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Analyzing the Factors Behind Crude Oil Price Increases from 2002 - 2007 and the Implications for the Oil Industry: A Non-Technical Assessment

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ANALYZING THE FACTORS BEHIND CRUDE OIL PRICE INCREASES FROM 2002 – 2007 AND THE IMPLICATIONS FOR THE OIL INDUSTRY: A NON-TECHNICAL ASSESSMENT

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ABSTRACT

In this paper I analyze how various price regimes inherent to different oil industry structures affected crude oil prices in the 20^{th} century. Overall, there are strong relationships between oil prices and the corresponding price regimes. Using an informal approach as well as concepts from economic theory, I also analyze the effects of supply and demand variables including spare capacity, stocks, futures prices, OPEC production, and GDP on crude oil prices from 2002 – 2007. The results of my analysis are fairly consistent with economic theory as they elucidate the consequences of severe underinvestment in the oil industry and price volatility. Additionally, I analyze current oil prices and assess the implications for the oil industry, OPEC, and alternative energy producers.

Acknowledgements

I dedicate this work to my wife, Beth, for her unwavering support, constant encouragement, and time spent reviewing the manuscript. I also dedicate this work to our daughter, Alana, for allowing me to be a temporary hermit in order to expedite the completion of this project. I love you both very much.

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Introduction

Throughout the oil industry's history, there have been periods of crude oil price volatility and periods of relative price stability. One can gain important insights into the direct causes of crude oil price volatility through examination of the various industry structures and price regimes inherent to each structure. From the break-up of Standard Oil in 1911 to today's complex global oil market, the industry has undergone significant structural changes that have had significant effects on oil prices. From the early 1920s until the onset of World War II oil prices exhibited volatile behavior as the Seven Sisters wielded their incredible market power and sought to gain access to reserves outside of their national borders. Following the end of World War II and until the late 1960s the Seven Sisters' dominance of global oil markets and tacit agreements to limit both production and outside competition resulted in relative oil price stability. The ascendance of OPEC in the early 1970s and their aggressive oil industry nationalization efforts unseated the Seven Sisters as the dominant player in the global oil market. Through belligerent export reductions, politically-motivated embargoes, price manipulation, and production losses resulting from geopolitical events OPEC successfully proved to the world that they controlled crude oil production and therefore prices. By the early 1980s, however, the emergence of non-OPEC producers significantly eroded OPEC's market share by selling oil at deep discounts to OPEC official prices. Following the oil price crash of 1986, oil market participants have played a key role in oil price discovery and price determination through liquid markets such as the market for futures contracts. The tradeoff, however, has been extremely volatile oil price behavior including the rapidly rising prices from 2002 to the summer of 2008 followed by an acute downturn and subsequent oil price crash in late 2008.

There are numerous explanations and theories as to why oil prices have exhibited volatility since the oil price collapse of 1986 but there has been more intense debate about what caused the recent price increases from $20 per barrel in January 2002 to $147 in July 2008. To put this in better perspective the average daily price of West Texas Intermediate (WTI) from January 1986 to December 2001 was $20.21 per barrel (Energy Information Administration 2009). In the much shorter period from January 2002 to July 2008 West Texas Intermediate fetched an average daily price of $54.85 (Energy Information Administration 2009). This latter period is of particular interest to crude oil researchers because of the various explanations as to why the price path turned sharply upward in 2002 and continued until July 2008 at a greater rate of change than any other time period since 1986.

Like most commodities, supply and demand variables play a significant role in oil price determination. In analyzing crude oil prices many researchers examine these variables in more detail as well as OPEC behavior and futures market activity. A number of researchers identify the following variables as significant in affecting prices: spare production and refining capacity (and therefore capacity utilization), stocks or days of forward supply, and futures prices. In my analysis I will examine the effects of these variables as well as general supply and demand dynamics on WTI spot prices through the context of fundamental economic theory. Additionally, I will examine the role of OPEC in affecting crude oil prices[1] and explain how crude oil price volatility has resulted in underinvestment in the oil industry.

Moebert (2007), Fattouh (2007a), Dees (2008), and Mabro (2006) make strong cases that spare production and refining capacities have significant effects on crude oil prices. In the U.S. the number of refineries has not increased since 1981 and global demand exceeded global refining capacity in 2004 (Dees 2008). Fattouh (2006a) provides similar data that show dwindling production capacity relative to crude oil production from 1970 – 2004 and argues that this shortage of production capacity tends to push up oil prices. These researchers also assert that the levels of stocks and the accompanying reactions by futures market participants are significant drivers of oil prices. They examine both additions and draw downs of existing stocks and how these actions affect the future outlook of the crude oil demand and supply balance.

In Section I of this thesis I will provide a historical overview of the oil industry beginning with the breakup of Standard Oil in 1911. I will examine how the industry structure changed throughout the 20th century and analyze the various oil price regimes that resulted from these structural changes. I will also analyze the economics behind each price regime and assess how prices responded to both artificial mechanisms and market mechanisms. In Section II I will examine a number of supply, demand, OPEC, and futures market variables and assess their influence on the rapid crude oil price increases from 2002 – 2007. I will also provide an analysis of how oil prices behaved following the aforementioned period to March 2009. Finally, I will discuss the

[1] It will be shown that examining OPEC's influence and its market structure is a daunting task that many researchers have attempted over the last 30 + years. Providing an in-depth analysis of OPEC is beyond the scope of this paper however, I will provide as much detail as possible in examining OPEC's role in determining crude oil prices.

implications of oil price volatility for the oil industry, OPEC, and alternative energy providers.

In addition to varying opinions regarding the influence of different variables, there are also a number of different methods in which to model oil price behavior. Fattouh (2007a) indentifies three approaches: models based on Hotelling's theory of exhaustible resources, models using supply and demand equations, and informal models that examine economic variables within the context of oil market history using concepts from economic theory to assess behavior.

In my analysis of oil price behavior (Section II) I will provide energy data from the Energy Information Administration and Baker Hughes to illustrate behavior of all variables in time series graphs. I will utilize the informal model research method described in Fattouh (2007a) in which I analyze oil price behavior *vis-à-vis* chosen variables and assess whether or not economic theory can accurately explain oil price behavior for the selected period. I have chosen the informal method for my analysis because of its simplicity and ability to capture the effects of many different types of variables over time. Additionally, this approach allows me to examine real oil data series trends over time and utilize fundamental economic concepts to analyze behavior of variables. The informal method is "useful in improving our understanding of how the different elements of the oil market function" (Fattouh 2007a, pp. 129). This method may not be useful, however, in forecasting oil price behavior because it is impossible to capture the various shocks that can influence oil prices (Fattouh 2007a). In other words, the informal approach is an adequate method to explain past behavior but is not effective in forecasting.

In Section III I will analyze how oil prices have behaved following the 2002 - 2007 period. Specifically, I will address the dramatic price peak in July 2008 followed by the sharp downturn leading to the extremely low relative prices in late 2008. Additionally, I will explain the implications for OPEC, alternative energy providers, and how oil price volatility has resulted in severe underinvestment in the oil industry. Finally, I will provide a brief discussion of an alternative approach to explaining oil prices through the Peak Oil Theory.

