.

Galloway and Kolb (1996), moreover, use stochastic volatility approach to model variance of various commodities and equities futures contracts for the period from 1969 to 1992. They have conducted OLS regression to capture the impacts of maturity effects on variance of corresponding futures contract and have found that contract month is important, especially, in volatility structure of agricultural

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[16] Bessembinder and Seguin (1993), Akin (2003)
[17] Domowitz and Hakkio (1985), Grammatikos and Saunders (1986), Han et. al. (1999), Rapach and Strauss (2008)

commodities. Walls (1999) analyzes the impact of maturity and volume on the volatility of electricity futures with conducting stochastic volatility model on daily electricity futures returns from March 29, 1996 to November 26, 1996. Walls find strong evidence of maturity effects in electricity futures. The study of Fackler and Tian (1999) also finds evidence that seasonality and maturity are important elements in volatility of soybean futures.

In recent years modeling volatility of crude oil has been a rising issue because the price of crude oil, as the primary input for all economies, matters for countries' policy makers. Pindyck (2001), in that sense, develops a model to describe the dynamics of inventories, spot and futures prices and volatility for weekly data of crude oil and heating oil. Pindyck finds that while the model fits well to heating oil data, opportunity cost variable, suggested in the model for crude oil, has the wrong sign. The study of Ewing et. al. (2002) uses daily closing values of two option indexes for natural gas and crude oil from April 1, 1996 to October 29, 1999. They have conducted a bivariate GARCH with VECH and BEKK specifications to model the interrelation between variance series of natural gas and crude oil. The study finds evidence of persistence in both markets and points out that while volatility in crude oil depends on its previous values, variance of natural gas is affected by news created in both markets.

Fong and See (2002) examine the behavior of crude oil price volatility with conducting Markov Switching model on daily returns of WTI contract for the period between January 2, 1992 and December 31, 1997. Study concludes that, regime switching models fit well to the data with capturing and dominating the GARCH effects and are powerful in terms of short-term forecasting. On the other hand, Agnolucci (2009) gives evidence that GARCH type models perform better in explaining price volatility of crude oil. The study of Yang et. al. (2002), also, conduct GARCH model to determine the factors affecting the crude oil price volatility. Yang et. al. find evidence that the most distinguishing factor would be the behavior of OPEC.

Moreover, Sadorsky (2006) conducts various GARCH models on daily closing prices of crude oil, heating oil, natural gas and gasoline futures contracts to forecast volatility. He points out that while threshold GARCH specification fits well to natural gas and heating oil, GARCH model fits to the crude oil and gasoline data. The study of Kang et. al. (2009) also refers to the comparison between GARCH model specifications for measuring volatility of crude oil market. Study finds evidence that component GARCH, CGARCH, and fractionally integrated GARCH, FIGARCH, are performing better in capturing the persistence.

In addition to the above mentioned studies which investigate the structure of volatility of various financial assets, there exist a number of studies analyzing the impact of futures trading on spot market variance. The study of Powers (1970), in that regard, is a leading study which builds an empirical relationship between spot and futures market of both pork belly and beef. Study finds that variance has decreased for the first four years period after the introduction of derivatives of mentioned commodities. Moreover, Edwards (1988) analyzes the interrelation between daily S&P 500 futures and spot returns for the period from 1972 to 1987 and shows that volatility has increased in the short-run but this trend does not carried in the long-run. Schwert (1990b) investigates the volatility of S&P 500 around a critical event, the stock market crash. Schwert found little evidence that futures trading has increased spot market volatility during 1980s. Study of Bessembinder and Seguin (1992), also, examines the impact of futures trading volume on stock price volatility and documents that an unexpected increase in futures trading volume positively affects the volatility.

Moreover, analyzing lead-lag relationship has become a commonly used methodology to investigate the cross relationship between spot and futures market. Using this methodology Chan (1992), Frino et. al. (2000) and Gwilym and Buckle (2001) find strong evidence that futures lead the cash market for different stock indices. Kasman and Kasman (2008) use Turkish Stock Exchange ISE100 and corresponding futures contract on Turkish Derivative Exchange to model the impact of futures trading on spot market volatility and their results imply that futures exchange has decreased the volatility of spot market for the period from 2002 to 2007.

Besides, the number of studies conducted to examine the interrelation between futures and spot market on different underlying assets, there exists few conducted on crude oil markets. The study of Antoniou and Foster (1992), constructs weekly volatility series of spot Brent crude oil prices from January 1986 to July 1990, with dividing period into pre and post futures using GARCH model and concludes that introduction of Brent futures has decreased the spot market volatility. Fleming and Ostdiek (1999), on the other hand, have studied on daily prices of WTI futures and spot prices for the period from 1983 to 1997 and have found out WTI Crude Oil futures trading has increased the spot market volatility of crude oil. The study of Silvapulle and Moosa (1999) conducts linear causality test on daily spot and futures prices of WTI covering the period between 2 January 1985 and 11 July 1996 and finds evidence of linear feedback from futures to spot. On the other hand, study finds bidirectional effect when using nonlinear causality test.

Also in recent years, due to the bubble created in crude oil and the other commodity prices, efficiency of futures market and effects on spot are being tested. Liao et. al. (2008) in this regard, tests the variance of daily Brent crude oil prices for structural breaks for the period between June 1, 2003 and September 30, 2006. They point out the significant impact of changes in electronic trading system on volatility of return of Brent crude oil prices. The study of Bekiros and Diks (2008) investigate linear and nonlinear causality of WTI spot and futures market with dividing the data in to two sub-periods; October 1991-October 1999 and November 1999-October 2007. Study conducts GARCH-BEKK model resulting with no significant and inconsistent leads and lags between two markets. Kaufmann and Ullman (2009) treat futures markets as the source of speculation and find evidence that the increase in crude oil prices in 2004 is originated from the long-term exacerbation of speculators.