Section I

Oil Industry History, Structure, and Price Regimes

Introduction

The oil industry in the 20th century is characterized by three distinct periods: the concession period from the early 1920s to the early 1970s, the OPEC-dominated period from 1973 to 1986, and the subsequent and current market period. The following mechanisms have largely determined oil prices, respectively, in each of the aforementioned periods: posted prices, OPEC administered prices, and market-determined prices. *Figure 1* below shows the price trend (log scale) of West Texas Intermediate crude from January 1946 to December 2007. The difficulty here is that different price concepts have arisen out of the oil industry's complex history (Mabro 1984). This section will focus mainly on the concepts of posted prices during the concession period and administered prices during the OPEC-dominated period. Each pricing regime was born out of the previous one largely because of the inefficiency of each pricing mechanism, non-transparency of the oil market, and the failure of each particular price to provide allocative signals to respective economic agents (Mabro 1984). This section will (1) provide a historical account of the oil industry and structure following the 1911 breakup of Standard Oil under the Sherman Anti-Trust Act to the oil price collapse of 1986. This section will (2) explain the economics of posted prices and OPEC-administered prices in the context of microeconomic theory. This section will (3) analyze how each price regime failed to provide an accurate price concept in the strict economic sense of the word.

Chapter 1

The Formation of the Seven Sisters

In May of 1911, U.S. Supreme Court Chief Justice White handed down an historic decision that would eventually reshape the structure of the world oil industry. John D. Rockefeller's Standard Oil Trust was ordered under the Sherman Anti-Trust Act of 1890 to divest itself of all subsidiaries within six months (Sampson 1975). Of the 38 companies formerly controlled by Rockefeller, five of them would eventually become part of a seven-company oil consortium which dominated the oil industry until the early 1970s. These seven companies or "majors" came to be known as the Seven Sisters. Although the consortium no longer exists as a single entity, their indelible influence and clout is apparent today. Fortune Magazine recently ranked Exxon-Mobil as the world's second most profitable company; boasting over $40 billion in earnings in 2007 (Fortune Magazine 2008).

The Seven Sisters included 5 American firms: Exxon, Texaco, Mobil, Gulf, and Standard Oil of California (Socal). The remaining two firms were British Petroleum and Royal Dutch/Shell; British and Dutch, respectively. By the early 1920s, these international oil companies (led by the American firms) had already captured a large market share in the world oil industry. During World War I the allied powers relied heavily on the American firms for oil supplies. American firms accounted for nearly 80% of oil supplied to the Allies; a quarter of which came from a single firm: Exxon

(Sampson 1975). The American firms led by Exxon emerged as the world's largest oil suppliers following the end of the war. However rapid industrial growth in America, particularly in the transportation sector, raised concerns over the depletion of current oil reserves. The specter of an oil shortage impelled both the American and European oil companies to secure additional reserves outside of their national borders (Sampson 1975).

The European oil companies (Royal Dutch/Shell and BP) recognized that America was endowed with incredible oil resource wealth and therefore sought to establish control over reserves in the Middle East. Although the European oil companies initially blocked American access to Middle East oil by outbidding American firms for concessions, the American oil companies gained access with the full help and support of the US Government under President Warren G. Harding (Sampson 1975). Sampson (1975) notes, however that the power of negotiation was in the hands of the company executives rather than in the hands of the federal government. According to some observers it appeared that Washington and the State Department "had simply abdicated the whole process of oil diplomacy to the oilmen…[the government] preferred to use the oil companies, at a discreet distance, as the instruments of national security and foreign policy" (Sampson 1975, pp.74). Sampson (1975) explains that British oil executives also played a large role in shaping British foreign policy. Government policy *vis-à-vis* the oil industry thus played a crucial role in shaping the structure of an industry already dominated by only a few large firms.

Adams (1977) keenly observes that the American oil industry's performance and market conduct "have been inextricably intertwined with government policy" and that anticompetitive practices are the result of government intervention[2] (Adams 1977, pp. 143). The rule of capture[3], which once applied to wild game in America, was extended to oil reserve discoveries in the early 1930s (Adams 1977). Simply, oil belonged to the person responsible for extricating it from the ground. Akin to the California gold rushes, oil discoveries drew many would-be oilmen to "acquire leases and drill as many wells as possible" (Adams 1977, pp. 144). The rate of crude production increased faster than the ability to transport it and thus had a negative effect on prices. In 1920 the average wellhead price of a barrel of crude was $3.07 and by 1929 it had fallen to $1.27 (Adams 1977). In August of 1931 the American petroleum market was in chaos. Daily crude production in Texas exceeded 1 million barrels and prices had plummeted to 13 cents per barrel while production costs were estimated at 80 cents per barrel (Yergin 1991). In order to mitigate the effects of over-drilling and the impairment of maximum ultimate recovery, oil-producing states such as Texas implemented a maximum efficiency rate (MER) rule that dictated the highest rate of production that would not damage the reserve or limit future crude production (Adams 1977, pp. 144). The deleteriously low oil prices "that portended ruin for most oil producers in Texas and around the country" caused Texas governor Ross Sterling to issue a shutdown order in July 1931 (Yergin 1991, pp. 250).

The Texas Railroad Commission (TRC) enforced the shutdown order through a system of "market demand prorationing" in which the supply of crude was restricted in order to keep the prices artificially high and to eliminate waste (Yergin 1991, pp. 250).

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[2] Adams (1977) cites T. Duchesneau. Competition in the U.S. Energy Industry. Ford Foundation Energy Policy Project, Ch. 3 pp. 150. 1975.

[3] Sampson (1977) also explains that this law contributed to depressed oil prices and that gas stations competed with one another by offering free chickens with gasoline purchases (See also Adelman, World Petroleum Market, pp. 43).

In other words, the state of Texas limited production by enforcing tough production quotas. Despite growing opposition and antipathy towards the TRC the prorationing measure was very effective in raising the price per barrel. Crude prices rose to 90 cents per barrel by April 1932; roughly 6.5 times the price a year earlier (Yergin 1991). However, the prorationing order met resistance. Many producers produced more oil than allowed by the quotas and subsequently smuggled it over the Texas border to sell in states that did not have production restrictions. This contraband oil or "hot oil" created a glut and threatened price stability. Senator Tom Connally drafted the Hot Oil Act of 1935 which restricted inter-state oil sales to production amounts set by quotas and gave states "sufficient police powers to curtail contraband oil" (Adams 1977; Yergin 1991, pp. 257). Provisions under FDR's New Deal provided the necessary political support to legitimize these anticompetitive practices. For example the Bureau of Mines calculated estimates of U.S. aggregate crude oil demand and assigned particular production amounts to each state (Yergin 1991). These involuntary quotas, although strictly enforced, were not impossible to evade. However, Yergin (1991) suggests that states had a strong incentive to abide by their respective quotas. If one state exceeded its quota, others might follow; resulting in over supply and thus low prices. "The memory of 10 cents a barrel was still strong both among oil producers and among the state governments that depended on oil revenues[4]" (Yergin 1991, pp. 257). Connally's Hot Oil Act and the resulting state quota regulations were, indeed, successful in preventing domestic price wars but foreign competition following World War II threatened the stability of U.S. oil prices.

[4] Although not specifically stated, it can be inferred that states favored high oil prices because higher prices resulted in higher tax revenue. See Chapter 2 below for similar policies *vis-à-vis* OPEC.

It is important to note that U.S. crude prices were neither set nor fixed by the federal government. However, demand estimates and therefore government-enforced production quotas were effective in establishing price stability. From 1934 to 1940 crude prices gently floated between $1 per barrel and $1.18 per barrel (Yergin 1991). Since the United States was a major crude exporter to the world market the Seven Sisters "adhered to a basing point system[5] in which crude and product prices throughout the world were quoted on the basis of U.S. Gulf Coast prices plus transportation costs" (Adams 1977. pp. 145). Therefore any changes in U.S. crude prices resulted in proportional changes in other crude prices worldwide (Adams 1977). However, the British government protested this pricing relationship regarding the shipment of fuel to support the Royal Navy during World War II. "There was no reason why fuel oil produced at BP's Abadan (Iran) refinery and shipped to Aden...should have been priced as if it had been refined in Texas and shipped halfway around the world" (Adams 1977, pp. 145). These protests resulted in the establishment of the Persian Gulf basing point price system; however Adams (1977) points out that these prices were initially identical to prices of U.S. Gulf Coast crude oil.

By 1949, however, Persian Gulf crude prices had fallen by two-thirds that of Gulf Coast crude prices (Adams 1977). These lower prices were much more attractive to U.S. refiners and thus had a dramatic effect on U.S. crude imports. U.S. crude imports more than tripled from 272,000 barrels per day in 1947 to more than 900,000 in 1956 (Adams 1977). Adams (1977) also notes that in 1956 crude oil imports accounted

[5] This is analogous to the price of "marker crudes" which I will explore in Chapter 2.

for 12.5% of refinery runs[6] compared with only 5.8% in 1947. Cheap foreign oil hurt U.S. oil producers' bottom line but consumers of refined petroleum products and refiners reaped the benefits of cheap crude imports. Once again, the U.S. government wielded its power by establishing import controls to protect domestic producers. The Eisenhower Administration's Mandatory Import Control Program became effective in March of 1959 following almost five years of unsuccessful voluntary import controls[7] (Adams 1977). However, the roots of the above anticompetitive practices did not entirely originate from within the U.S. government, *per se*. The secretive collusion among the bosses of the "Big Three" (Exxon, Royal Dutch/Shell and BP) prior to these events laid the groundwork for the further restricting of competition in an already anticompetitive industry[8].

By the late 1920s Sir Henri Deterding of Royal Dutch/Shell had established control of reserves in the Middle East, India, and was seeking access to reserves in Russia (Sampson 1975). Mobil had, likewise, established control of reserves in India and viciously undercut Shell prices. Furious, Deterding countered by further undercutting Mobil and subsequently set off a vicious price war in India. The oil industry was soon involved in a dangerous price war; resulting in a glut of oil on the world market and sharp decreases in oil prices (Sampson, 1975). In 1927 the three largest oil companies (in terms of industry profits) were Exxon led by Walter Teagle,

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[6] A refinery run is simply the amount of crude oil inputs necessary for production of refined petroleum products.

[7] Adams (1977) and Adams (2003) note that these voluntary import controls proved largely ineffective because although importers voluntarily accepted quotas they were threatened with mandatory controls if they did not comply.

[8] History would eventually show that the cartelization of OPEC was by no means a coincidence nor was it entirely unprecedented. Sampson (1975) indicates that Venezuela, a founding member of OPEC, hired a Texas Railroad Commission employee as an advisor on the practice of prorationing to maintain rigid prices. The author also states that OPEC used the Texas Railroad Commission as a model in forming the Middle East cartel to control and exploit crude oil production in 1960.

Royal Dutch/Shell under Deterding, and BP led by Sir John Cadman. Facing a price war and thus collapsing prices, the "Big Three" had the most to lose from the intense competition. In 1928, Deterding invited Teagle and Cadman to Achnacarry Castle in Scotland "for a little shooting and fishing" and to discuss strategies to maintain oil price stability (Yergin 1991, pp. 263). For two weeks the three leaders deliberated and formulated a set of industry principles that, although never fully put into practice, reverberated through the industry well into the late 1950s (Sampson 1975). The Achnacarry Agreement[9], or more familiarly the As Is Agreement, denounced smaller oil companies clamoring to enter the industry. It also claimed that "excessive competition has resulted in the tremendous overproduction of today" and that price competition has resulted in industry destruction (Sampson 1977, pp. 87). Yergin (1991) notes that given higher operating costs "waste must be eliminated [and] the expensive duplication of facilities [must be] curtailed" (Yergin 1991, pp. 264). The latter point is perhaps the most ominous to the future of the oil industry because it called for limiting the construction of production facilities (i.e. wells and rigs). These facilities were to be added as necessary to support increased oil requirements as efficiently as possible (Sampson, 1975). In other words, this non-competitive consortium set out to maintain crude price stability under the auspice of supplying the world markets with just enough oil to meet demand.

The As Is Agreement ultimately failed, however; largely due to its noncompliance with America's antitrust laws. Additionally, Yergin (1991) explains that even though the agreement involved the dominant oil companies "there were

[9] Yergin (1991) refers to this document as the "Pool Association" but "As Is" is recognized as the more familiar name.

enough ‘fringe’ players...who did not hesitate to nibble away at the market share of the major companies” (Yergin 1991, pp. 265). Following the return from Achnacarry, Teagle, with the support of 17 oil companies, founded the Export Petroleum Association[10] “which would jointly manage their oil exports and allocate quotas among them” (Yergin 1991, pp. 265). In 1932 six of the Seven Sisters met to adopt resolutions that would enforce quotas and restrict competition (Sampson 1975). However, it was not until the 1934 London meeting when Exxon, Shell, and British Petroleum (BP) agreed on the Draft Memorandum of Principles. The Draft Memorandum of Principles contained stipulations that restricted competition and profit sharing from outsiders (Sampson 1975). By 1938 the Seven Sisters had achieved their goals of maintaining price stability, maximizing industry profits, and restricting competition by creating barriers to entry. “Most of the world’s oil resources were in the hands of the big companies” and Rockefeller’s oil monopoly had evolved into a global cartel (Sampson 1975, pp. 92). However, the emergence of fringe players, industry nationalization, foreign exchange controls, import quotas, and price-setting constantly challenged the market power of the cartel (Yergin 1991). Although the Big Three kept each other apprised of their intentions, their collaboration attempts were hindered by “pervasive distrust, wariness, and deep-seated rivalry” among the bosses (Yergin 1991, pp. 267). Thus the exigencies posed by fringe players and the bellicosity of the Big Three contributed to further price erosion and imbalances in the world oil industry.