The contribution of this thesis to above mentioned literature would be using a combination of previous methodology rather than obtaining a new one. This study will capture the variance series of spot and futures crude oil prices by control the structural breaks in spot market and day of the week and maturity effects in futures market. Then, causality and co-integration analyses will be done in order to investigate the interrelationship between two markets.

4.2 Methodology

The primary conditional volatility model; Autoregressive Conditional Heteroskedasticity, ARCH(p) developed by Engle (1982) is;

$$\sigma_t^2 = \varpi_0 + \sum_{i=1}^{p} (\alpha_i \times \varepsilon_{t-i}^2) \tag{1}$$

where, σ_t^2 is conditional variance and ε_{t-i}^2 is the information provided by lagged residuals.

Equation (1) satisfies non-negativity constraint with ϖ_0>0 and α_i ≥0. Most obvious weakness of this model was absence of lagged variance terms. Bollerslev (1986) has extended ARCH model by involving the impact of lagged terms of conditional variance series by developing Generalized Autoregressive Conditional Heteroskedasticity, GARCH (q,p);

$$\sigma_t^2 = \varpi_0 + \sum_{j=1}^{q} (\alpha_j \times \varepsilon_{t-j}^2) + \sum_{i=1}^{p} (\beta_i \times \sigma_{t-i}^2) \tag{2}$$

where, σ_{t-i}^2 is the lagged series of conditional variance and ϖ_0>0.

Moreover, GARCH model must satisfy non-negativity condition so β_i ≥0 and α_j ≥0. $(\alpha_j + \beta_i)$ is the strength of persistence of shock to the conditional volatility; as the value of term gets close to 1 shock is more persistent.

Although GARCH model has been developed further on ARCH model, it still has the constraint of non-negativity. In addition to this constraint, shocks are acknowledged as symmetric, i.e. both negative and positive shocks have the same magnitude of impact on volatility. Nelson (1991) has developed Exponential GARCH, EGARCH (p,q) model to handle with these constraints.

$$\ln(\sigma_t^2) = \varpi_0 + \sum_{j=1}^{p}\left[\left(\phi_j \times \left|\frac{\varepsilon_{t-j}}{\sqrt{\sigma_{t-j}^2}}\right|\right) + \left(\alpha_j \times \frac{\varepsilon_{t-j}}{\sqrt{\sigma_{t-j}^2}}\right)\right] + \sum_{i=1}^{q}[\beta_i \times \ln(\sigma_{t-i}^2)] \qquad (3)$$

where, $\frac{\varepsilon_{t-j}}{\sqrt{\sigma_{t-j}^2}}$ and $\left|\frac{\varepsilon_{t-j}}{\sqrt{\sigma_{t-j}^2}}\right|$ are the asymmetric term and the size effect respectively.

EGARCH model in equation (3) overcomes the constraints with logarithmic structure and asymmetric terms, if the term α_j is statistically significant and negative than asymmetry rises in the model. ϕ_j captures the size effect in the model. On the other hand, the only restriction EGARCH model imposes is that, sum of coefficients of parameters must not exceed 1 in order to satisfy the stationary process.

This thesis will test these three ARCH-type volatility models for accuracy in explaining the variance of crude oil spot and futures prices. Once the appropriate model is selected[18], variance of two markets will be captured. Afterwards the relationship between two markets will be analyzed. Therefore, this section will briefly introduce the sequential methodology used in modeling spot and futures volatility and in analyzing interrelationship between two markets.

4.2.1 Spot and Futures Market Volatility Modeling

This thesis uses autoregressive of order one mean equation and GARCH variance equation, AR(1)-GARCH(1,1) model[19] in order to capture daily variance series of both spot and futures crude oil markets. Mean and variance equations for both series are as follows;

$$r_{i,t} = \gamma_1 + \delta_1 \times r_{i,t-1} + \varepsilon_{1t} \qquad (4)$$

[18] Details selection criteria are available in Empirical Results Section

[19] Rank orders are estimated by Maximum Likelihood Estimation

$$\sigma_{i,t}^2 = \varpi_0 + \alpha_1 \times \varepsilon_{i,t-1}^2 + \beta_1 \times \sigma_{i,t-1}^2 \qquad (5)$$

where, $i = s \, or \, f$ corresponding to spot or futures market and therefore to spot market variance ($\sigma_{s,t}^2$) and futures market variance ($\sigma_{f,t}^2$) respectively.

4.2.2 Interrelationship Between Crude Oil Spot and Futures Markets

Granger-causality[20] test is conducted to estimate lead-lag relation between two variance series;

$$\sigma_{s_t}^2 = \omega_1 + \sum_{i=1} \beta_i \times \sigma_{s_{t-1}}^2 + \sum_{j=1} \alpha_j \times \sigma_{f_{t-1}}^2 + \delta_1 \times \bar{z}_{t-1} + \varepsilon_{1_t}$$

$$\sigma_{f_t}^2 = \omega_2 + \sum_{i=1} \beta_i \times \sigma_{s_{t-1}}^2 + \sum_{j=1} \alpha_j \times \sigma_{f_{t-1}}^2 + \delta_2 \times \bar{z}_{t-1} + \varepsilon_{2_t} \qquad (6)$$

where $\sigma_{s_t}^2$ and $\sigma_{f_t}^2$ are volatility of spot and futures return of crude oil respectively and $\bar{z}_{t-1}$ is the error correction term.