[10] The Export Petroleum Association operated auspiciously under the Webb-Pomerene Act of 1918 which, as Yergin (1991) explains, allowed U.S. companies to form trusts as long as operations took place outside the United States.

Vertically Integrated Industry Structure

The Seven Sisters' dominance of the oil industry can not be understood in isolation from the industry's complex structure. Sampson (1975) suggests that in addition to laying the framework for future multinational companies, the majors had begun to pioneer a new type of industrial organization in the years following the breakup of Standard Oil. Each international oil company was vertically integrated; "controlling not only its own production, but also transportation, distribution, and marketing" (Sampson 1975, pp. 70). Adams (2003) asserts that the oil industry's history of vertical integration "[has] been and continue[s] to be critical in determining industry structure-performance relationships" (Adams 2003, pp. 25). By 1950 the Seven Sisters controlled almost 100% of crude oil production outside of the United States and Communist Bloc (Adams 2003). Through a series of joint ventures beginning in the 1920s, the vertically-integrated major oil companies horizontally integrated in order to monopolize access to reserves in the oil-rich Middle East. Adams (2003) cites observations from Hartshorn (1993, pp. 117):

> *"The international companies' vertical integration was complemented in practice by a degree of informal but effective horizontal integration. Their joint ownership of operating companies in the Middle East, and their voting rights under the complex operating agreements through which they controlled exploration, development and offtake there, gave them a unique degree of knowledge of each others' opportunities to increase crude offtake, and some leverage to influence each others' opportunities."*

Sampson (1975), Fattouh (2006c), and Mabro (1984) also imply that the industry structure under the Seven Sisters was oligopolistic and non-competitive. There was a high degree of information-sharing, collusion, and other anti-competitive behavior among the Seven Sisters. Sampson (1975) notes the following:

> *"More seriously disturbing for the advocates of free enterprise was the tendency of the giant [oil] companies, as they ventured further abroad, to cling together in consortia and to reach hidden understandings with each other in their attempts to bring order to the volatile market…Like the classical sisters, who were translated by Zeus into stars, they seem to have acquired immortality. But like mortal sisters, they fought and competed with each other, while still preserving a family likeness and closing ranks when challenged by outsiders"* (Sampson 1975, pp. 71).

The above implicitly labels the Seven Sisters as a cartel. The popular literature on the Seven Sisters[11] explicitly describes the oil consortium as a cartel. The following section will examine the validity of these conjectures.

Microeconomic Cartel Model

In the cartel model each firm cooperates and colludes in order to affect prices. Cartel members do not act as price takers as found in perfectly competitive models (Nicholson 1989). Through coordinated output decisions a cartel has the potential to earn monopoly profits. I can illustrate the Seven Sister's cartel-like behavior of maximizing industry profits through a multiplant monopoly model developed in Nicholson (1989). If there are *i* individual firms in the cartel and each chooses output levels $Q_1, Q_2 \ldots Q_i$ then the profit equation looks like this:

[11] Yergin (1991) and Sampson (1975)

$$(1)\ \pi = P(Q_i)Q_i - \sum TC_i(Q_i)$$

where $P(Q_i)$ = price and TC_i = total costs of production for each firm (fixed costs plus variable costs). Taking the partial derivative of π with respect to Q_i yields the first order condition for a maximum:

$$(2)\ \partial\pi / \partial Q_i = P + (\partial P / \partial Q_i)\ Q_i - MC(Q_i) = 0$$

$$(3) = MR(Q_i) - MC(Q_i) = 0$$

Therefore a cartel will produce total output Q where $MR = MC$. Since output is coordinated or dictated by cartel membership laws it is assumed that the cartel exhibits constant marginal costs of production. This restriction also dictates how monopoly profits are shared among cartel members. Microeconomic theory indicates that given these assumptions cartel members may have an incentive to exceed agreed-upon production levels. Specifically, some members may produce more than allowed as long as they produce where $P > MC$. However, according to Adams (2003) the Seven Sisters did not have an incentive to cheat and therefore may not entirely fit the mould of a cartel. If one member decided to produce more than the allotted quota in order to take advantage of rising prices then this would impel other members to increase their production as well. Clearly, increases in production would significantly erode revenues. The strong possibility of significant revenue losses due to overproduction served as a tacit rule to not overproduce and therefore kept prices and production fairly stable.

The horizontal integration of the Middle East joint ventures enforced restrictions on crude oil production (Adams 2003). Information among members was very transparent and there were bureaucracies in place that mandated individual members to file their crude requirements in advance. In the case of the Iraq Petroleum Company (operated mainly by Royal Dutch/Shell, BP, and CFP[12]) there was a 5-year advance obligation in which to file for crude requirements (Adams 2003). Each member therefore had uninhibited access to other members' plans and therefore it was relatively easy to detect cheating on production. Stigler (1964) makes the case that joint ventures are a good deterrent for cheating because "the more rapidly cheating is likely to be detected, and therefore subject to retaliation, the less likely cheating is to occur" (Stigler 1964, pp. 44-61). It is also important to note that overproduction has the potential to negatively affect prices. If prices fall then each cartel member will face falling revenues.

Major Middle East Oil Concessions – Saudi Arabia, Kuwait, and Iran

The majors obtained access to crude reserves in the Middle East by purchasing licenses or concessions from host countries. Although oil-rich, the Middle East neither produced oil nor contributed to oil price determination until the formation of OPEC in 1960 (Fattouh 2006c). Rather, each producing nation competed in selling concessions to the international majors. In addition to concession fees, the majors compensated the host counties' governments by paying an *ad valorem* tax or royalty based on the posted price[13] of a notional barrel of oil. Broadly speaking, posted prices were official selling prices for crude oil and were determined based on tax and royalty rates by host countries and oil companies. The period from 1933 to 1947 is characterized by three significant concessions granted by Middle East governments to a handful of international majors.

[12] CFP was the French oil company Compagnie Française des Pétroles.
[13] See Chapter 2 for a full treatment of posted prices.

Saudi Arabia granted a 60 year concession to Socal in 1933. Socal had been in competition with Anglo-Persian and the Iraq Petroleum Company (both U.K. oil companies operating under BP) but in the end, King Ibn Saud accepted Socal's offer of generous royalties and cash payments in gold[14]. Prior to this concession, oil reserves had been discovered in Bahrain by New Zealander Frank Holmes. Holmes, a speculator in concessions, worked for a London-based enterprise and subsequently offered the concession to some of the large American oil companies (Sampson 1975). Although Teagle of Exxon rejected the offer[15], Holmes sold the concession to Gulf for $50,000. Gulf at this time was part of the Iraq Petroleum Company but previous agreements[16] restricted Gulf from operating in Bahrain[17]. Gulf attempted to attract BP to Bahrain but BP's top geologist insisted that Bahrain would not yield valuable amounts of oil (Sampson 1975). Gulf would also come to regret their decision to sell the concession to Socal. In 1932 Socal struck oil in Bahrain thus increasing the likelihood of finding oil in Saudi Arabia; just 20 miles off the shores of Bahrain. Sampson (1975) notes that although the sands of Bahrain did not yield significant amounts of crude oil, its proximity to Saudi Arabia led to King Ibn Saud's granting of a concession to Socal. The concession gave Socal access to over 360,000 square miles and King Ibn Saud "provided a great incentive to Socal to move as expeditiously as it could" (Yergin 1991,

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[14] It is important to bear in mind that the United States went off the gold standard in 1931 and that obtaining the amount of gold to compensate Ibn Saud was somewhat difficult. The gold was eventually obtained from Guaranty Trust of London; then in Socal's service (Yergin 1991, pp. 291-292)

[15] Sampson (1975) notes that Teagle later lamented his short-sightedness over this "billion dollar error".

[16] The Turkish Petroleum Company's boss, Gulbenkian, had restricted access to oil reserves within the boundaries of the former Ottoman Empire. The exact territory of the former Ottoman Empire was never quite clear so Gulbenkian literally drew a red circle on a map of Middle East; indicating that independent drilling and exploration within the circle was off limits unless granted by concession. Although originally drawn in 1914, the Red Line Agreement did not become official until 1 July 1928 (See Yergin 1991, pp. 204 – 205).

[17] Bahrain was located within the red circle drawn by Gulbenkian and therefore fell under the restrictions of the Red Line Agreement (See Yergin 1991, pp. 204 – 205; Sampson 1975, pp. 78 – 82).

pp. 291). This concession was significant, not least because of the presence of an American oil company in the Middle East, but mostly because the race to establish control over crude reserves in the oil-rich Middle East had begun (Yergin 1991).

The second major concession was granted by Kuwait to Gulf and Anglo-Persian. The decision to seek a concession was more defensive on the part of Gulf and Anglo-Persian as "the world market [was] already laboring under great surplus" (Yergin 1991, pp. 292). The move also strengthened Anglo-Persian because the Kuwait flank complemented Anglo-Persian's dominant positions in Iraq and Iran (Yergin 1991). The concession was mutually auspicious: on the one hand Gulf and Anglo-Persian blocked access to Kuwait from other majors and on the other hand Kuwait had fallen on hard economic times (Yergin 1991). Gulf and Anglo-Persian had initially been intense rivals and the British government had grown wary of the increasing American influence in the Middle East. After tough negotiations the Kuwait Oil Company joint venture was born out of Gulf and Anglo-Persian. Still suspicious of American expansion in the Middle East, the British government insisted that operations be controlled completely by the Anglo-Persian component of the joint venture. Although Gulf and Anglo-Persian initially competed for the concession and despite Britain's circumspection *vis-à-vis* the United States, Sheik Ahmad granted a 75 year concession to the Kuwait Oil Company in 1934 (Yergin 1991).

The formation of the Iran Consortium, perhaps the most complex of the three major concessions, "marked in some respects the apogee of the influence of the Seven Sisters, both with the Middle East governments and with their own home governments" (Sampson 1975, pp. 164). The Soviet Union under Josef Stalin occupied the area of

Azerbaijan following the close of WWII and demanded an Iranian oil concession. Anglo-Iranian (BP) already had a dominant position in Iran and the only way to deter Soviet interest was to make Iranian concessions attractive to American companies (Yergin 1991). BP abdicated the negotiating role to Exxon and the end result was that all Seven Sisters[18] gained access to Iranian crude oil. Anglo-Iranian (BP) and Shell controlled 40% and 14% respectively. The five American sisters each controlled 8% and CFP controlled the remaining 6% (Sampson 1975). The National Iranian Oil Company under Mossadeq owned and controlled the reserves and refineries and the "consortium would buy oil from them" (Sampson 1975, pp. 156). This deal (from the vantage point of the Seven Sisters) was a "clandestine" operation because of the consortium's goal of restricting production to avoid excess supply (Sampson 1975, pp. 157). The "Aggregate Programmed Quantity" (APQ) formula restricted oil production among each but ensured the greatest production levels to the largest members, BP and Shell (Sampson 1975). Smaller independent American oil companies resented the fact that the Iranian Oil Consortium consisted of only large oil companies. Under the threat of Washington trust busters the five American sisters eventually capitulated to the independents' demands for concession shares (Sampson 1975). In 1955 the American sisters "gave up an eighth of their holding, to allow 5% of the consortium to be held by nine of these 'independents'" (Sampson 1975, pp. 158). Sampson (1975) also notes the following:

> *"From the viewpoint of the seven there was nothing sinister about the carve-up: it merely reflected the elementary fact that only huge companies with resources*

[18] At this time the Seven Sisters were actually eight; Compagnie Française des Pétroles (CFP) of France had captured a large share of the world oil market. See Adams (2003), Sampson (1975) and Yergin (1991).

> *and markets were in a position to develop and sell the oil. And without joint arrangements, in a world of glut, there would only be cutthroat competition and sudden floods of cheap oil, such as had made life so intolerable in the mid-twenties: it was only common sense to agree to restrict supplies."* (Sampson 1975, pp. 161 – 162).

As the "center of gravity" *vis-à-vis* petroleum shifted towards the Middle East, Yergin (1991) alludes to the portentous consequences[19] that would follow in the years to come regarding the formation of OPEC. However, at this juncture it is now necessary to examine the economics of the price regime during the concession period: posted prices, *ad valorem* taxes, and royalties.

[19] Yergin (1991) as well as Sampson (1975) and Mabro (1984) note that the great concentration of the oil industry in the Middle East and the ensuing posted price reductions created the conditions necessary for the ascendance of OPEC as a dominant player with incredible market power.

Chapter 2

Posted Prices Under the Concession System

The posted price according to Mabro (1984) was simply the price that a seller was willing to accept for parting with a barrel of oil. Economically speaking however, posted prices did not respond to the usual dynamics of market forces. Instead, host governments and oil companies jointly determined posted prices in order to calculate the tax liabilities paid by the latter to the former. Therefore posted prices failed to provide allocative signals to economic agents (Mabro 1984). Posted prices did not reveal any information regarding demand or supply and “the problem of intertemporal allocation of oil resources was rarely raised” (Mabro 1984, pp. 3). Furthermore, there were very few spot transactions or arms-length-deals. Oil sales were conducted via secretive long-term contracts and the actual contract prices were often lower than official posted prices (Mabro 1984). Even though contract prices were more responsive to market forces than posted prices, Fattouh (2007b) argues that long-term contract prices “played a very limited role in price discovery” because of the non-competitive practices of information sharing and collusion that characterized the vertical and horizontal integration of the Seven Sisters (Fattouh 2007b, pp. 3). Governments of oil-producing countries did not favor the use of contract prices in calculating taxes and royalty payments since using lower prices in tax formulae resulted in lower tax revenue for producing countries. Mabro (1984) provides this simple formula for calculating the tax liability of oil companies,

$$(4)\ T_1 = f(P, C, s, r) = (P - C)s + Pr$$

where P = posted price, C = cost of production per barrel, s = tax rate on notional profits ($0 < s < 1$), and r = royalty rate ($0 < r < 1$). Taxes were therefore a percentage of the difference between posted price and costs of production plus royalty payments. Therefore Mabro (1984) and Fattouh (2006c) argue that posted prices were merely fiscal parameters which were used primarily to calculate tax liabilities and royalties paid to host governments of producing countries.