Granger causality determines the short term relationship whereas in order to estimate the long-run co-integration, the model developed by Engle and Granger (1987) is conducted on crude oil spot and futures prices.

$$p_{f_t} = \alpha_1 + \beta_1 \times p_{s_t} + \varepsilon_{1t}$$

$$p_{s_t} = \alpha_2 + \beta_2 \times p_{f_t} + \varepsilon_{2t} \qquad (7)$$

where p_{f_t} and p_{s_t}, which are tested for unit root and found to be I(1) process, are futures and spot prices respectively.

[20] Granger (1969)

Equation (13) is constructed to capture residuals, ε_{1t} and ε_{2t}, and test for unit root. Any evidence that indicates non-stationary process in residual series would lead a conclusion that crude oil futures and spot prices are co-integrated.

4.2.3 Capturing the Impacts of Futures Trading on Crude Oil Spot Market,

Above mentioned analysis is appropriate to test whether there exists a significant relationship, i.e. short-run lead-lag or long-run co-movement, between two markets. On the other hand, to capture the impacts of futures market on spot is the other consideration of this thesis. Therefore, spot price volatility of crude oil has been modeled with inclusion of daily futures trading volume of crude oil contracts. Moreover structural break analysis with using Iterated Cumulative Sum of Squares, ICSS, algorithm which was first introduced by Incl´an and Tiao (1994), has been also applied to test the persistency of variance equation. Once the break points have been captured, they have been included as the dummy variables controlling N break points. The revised version of spot market volatility model is as follows;

$$\sigma_{s,t}^2 = \varpi_0 + \alpha_1 \times \varepsilon_{s,t-1}^2 + \beta_1 \times \sigma_{s,t-1}^2 + \theta_1 \times Vol + \sum_{n=1}^{N} (\varphi_n \times D_n) \quad (8)$$

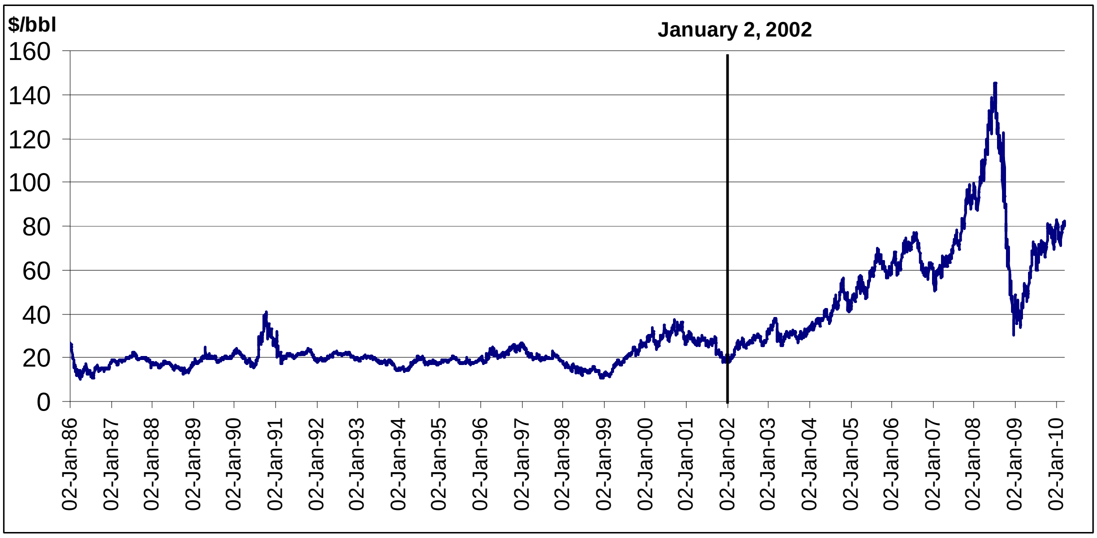
where, Vol is the total volume of the contract under investigation and D_n are the dummy variables of the break points.

4.3 Data

In order to implement above mentioned methodology, the data used in this thesis covers the daily closing prices of WTI and Brent benchmarks crude oil futures nearest month contracts and WTI and Brent benchmarks crude oil spot prices. The calculations provided in sections 4.2.1 and 4.2.2 have been done on WTI crude oil futures and spot markets for the period between January 2, 1986 and March 16, 2010.

On the other hand, due to the availability of volume data methodology provided in 4.2.3 to capture the impacts of futures trading activity has been done on Brent crude oil markets for the period from January 2, 2008 to March 16, 2010. Before moving further to details of summary statistics and diagnostics tests, it would be convenient to analyze the benchmarks graphically.