Mabro (1984) characterizes the oil-exporting countries as tax farmers and the oil companies as tax payers. From the above equation it is clear that the tax paid to host governments is a linear function of the posted price. Thus "any change in P leads to a proportional change in per-barrel tax, [T]" (Mabro 1984, pp. 8). Under this type of price regime it is clear that host governments had a strong incentive to maintain posted price rigidity in order to maximize tax revenues. On the other hand, oil companies had a strong incentive to lower the posted price in order to minimize their tax liability. However, as mentioned above, not all crude oil was sold at the relevant posted price; long-term contract prices were based on negotiations in which the actual prices were not made public. Third party deals took place outside of OPEC's authority and these prices were more representative of market prices as they responded more to supply and demand considerations. It is worth noting that although third party deals were rare "market transactions will be found wherever the planned system is fractured by some flaw" (Mabro 1984, pp. 53). Additionally, despite increasing oil demand in the 1950s production capacity grew more rapidly[20] and "more oil was in search of markets than there were markets for oil" (Yergin 1991, pp. 514). The glut of oil on the market depressed contract prices impelling the major oil companies in the Middle East to offer deeper and deeper discounts relative to posted prices. Contract prices thus provided some information regarding demand and supply of crude oil and therefore functioned more as an allocative signal better than the polarized[21] posted prices.

By the late 1950s the posted price was a "fictional price" and the host governments began taking higher percentages[22] of oil companies' profits realized from the actual or contract prices (Yergin 1991, pp. 515). Clearly, the oil companies absorbed revenue losses due to reductions in actual crude oil contract prices even though they sold more crude. Adams (2003) notes the following:

> *"From the companies' point of view, the posted price system worked well as long as transactions prices were level or rising. Falling transactions prices combined with unchanging posted prices meant that an increasing share of profit went to host countries in the form of taxes that were levied based on the posted price."* (Adams 2003, pp. 28).

The late 1950s also saw the emergence of the Soviet Union as a "force to be reckoned with in the international petroleum field" according to a CIA source (Yergin 1991, pp. 515). With vast oil reserves and access to ports in the Caspian Sea and Pacific, the

[20] The rise of independent oil producers (outside of the Seven Sisters) contributed to the increase in production capacity and the resulting glut of oil on the market. Adams (2003) and Yergin (1991) provide further detail about how host countries granted concessions to independents as a way of "breaking the grip of the Seven Sisters on the world oil market" (Adams 2003, pp. 28).

[21] Mabro (1984) uses this term to reinforce the point that posted prices did not respond to the usual forces of market perceptions or supply and demand considerations. The posted price was simply a fiscal parameter used to calculate royalties and taxes paid to host governments.

[22] Yergin (1991) estimates that the profit taxes were between 60 and 70 per cent; a large jump from the original posted price tax rate of 50 per cent.

international majors realized that the addition of Soviet crude supplies on the open market would further exacerbate the problem of low prices and that they would end up absorbing the price reductions as revenue losses (Yergin 1991). The only way to alleviate the tax burden was to lower posted prices. This action directly cut into the tax revenues of the host countries and led to the formation of the Organization of Petroleum Exporting Countries in 1960.

Posted Price Reductions and the Formation of OPEC

Beginning with BP's 10% per barrel[23] reduction in 1959 and then followed by Exxon's 7% per barrel[24] reduction in 1960, all major oil companies with concessions in the Middle East were eventually engaged in a posted price war (Yergin 1991; Adams 2003). Adams (2003) notes that price reductions were logical responses to the imbalance between supply and demand. The emergence of independent producers who gained access to crude reserves outside the control of the Seven Sisters (including the Soviet Union) flooded the market with more oil than could be consumed thus depressing prices (Adams 2003). Sampson (1975) notes that the Seven Sisters were so interdependent and that price cuts of one had to be followed by all. BP's 10% reduction alone resulted in a $132 million decrease in taxes to producing countries (Sampson 1975). Facing falling tax revenues, the Arab Petroleum Congress met in Cairo and agreed that reductions in the posted price should not take place without the explicit consent of the governments of the producing countries (Sampson 1975).

[23] BP's posted price was approximately $1.80 per barrel; the 10% reduction reflected an 18 cent price reduction. Calculation made by author. Data provided in Yergin (1991) pp. 515 and Sampson (1975) pp. 188.

[24] Exxon's posted price was approximately $2.00 per barrel; the 7% reduction reflected a 14 cent price reduction. Calculation made by author. Data provided in Yergin (1991) pp. 521.

Despite this warning against unilateral price movements on the part of the majors, Exxon led another round of posted price reductions and triggered another meeting of producing countries' governments. The governments of Iraq, Iran, Venezuela, Saudi Arabia, and Kuwait[25] met in Baghdad and formed the Organization of Petroleum Exporting Countries on 14 September 1960. OPEC's immediate goal was to defend the price of oil and restore it to the levels prior to the price reductions (Yergin 1991). Mabro (1984) argues that the original cartel (Seven Sisters) "played competitive market games and in doing so it lost cohesiveness and, unwittingly, helped the emergence of another 'cartel'" (Mabro 1984, pp 10). OPEC was largely ineffective, however, in its first few years as a world organization. Sampson (1975) explains that the founding members could not agree of the proper methods to fix prices or to restrict competition; naturally each member wanted to capture the largest market share. The Soviet Union was still "spoiling the market" and new producers such as Nigeria made OPEC's price fixing goals more and more difficult. For most of the 1960s according to an OPEC executive, OPEC was a "sideshow" in a world dominated by U.S. import quotas, Russian exports, and fierce competition (Yergin 1991. pp. 525). However, OPEC did achieve some success *vis-à-vis* negotiations with the major oil companies.

Expensing Royalties – OPEC's First Display of Power

OPEC was never able to restore posted prices to the original levels prior to the cuts but they "did manage to hold the line on taxes" and prevent further price reductions (Dahl 2004, pp. 147). In 1964 OPEC members negotiated a uniform rate for royalties in which royalties would not be deductible from income taxes paid to host countries.

[25] It is important to note that these 5 countries accounted for nearly 80% of world crude oil production in 1960 (Sampson 1975, pp. 191).

Mabro (1984) explains that these royalties were "treated as a cost in calculating the 'profit' tax and paid in addition to the profit tax" (Mabro 1984, pp. 8 - 9). Known as "expensing of royalties", this procedure increased host countries' per-barrel take even if prices were falling. An extension of equation (4) developed in Mabro (1984) shows the expensing of royalties:

$$(5)\ T_2 = f(P, C, s, r) = (P - C - Pr)s + Pr$$
$$= (P - C)s + Pr(1 - s)$$

Clearly a share of the royalty, $Pr(1 - s)$ was paid above and beyond the normal profit tax[26] $(P - C)s$. To the producers, this essentially resulted in an extra 4-cent per barrel concession (Sampson 1975). It is important to note that production costs during this time were extremely low relative to average per barrel prices. Production costs were on average 10 cents per barrel and average prices were $1.80 per barrel (Mabro 1984). Therefore tax revenue to host countries depended mostly on the posted price and these tax revenues changed proportionally with changes in the posted price (Mabro 1984).

From equations (4) and (5) it is clear that $T_2 > T_1$ and that OPEC benefited from the increase in tax revenue. Therefore posted prices fulfilled a distributional role rather than an allocative role: oil producers were primarily concerned with tax revenue from crude oil production (Mabro 1984). OPEC's original goal of maintaining price stability initially meant that tax revenue was a function of the posted price. However, as noted in Mabro (1984) as OPEC members bargained for greater tax revenues, the tax rate became the determinant of the price (Mabro 1984). Therefore any increase in the tax rate required an increase in the posted price. Finally, Mabro (1984) argues that the

[26] Mabro (1984) notes that the conventional tax arrangements were "fifty-fifty" deals therefore s = .5.

“fiscalisation” of oil prices was the symptom, not the cause, of 1960s oil industry *status quo* (Mabro 1984, pp. 12).

Nationalization and Equity Participation

By the late 1960s the Seven Sisters still dominated the world oil industry despite OPEC’s growth and burgeoning clout. In 1966 the Seven Sisters controlled 76% of production outside of the U.S. and Soviet Union (Sampson 1975). OPEC had succeeded in preventing further posted price reductions but a glut of oil kept prices on third-party deals low. The growing number of independents contributed to the over-supply and falling prices. In the late 1950s Libya granted 84 concessions to 17 independent producers. By 1961 Libya had become a major exporter of light sweet[27] crude oil that could easily be refined into gasoline and other petroleum products. By 1965 Libya was the 6th largest exporter[28] of crude oil and was producing 3 million barrels per day by the end of the decade. However, this surge in production contributed to already declining world oil prices. From 1960 to 1969 third party contract prices[29] fell by 36 cents; reflecting a decrease per barrel of 22%[30]. Cutthroat competition had a significant negative impact on Libya’s oil revenues (Yergin 1991).

Following Colonel Qadaffi’s ascension to power in 1969, he renegotiated the terms of the concessions previously granted to independents. He realized that the

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[27] Crude oil is categorized according to its sulfur content. Light sweet crude means low sulfur content. Light sweet crudes are more easily refined into petroleum products. This and other definitions regarding the types of crude oil, physical and chemical properties, and relevant price differences will be discussed later in this chapter as well as Chapter 5.

[28] Libya’s proximity to the Mediterranean Sea gave then a competitive advantage in supplying European markets.

[29] These third party contract prices can be loosely interpreted as market prices. However, there were very few third party buyers and sellers so one cannot unequivocally refer to these as market prices.

[30] Yergin (1991) also shows that when corrected for inflation the decrease was closer to 40% (Yergin 1991, pp. 529).

independents did not possess the bargaining power[31] of the international majors and thus they capitulated to the demands of higher prices and taxes in 1970. Colonel Qadaffi ordered Occidental Petroleum Company to reduce its daily output from 680,000 barrels per day to 500,000 barrels per day and ordered an increase in the posted price by 30 cents per barrel "to make retroactive payment to compensate for the lost revenue since 1965" (Sampson 1975; Fattouh 2006c, pp. 45). Other countries soon followed suit in demanding higher prices and taxes. The "leapfrog effect" leaped to Iraq, Iran, Algeria, and Kuwait (Sampson 1975, pp. 257). This collective decision resulted in an increase in the tax rate from 50% to 55% (Fattouh 2006c). Adams (2003) points out that although producing countries had exerted more control on crude oil production, the major oil companies owned the operating companies through a complex network of horizontal joint ventures and thus had more power in production decision-making. Realizing that the majors still had considerable power and influence in the region, producing countries such as Algeria, Iraq, and Saudi Arabia led the way in nationalizations of their oil industries[32]. Fattouh (2006c) describes the nationalization trend in the early 1970s as a major transformation of the oil industry. Governments either claimed equity participation over some of their respective oil industries, opted for full nationalization as in the cases of Iran, Iraq, and Libya, or discontinued granting concessions entirely (Fattouh 2006c). For these and other reasons the oil industry "saw the price setting power shift from the multinational oil companies to OPEC" (Fattouh,

[31] Adams (2003) explains that independents did not have the luxury of threatening to reduce output or seeking out supplies elsewhere like the majors. The independents could not easily or quickly move to other countries or territories.

[32] In short producers began demanding partial or full ownership of previously granted concessions. In 1972 Algeria nationalized 51% of French interests, Iraq nationalized 100% of Iraq Petroleum Company's (BP) interests, and Saudi Arabia nationalized 25% of Aramco's interests. See Sampson (1977) for a full treatment of this subject.

2007b, pp. 3). These actions introduced new price concepts that eventually evolved into OPEC's administered prices.

OPEC Official Prices and the Marker Crude

Equity participation required the definition of a new price concept. Official prices or Government Selling Prices (hereafter referred to as GSPs) established the price for third party deals which had grown in significance by the early 1970s (Mabro 1984). OPEC member countries set GSPs as a percentage of the original posted prices. OPEC initially set the GSP at 93% of the posted price or specifically, $GSP = .93P$ (Mabro 1984). OPEC governments, however, were not vertically integrated like the Seven Sisters. OPEC dominated the upstream sector of the oil industry but did not have the transportation, refining, or marketing capabilities downstream necessary for third party oil sales. Therefore, OPEC governments mandated buy-back arrangements where the governments sold the oil to the "very companies which produced it on their territories" for a buy-back price (Mabro 1984, pp. 19). This strategy eventually backfired because the concessionaires could buy crude oil at the buy-back price from OPEC and then sell it for higher realized prices[33] in the narrow spot market or in secretive third-party contracts (Mabro 1984).

OPEC's decision to abandon posted prices in favor of GSPs (administered prices) initially caused confusion and chaos in the oil industry. Growing equity participation and full-scale nationalization on the part of producing governments brought about another price concept: tax-paid cost; which Mabro (1984) defines as the sum of costs of production, C, and the per-barrel tax revenue, T. Concessionaries could

[33] These particular prices were more sensitive to the dynamics of market forces and thus enhanced price discovery. However, there were very few buyers and sellers relative to the size of the market today.

acquire crude oil at both tax-paid cost and buy-back prices from host governments[34] and as mentioned above sell for higher realized prices to buyers around the world. However, OPEC governments were becoming more and more loath to make concessions available to outside oil companies. By 1974 "governments retained the cumbersome arrangements involving posted prices, notional profit taxes, and royalties for company crude, while introducing GSPs and buy-back prices for their own oil" (Mabro 1984, pp. 22). The negotiations between governments and oil companies became more and more complex as the former sought higher taxes and royalties while the latter sought higher profit margins and lower costs. Oil companies' resistance of higher tax and royalty rates were met with threats of greater equity participation by host governments (Mabro 1984). OPEC also threatened further equity participation because of the increase in third party oil deals outside of OPEC's authority. Fattouh (2006c) explains that the vertically integrated structure of the majors occasionally resulted in imbalances between upstream production and downstream requirements. Specifically, the majors often sold crude in excess of downstream requirements to other companies who were crude short in a narrow spot market[35] (Fattouh 2006c). With increased equity participation and nationalization, OPEC's system of posted prices, profit taxes, and royalty taxes soon became irrelevant. Mabro (1984) argues that aside from matters of practicality the concession system failed largely because of the failure to achieve an

[34] Mabro (1984) notes that OPEC governments sold very little crude oil at official prices or GSPs. GSPs were based off spot transactions and non-public third-party contract prices. (See Mabro 1984, pp. 18 – 20).