Figure 4.1 WTI Crude Oil Spot Prices from January 2, 1986 to March 16, 2010

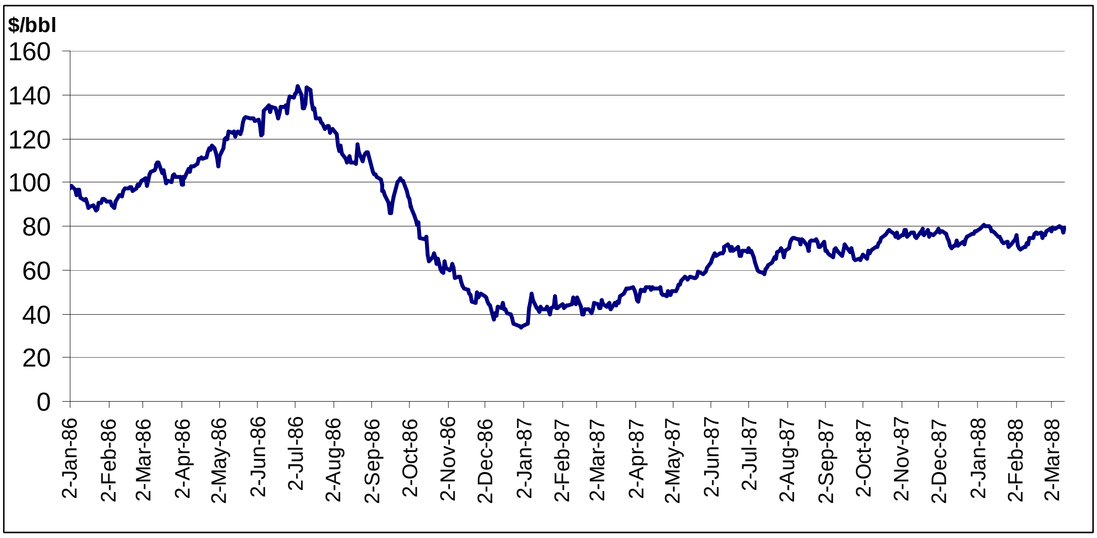


Source: Energy Information Administration, USA

As apparently seen from the Figure 4.1 WTI crude oil prices have been very stable during the period between January 1986 and January 2002. Afterwards, it has an increasing trend till the credit crunch in summer 2008 and a decreasing one during post-crisis period and during post-2002 volatility seems to increase. Therefore, this study divides the period of investigation in to two sub-periods, namely, pre and post 2002 periods. Volatility models proposed in the methodology section will be implemented on both sub-periods and on whole period from January 1986 to March 2010.

On the other hand, during these subjected periods volume of futures contracts for WTI benchmark couldn't be captured, so methodology in section 4.2.3 will be implemented on daily Brent crude oil spot prices from January 2008 to March 2010 which is represented in Figure 4.2. According to the figure Brent crude oil prices have increasing and declining trends followed by an increasing one and therefore represents high volatility.

Figure 4.2 Brent Crude Oil Spot Prices from January 2, 2008 to March 16, 2010



Source: Energy Information Administration, USA

According to the Table 4.1, which represents the summary statistics of all data used in this thesis, January 2, 2002 has been a milestone in the structure of crude oil prices because since than the standard deviation has become five times larger when compared with pre-2002 period. Brent prices during post-2008 period, also, represent a high variance value which makes modeling volatility of this period essential.

Table 4.1 Summary Statistics of WTI and Brent Crude Oil Markets Data

	Pre – 2002 (WTI)		Post – 2002 (WTI)		Whole Period (WTI)		Post – 2008 (Brent)	
Descriptive Statistics	p_s	p_f	p_s	p_f	p_s	p_f	p_s	Vol
Mean	20.20	20.18	57.54	57.56	32.86	32.85	79.06	291536.20
Median	19.51	19.51	57.52	57.65	21.81	21.78	74.34	287185.00
Maximum	41.07	40.42	145.31	145.29	145.31	145.29	143.95	713496.00
Minimum	10.25	10.42	18.02	17.97	10.25	10.42	33.73	16548.00
Std. Dev.	4.86	4.83	25.71	25.71	23.50	23.51	27.08	77656.14
Skewness	1.04	1.02	0.88	0.88	1.92	1.92	0.50	0.70
Kurtosis	4.34	4.30	3.67	3.67	6.63	6.62	2.38	5.46
J-B Statistics	983.91*	1016.03*	306.70*	304.91*	7066.78*	7046.19*	32.23*	185.88*
Observations	4009	4009	2055	2055	6064	6064	555	555

* represents statistical significance at 99% confidence interval

Moreover, as Table 4.1 gives evidence that all the series are positively skewed and leptokurtic. It is known that GARCH type volatility models fit well to leptokurtic distribution. Since J-B statistics, which test null hypothesis of non-normality, are statistically significant, our primary assumption of parametric calculations holds.

4.4 Results

The primary prerequisite for the GARCH type volatility modeling is the stationarity of variables. In this regard Augmented Dickey and Fuller, ADF, (1981) and Kwiatkowski-Phillips-Schmidt-Shin, KPSS, (1992) tests are conducted on the series. Results of these tests are provided in the Table 4.2.

Table 4.2 Results of Unit Root Test (with Trend) conducted on Futures and Spot Prices

	Pre – 2002 (WTI)		Post – 2002 (WTI)		Whole Period (WTI)		Post – 2008 (Brent)
Test Statistics	p_s	p_f	p_s	p_f	p_s	p_f	p_s
ADF (Level)	-3.40***	-3.31***	-1.93	-1.88	-2.32	-2.39	-0.89
ADF (1^{st} Difference)	-19.97*	-19.72*	-21.01*	-7.59*	-29.80*	-36.48*	9.67*
KPSS (Level)	0.35*	0.35*	0.32*	0.33*	1.48*	1.48*	0.44*
KPSS (1^{st} Difference)	0.03	0.03	0.06	0.06	0.02	0.02	0.19**

*,** and *** represents statistical significance at 99%, 95% and 90% confidence interval respectively

As Table 4.2 represents first difference of all variables are integrated of order zero, I(0) which leads a remark that logarithmic return transformation, provided in equation (9), on variables may be done to follow the volatility modeling approach.

$$r_{i,t} = \log(p_{i,t} / p_{i,t-1}) \quad (9)$$

where, $i = s \; or \; f$ corresponding to spot or futures respectively.

Once return series have been captured mean and variance equations are found. To select the most appropriate GARCH-type model, all series of all periods are first tested for asymmetry in variance equations. Selection is done according to the significance of the coefficient of asymmetric term in EGARCH models. If there are no asymmetry in variance equations results of EGARCH estimates are provided in

Appendix section and GARCH type volatility modeling used to model volatility in series. Provided that there exists significance of the coefficient of asymmetric term, than EGARCH volatility model is used.

Ljung-Box tests on normalized and squared residuals and ARCH-LM tests, which are provided in Appendix section, conducted to find out whether the mean and variance equations are suggested appropriately. According to the results of Ljung-Box test, mean equations for all series are properly defined. Moreover, results of ARCH-LM test imply that after variance equations there exist no arch effect left in the series.

4.4.1 Results of Spot and Futures Volatility Model Estimations During Pre-2002

According to the estimation results of EGARCH variance model conducted on returns of WTI spot prices during pre-2002, the coefficient of asymmetric term is statistically significant but positive stating theoretically that pre-2002 spot market variance does not show any asymmetry. Moreover, similar consequence is derived from the estimation results of EGARCH volatility model conducted on returns of WTI futures prices during the same period. The coefficient of asymmetric term is neither significant nor negative, leading to a conclusion that in order to capture variance series GARCH model can be used for both markets during pre-2002.

Estimation results for AR(1)–GARCH(1,1) variance equation (Equations 4&5) for both markets, are as follows.

Table 4.3. Mean Equations of WTI Spot and Futures Market

		γ_1	δ_1
Spot Market	Estimate	-4.74×10^{-5} (-0.182)	0.003 (0.155)
Futures Market	Estimate	-4.41×10^{-6} (-0.017)	0.018 (1.103)

Numbers in parentheses are z-statistics. *,** and *** represents significance at 99%, 95% and 90% confidence interval.

Table 4.4. GARCH Estimation Results of WTI Spot and Futures Market

		ϖ_0	α_1	β_1
Spot Market	Estimate	-5.96×10^{-6} (5.831*)	0.116 (20.201*)	0.878 (140.56*)
Futures Market	Estimate	-7.40×10^{-6} (6.931*)	0.115 (19.560*)	0.883 (137.233*)

Numbers in parentheses are z-statistics. *,** and *** represents significance at 99%, 95% and 90% confidence interval.

Afterwards, variance series for both spot and futures market are captured to analyze the interrelationship between spot and futures market. With this regard Granger-Causality and Cointegration analysis, shown above as equations (6) and (7), have been conducted to find the relationship in short-run and long-run, respectively.

Table 4.5. Results of Granger Causality Test Conducted on Pre-2002 Spot and Futures Variance Series

	F-statistics	
Dependent Variable	$\sigma^2_{s_t}$	$\sigma^2_{f_t}$
$\sigma^2_{s_t}$	-	4.692*
$\sigma^2_{f_t}$	20.629*	-

* indicates the significance level at 1%, optimum lag length has been determined by AIC.

Results of Granger Causality test imply that there exists strong bidirectional lead-lag relationship between two markets. Moreover, futures markets leading is, obviously, more significant than spot markets one. On the other hand, cointegration test results imply that two markets are related with each other in long-term too. This results show significant co-movement of two markets during pre-2002 period.

Table 4.6. Results of Cointegration Test Conducted on Spot and Futures Price Series

Model Specificaition	ADF	
$p_{f_t} = \alpha_1 + \beta_1 \times p_{s_t} + \varepsilon_{1t}$	η_0	-27.892*
	η_1	-27.934*
$p_{s_t} = \alpha_2 + \beta_2 \times p_{f_t} + \varepsilon_{2t}$	η_0	-27.945*
	η_1	-27.949*

* indicates the rejection of null hypothesis at significance level 1%, n is the optimum lag length, η_0 and η_1 are unit root test without and with trend respectively.

Preliminary results show that there exists a strong relationship between futures and spot markets in terms of both price and variance levels for the pre-2002 period, during which the prices are considerably more stable when compared with post-2002 period.

4.4.2 Results of Spot and Futures Volatility Model Estimations During Post-2002

A very different result is obtained for the post-2002 period. Estimation results for EGARCH model imply that the asymmetric term is statistically significant, whereas, according to the results of Ljung-box test conducted on squared residuals of EGARCH (1,1) of both spot and futures market, the ARCH effect does not disappear. To overcome the problem, the model must be re-assumed by changing rank orders of ARCH and/or GARCH terms with considering maximum likelihood statistics. In our case, after the rank order of GARCH term is increased to two, EGARCH model fits well for both markets. Referring back to the equation (3) for EGARCH(p,q), the results that are captured for mean and variance equations are as follows.

Table 4.7. Mean Equations of WTI Spot and Futures Market

		γ_1	δ_1
Spot Market	Estimate	0.001 (2.04**)	-0.070 (-3.25*)
Futures Market	Estimate	0.1×10^{-2} (1.89***)	-0.042 (-1.92***)

Numbers in parentheses are z-statistics. *,** and *** represents significance at 99%, 95% and 90% confidence interval.

Table 4.8. EGARCH Estimation Results of WTI Spot and Futures Prices

		ϖ_0	β_1	β_2	α_1	ϕ_1
Spot Market	Estimate	-0.328 (-5.81*)	0.225 (4.90*)	0.752 (16.26*)	-0.051 (-3.18*)	0.197 (11.11*)
Futures Market	Estimate	-0.265 (-5.44*)	0.266 (2.97*)	0.715 (7.96*)	-0.085 (-4.99*)	0.160 (8.21*)

Numbers in parentheses are z-statistics. *,** and *** represents significance at 99%, 95% and 90% confidence interval.

As it can be seen from the estimation results for both markets during post-2002 period, there exist asymmetry. This subjected period is more volatile when compared with pre-2002 and it has two subsequent trends; increasing and decreasing, respectively. Therefore, this result is an expected one, such that in these high volatile periods, prices are more sensitive to the released information. Moreover, this period witnesses a major and negative shock namely credit crunch, which, obviously, is the main reason of the decreasing trend not only for crude oil market prices but also for all other commodities'.

Table 4.9. Results of Granger Causality Test Conducted on Pre-2002 Spot and Futures Variance Series

	F-statistics	
Dependent Variable	$\sigma^2_{s_t}$	$\sigma^2_{f_t}$
$\sigma^2_{s_t}$	-	9.177*
$\sigma^2_{f_t}$	15.601*	-

* indicates the significance level at 1%, optimum lag length has been determined by AIC.

Table 4.10. Results of Cointegration Test Conducted on Spot and Futures Price Series

Model Specificaition	ADF	
$p_{f_t} = \alpha_1 + \beta_1 \times p_{s_t} + \varepsilon_{1t}$	η_0	-24.96*
	η_1	-25.00*
$p_{s_t} = \alpha_2 + \beta_2 \times p_{f_t} + \varepsilon_{2t}$	η_0	-24.96*
	η_1	-24.98*

* indicates the rejection of null hypothesis at significance level 1%, n is the optimum lag length, η_0 and η_1 are unit root test without and with trend respectively.

Results of Granger causality and cointegration tests imply that during post-2002 period there exist strong short run bidirectional lead-lag relationship and long term co-movement between spot and futures market.

4.4.3 Results of Spot and Futures Volatility Model Estimations for Whole Period

An interesting result has been obtained when the models cover whole period. While spot market volatility shows no evidence of asymmetry, EGARCH has fitted to the futures market variance model, implying the significance of asymmetry. After determination of rank orders, GARCH(1,1) and EGARCH(1,2) has suggested for spot and futures market data, respectively.

Table 4.11. Mean Equations of WTI Spot and Futures Market

		γ_1	δ_1
Spot Market	Estimate	0.2×10^{-2} (1.23)	-0.017 (-1.29)
Futures Market	Estimate	0.3×10^{-3} (1.46)	-0.009 (-0.69)

Numbers in parentheses are z-statistics. *, and *** represents significance at 99%, 95% and 90% confidence interval.**

Table 4.12. GARCH Estimation Results of WTI Spot Prices

		ϖ_0	α_1	β_1
Spot Market	Estimate	0.66×10^{-5} (7.13*)	0.098 (22.73*)	0.898 (188.02*)

Table 4.13. EGARCH Estimation Results of WTI Futures Prices

		ϖ_0	β_1	β_2	α_1	ϕ_1
Futures Market	Estimate	-0.323 (-13.92*)	0.331 (9.18*)	0.652 (18.18*)	-0.022 (-3.54*)	0.257 (24.39)

Numbers in parentheses are z-statistics. *, and *** represents significance at 99%, 95% and 90% confidence interval.**

As discussed above and as the results imply that WTI futures market volatility shows asymmetric effect while spot market does not. This would, primarily, be the consequence of increasing trading activity and the bubble that is formed around credit crunch period. During this period, the decisions of mass traders explain why the negative shocks have greater impacts than positive ones. On the other hand, since spot market is more related with the physical market conditions it does not show asymmetry.

Table 4.14. Results of Granger Causality Test Conducted on Pre-2002 Spot and Futures Variance Series

	F-statistics	
Dependent Variable	$\sigma^2_{s_t}$	$\sigma^2_{f_t}$
$\sigma^2_{s_t}$	-	5.555*
$\sigma^2_{f_t}$	15.137*	-

* indicates the significance level at 1%, optimum lag length has been determined by AIC.

Table 4.15. Results of Cointegration Test Conducted on Spot and Futures Price Series

Model Specificaition	ADF	
$p_{f_t} = \alpha_1 + \beta_1 \times p_{s_t} + \varepsilon_{1t}$	η_0	-33.55*
	η_1	-33.58
$p_{s_t} = \alpha_2 + \beta_2 \times p_{f_t} + \varepsilon_{2t}$	η_0	-33.56*
	η_1	-33.57*

* indicates the rejection of null hypothesis at significance level 1%, n is the optimum lag length, η_0 and η_1 are unit root test without and with trend respectively.

The relationship between spot and futures variance series, which are captured from each model, is consistent with previous results and is strong in both short and long run. In the short-run there exists a bi-directional lead-lag relationship. Cointegration test provided in Table 4.15 shows strong co-movement of two markets in the long-run.

The analysis, conducted so far, shows that the volatility of WTI spot and futures markets are strongly related. During pre-2002 period, the markets do not show any asymmetric structure while they do during post-2002 period. And if one analyzes the whole period it is understood that the asymmetry during post-2002 period rises because of the strength of futures market to lead the spot one. It could be derived that the variance of futures market is one of the effects of the increase in variance of spot market therefore, next section will analyze how futures trading activity affect the spot market variance.

4.4.4 Results of Brent Spot Market Volatility Model Estimations During Post-2008

In order to determine the impacts of futures market on spot market volatility, endogenous factors have first been determined. In this regard structural breaks of spot market trend are captured using ICSS algorithm. ICSS algorithm has captured four endogenous structural breaks such as; June 3, 2008 (D_1), which is the exact date of the end of increasing trend and beginning of decreasing one, October 9, 2008 (D_2), April 2, 2009 (D_3), and October 6, 2009 (D_4). These dates are used as dummy variable in variance equations (Table D.2 in the Appendix Section)

The preliminary result of EGARCH model, without structural break dummies, is provided in Table D.1 in Appendix section. According to this result volatility of Brent crude oil spot market shows evidence of asymmetric effect during post-2008 era. Therefore further analyses on market have been done with conducting EGARCH model. As implied by EGARCH estimate with structural break dummies, inclusion of all dummies are deteriorated the variance estimate. When all the dummies are tested individually to find the appropriate variance equation, only D_1 is found to be statistically significant with positive coefficient, which implies that this structural break has increased the spot market volatility.

Brent crude oil futures trading volume has been included into variance equation investigate the interrelationship between futures trading activity and spot market volatility. Moreover, exponential smoothing has been applied on volume series to capture a detrended series. Since unit root test result, provided in the Table D.3 imply that de-trended volume is not stationary, therefore percentage change level is used in variance equation.

The final version of mean and variance equations, in which D_1 and trading volume are included together, are as follows.

Table 4.16. Mean Equations of Brent Spot Market

		γ_1	δ_1
Spot Market	Estimate	-0.3×10^{-4} (-0.39)	0.030 (0.67)

Numbers in parentheses are z-statistics. *, and *** represents significance at 99%, 95% and 90% confidence interval.**

Table 4.17. EGARCH Estimation Results of WTI Spot Markets

		ϖ_0	β_1	α_1	ϕ_1	θ_1	φ_1
Spot Market	Estimate	-0.032 (-2.27**)	0.997 (475.41*)	-0.072 (-8.47*)	0.005 (0.36)	0.611 (2.97*)	1.416 (4.93*)

Numbers in parentheses are z-statistics. *, and *** represents significance at 99%, 95% and 90% confidence interval.**

According to the variance estimates, since α_1 is negative and statistically significant Brent crude oil market volatility shows asymmetric structure during post-2008 period. Moreover, coefficients of futures trading volume and first structural break dummy is positive and statistically significant, implying both of them have increased volatility of spot market. These results are expected ones, hence, first structural break, captured in June 3, 2008, is the main controlling factor of the shock created by credit crunch period. Moreover, as discussed earlier, since futures exchanges became dominant in determining world-wide crude oil prices, changes in trading volume, which represents the demand for crude oil contracts, would likely to have a huge impact on variance of spot market.

5 Conclusion

This thesis has analyzed the impact of futures trading activity on crude oil spot market volatility. In this regard, WTI and Brent markets data has been investigated in detail. Since chosen time horizon for WTI market is very long, namely from 1986 to 2010, it has divided into two according to the major trend of crude oil prices; pre-2002 and post-2002 periods. On the other hand, due to the availability of the data Brent market volatility has analyzed for the period between 2008 and 2010.

Following results have been derived from the empirical analysis section:

- For pre-2002 sub-period (WTI market);
    - WTI futures and spot market volatility do not show any asymmetry, stating that the positive and negative shocks to the variance data have almost the same magnitude of effect.
    - There exists statistical evidence that two markets have a bidirectional lead-lag relationship stating that variance of both markets are leading each other.
    - Long-run co-movement between two markets have been found.
- For post-2002 sub-period (WTI market):
    - Significant asymmetric effect has been found in volatility of both markets, stating that negative price shocks have greater impact on variance than the positive ones. This result is an expected result since

credit crunch, known as the most striking financial crisis ever, has been witnessed during this sub-period. Crude oil prices had skyrocketed at 145 $/bbl and declined to nearly 45 $/bbl after the credit crunch, while there were no other relevant changes in physical market conditions.

  - There exists bidirectional short-term lead-lag relationship between two markets.
  - There exists long-term co-movement between two markets.

- For whole period (WTI market):
  - Asymmetric effect has been found in volatility of futures market while spot market variance does not show any. This result empirically proves that futures market variance is more subjected to the financial market conditions than the spot market one.
  - Short-term bidirectional causality and long-term co-movement have been found as the evidence of interrelationship between two markets.

- For Brent spot market:
  - Four structural breaks in variance data have been captured by ICSS algorithm. These are; June 3, 2008 (D_1), October 9, 2008 (D_2), April 2, 2009 (D_3), and October 6, 2009 (D_4).
  - Asymmetric effect has found to be statistically significant
  - Only first structural break dummy, which is the exact date of the end of increasing trend and beginning of decreasing one because of credit

crunch period, is found to statistically and positively effect the variance.

- Coefficient of Brent crude oil futures trading volume in Brent spot market variance equation is statistically significant and positive stating that increase in trading volume is increasing the spot market volatility.

According to these results futures trading activity in crude oil markets is increasing volatility of spot market. While the main objective of futures market would be to increase the efficiency of underlying spot market, for the WTI and Brent crude oil market cases, futures trading activity functions in exactly opposite direction and in that sense have failed the primary mission.

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Appendix

A. Pre-2002 Volatility Modeling

Table A.1 EGARCH Estimation Results of WTI Spot and Futures Markets

		ϖ_0	β_1	α_1	ϕ_1
Spot Market	Estimate	-0.262 (-12.91*)	0.242 (21.95*)	0.014 (2.51**)	0.989 (470.76*)
Futures Market	Estimate	-0.282 (-12.64*)	0.225 (22.03*)	0.006 (1.18)	0.985 (437.84*)

Numbers in parentheses are z-statistics. *, and *** represents significance at 99%, 95% and 90% confidence interval.**

Table A.2 Ljung Box Test on Normalized and Squared Residual of WTI Spot and Futures Markets (Pre-2002 Period)

	Normalized Residuals						Sqaured Residuals					
	ε_{rs}			ε_{rf}			ε_{rs}^2			ε_{rf}^2		
Lag	ACF	PACF	LB	ACF	PACF	LB	ACF	PACF	LB	ACF	PACF	LB
1	0.018	0.018	1.274	0.019	0.019	1.4764	-0.012	-0.012	0.549	0.005	0.005	0.0969
2	-0.027	-0.027	4.192	-0.039	-0.039	7.4655	0.021	0.021	2.382	0.004	0.004	0.1684
5	-0.015	-0.017	7.840	-0.023	-0.025	12.870	0.003	0.002	2.589	0.006	0.006	2.0272
10	0.004	0.004	10.888	0.010	0.010	20.022	-0.022	-0.021	13.275	-0.024	-0.023	16.967
20	0.023	0.025	22.861	0.031	0.030	28.234	-0.007	-0.011	20.354	0.015	0.013	34.105

Table A.3 ARCH-LM Test Results of WTI Spot and Futures Markets

	Squared Residuals	F-statistics	LM-statistics
ε_{rs}^2	-0.012	0.548	0.548
ε_{rf}^2	0.005	0.097	0.097

B. Post-2002 Volatility Modeling

Table B.1 Ljung Box Test on Normalized and Squared Residual of WTI Spot and Futures Markets

	Normalized Residuals						Sqaured Residuals					
	ε_{rs}			ε_{rf}			ε_{rs}^2			ε_{rf}^2		
Lag	ACF	PACF	LB	ACF	PACF	LB	ACF	PACF	LB	ACF	PACF	LB
1	0.020	0.020	0.8253	0.006	0.006	0.0777	0.029	0.029	1.7029	0.025	0.025	1.3276
2	-0.011	-0.011	1.0628	-0.008	-0.008	0.2086	0.107	0.106	25.193	-0.013	-0.014	1.6680
5	-0.032	-0.033	4.8029	-0.019	-0.019	1.5064	0.049	0.050	30.331	0.042	0.041	6.0890
10	0.027	0.027	11.900	0.022	0.022	8.4006	-0.007	-0.008	33.681	0.004	0.001	7.9562
20	-0.016	-0.014	16.104	-0.006	-0.004	15.016	0.006	0.008	39.621	0.011	0.015	14.754

Table B.2 ARCH-LM Test Results of WTI Spot and Futures Markets

	Squared Residuals	F-statistics	LM-statistics
ε_{rs}^2	0.029	1.699	1.699
ε_{rf}^2	0.025	1.325	1.325

C. Whole Period Volatility Modeling

Table C.1 EGARCH Estimation Results of WTI Spot and Futures Markets

		ϖ_0	β_1	α_1	ϕ_1
Spot Market	Estimate	-0.248 (-14.91*)	0.988 (570.68*)	0.003 (0.72)	0.206 (26.21*)

Numbers in parentheses are z-statistics. *, and *** represents significance at 99%, 95% and 90% confidence interval.**

Table C.3 Ljung Box Test on Normalized and Squared Residual of WTI Spot and Futures Markets

	Normalized Residuals						Sqaured Residuals					
	ε_{rs}			ε_{rf}			ε_{rs}^2			ε_{rf}^2		
Lag	ACF	PACF	LB	ACF	PACF	LB	ACF	PACF	LB	ACF	PACF	LB
1	0.012	0.012	0.9432	0.022	0.022	2.8145	0.000	0.000	0.0014	0.007	0.007	0.3385
2	-0.018	-0.018	2.8574	-0.034	-0.034	9.7722	0.021	0.021	2.5608	0.035	0.035	7.8525
5	-0.019	-0.019	6.8573	-0.020	-0.022	15.850	0.012	0.012	3.9982	0.013	0.011	15.964
10	0.015	0.015	13.505	0.018	0.017	23.874	-0.019	-0.018	15.076	-0.013	-0.011	23.213
20	0.012	0.012	21.523	0.020	0.020	30.382	-0.003	-0.005	23.501	0.014	0.016	33.632

Table C.3 ARCH-LM Test Results of WTI Spot and Futures Markets

	Squared Residuals	F-statistics	LM-statistics
ε_{rs}^2	0.4×10^{-3}	0.001	0.001
ε_{rf}^2	0.008	0.338	0.338

D. Post-2008 Volatility Modeling

Table D.1 EGARCH Estimation Results of WTI Spot and Futures Markets

		ϖ_0	β_1	α_1	ϕ_1
Spot Market	Estimate	-0.118 (-3.56*)	0.052 (2.11**)	-0.073 (5.43*)	0.989 (286.27*)

Numbers in parentheses are z-statistics. *, and *** represents significance at 99%, 95% and 90% confidence interval.**

Table D.2 EGARCH Estimation Results of WTI Spot and Futures Markets

		ϖ_0	β_1	α_1	ϕ_1	D_1	D_2	D_3	D_4
Spot Market	Estimate	-7.565 (-6.91*)	-0.065 (-0.41)	0.020 (0.42)	0.182 (2.67*)	-1.077 (-0.05)	-2.820 (-1.70***)	2.691 (0.26)	1.084 (0.09)

Numbers in parentheses are z-statistics. *, and *** represents significance at 99%, 95% and 90% confidence interval.**

Table D.3 Unit Root Test (with Trend) Results of Brent Crude Oil Futures Trading Volume (De-trended)

Variable	ADF (Level)	ADF ((1st Difference)
Volume (Exponential Smoothing)	-1.526	-11.458*

***,** and *** represents statistical significance at 99%, 95% and 90% confidence interval respectively**

Table D.4 Ljung Box Test on Normalized and Squared Residual of Brent Spot and Futures Markets

	Normalized Residuals			Sqaured Residuals		
	ε_{rs}			ε_{rs}^2		
Lag	ACF	PACF	LB	ACF	PACF	LB
1	0.004	0.004	0.0090	0.000	0.000	0.0000
2	-0.005	-0.005	0.0252	0.028	0.028	0.4334
5	0.068	0.068	2.6330	0.005	0.005	1.4615
10	0.067	0.064	11.444	-0.023	-0.026	4.1742
20	-0.027	-0.001	31.127	0.003	0.012	12.376

Table D.5 ARCH-LM Test Results of Brent Spot Market

	Squared Residuals	F-statistics	LM-statistics
ε_{rs}^2	-0.1×10^{-3}	1.98×10^{-5}	1.99×10^{-5}