[35] With increased nationalizations, major oil companies lost more and more of their access to crude reserves. This encouraged independent producers to seek sources outside of OPEC's control and eventually resulted in large losses in OPEC's market share. See Chapter 4 below.

equilibrium price[36] for crude oil. The fiscal parameters (posted prices, profit tax rate, and royalty tax rate) were eventually abandoned entirely in 1975 in favor of GSPs.

OPEC chose Arabian Light 34° API[37] crude oil as its marker crude[38] in the early 1970s. The GSP pricing system "was centered on the concept of reference or marker price" with Arabian Light serving as the marker crude (Fattouh 2006c, pp. 47). Individual OPEC members maintained their own GSPs for their respective crudes "but [these GSPs] were now set in relation to the chosen reference price" (Fattouh 2006, pp. 47). In other words OPEC members other than Saudi Arabia priced their crudes off the marker, Arabian Light. The price of Arabian Light thus served as OPEC's GSP throughout the 1970s and early 1980s. Other OPEC crude varieties traded at a discount or premium to the marker; depending on the quality of the crude relative to Arabian Light. If OPEC agreed to increase the price of Arabian Light, other OPEC crude varieties would also adjust relative to the marker[39]. The choice of a marker crude and reference price, determined solely by OPEC, helped create the necessary environment for OPEC to wield its new-found market power.

[36] Equilibrium prices are prices which equate demand and supply in a market for a particular good. As noted throughout this paper, posted prices were fiscal parameters designed to determine tax revenue and royalties paid to host countries and were insensitive to actions of economic agents. Outside of OPEC, crude oil was more responsive to market forces although the relative scope of these markets was small.

[37] API Gravity Index measures sulfur content which determines whether the crude is light/sweet or heavy/sour. A higher API indicates low sulfur levels and therefore a lighter crude variety. A lower API reflects higher sulfur content and therefore a heavier crude variety.

[38] The marker crude served as a reference point for the pricing of other crudes. Different crude varieties fetch different prices because of differences in quality (API gravity index, sulfur content, etc).

[39] Administering the price of the marker crude as well as the differentials between the marker and other crudes proved to be problematic for OPEC. See Section XII below for the problems of GSP administration. The reader should consult Mabro (1984) pp. 31 – 42 for a full treatment of the problems associated with administering OPEC price differentials.

Chapter 3

OPEC Market Power – 1973 Unilateral Price Hike and the Arab Oil Embargo

It is important to note that during the early 1970s supply conditions were much tighter and world oil demand had been steadily increasing. Nationalizations among oil producing countries resulted in crude supplies and ownership of supplies becoming more and more concentrated in the Middle East. Adams (2003) notes that estimated crude reserves in the Middle East were 333.5 billion barrels; compared to only 67.4 billion barrels in the western hemisphere. There was also chatter among the leading oil companies of a looming crude oil shortage. With increased nationalizations, the vertically integrated majors lost their ability to supply enough crude oil to maintain profitability downstream. Sampson (1975) notes that Exxon severely underestimated growth in world demand for crude oil and that estimates made for 1970 "were 8% lower than actual consumption" (Sampson 1975, pp. 286). U.S. oil production had been falling as well and thus contributed to the strain on world production capacity. Data provided in Adams (2003) indicate that U.S. crude oil production peaked in 1970 and has trended downward since then. See *Figure 2* below. In that same year crude oil imports reached 28% of domestic consumption in the U.S. By September of 1973, for the first time since the formation of OPEC, the market price of crude oil exceeded OPEC's posted price (Sampson 1975). Clearly, OPEC was in a very advantageous position *vis-à-vis* oil consumers. Given the above conditions, the early 1970s were very significant years in the oil industry's history because the power of the once dominant Seven Sisters slowly slipped into the hands of OPEC and its growing membership[40].

OPEC's unilateral decision in October 1973 to increase the price of their marker crude, Arab Light, by 70% from $3.65 to $5.11 per barrel reflected elements of both the economic and political environments. On the economic side, crude oil sold to third parties on the open market commanded a higher price than OPEC oil. Independents who had purchased crude oil at buy-back prices were selling this "participation oil" at a per-barrel-premium over OPEC posted prices (Sampson 1975, pp. 298). Sampson (1975) also notes that non-energy inflation had increased by 2.5% therefore "the price of other commodities which OPEC countries had to import was far outstripping the oil price" (Sampson 1975, pp. 298). OPEC's position became more advantageous in the face of growing global oil demand because there lacked a "short-term alternative to OPEC" as a source of marginal crude production (Fattouh 2006c, pp. 45). The Seven Sisters' staunch refusal to capitulate to OPEC's demand for higher posted prices further intensified relations between the major oil companies and the growing cartel (Fattouh 2006c). Geopolitical tensions also contributed to OPEC's decision to raise the posted price of the marker crude. Egypt and Syria invaded Israel on 6 October 1973 in an attempt to drive the Israelis out of disputed territory. The United States under President Richard M. Nixon pledged shipments of military equipment and other goods to aid the Israeli armed forces during the Yom Kippur War. OPEC also announced an embargo in which OPEC cut production by 5% and pledged to continue with 5% production cuts each month until the U.S. ceased support of Israel. Oil supplies from the Middle East

[40] In addition to the original five founding members OPEC included Qatar, Indonesia, Libya, United Arab Emirates, Algeria, Nigeria, and Ecuador. See OPEC Official Website: www.opec.org. Specific URL: http://www.opec.org/aboutus/history/history.htm

fell from 20.8 mbd in October of 1973 to 15.8 mbd in December of that same year (Yergin 1991). Prior to the embargo, the U.S. imported 1.2 mbd from OPEC but by February of 1974 U.S. imports had fallen by 98% to a mere 18,000 bpd (Sampson 1975). Sampson (1975) notes that although OPEC threatened cut backs of 5%, U.S. supplies had actually fallen by 7.4%. Yergin (1991) indicates that the production cuts were especially significant because of the lack of spare capacity in the U.S. and that the U.S. "had lost its critical ability to influence the world oil market" (Yergin 1991, pp. 614). The situation worsened when OPEC further raised the posted price of its marker crude to $11.65 in December of 1973 (Fattouh 2007b). While not the direct cause, the oil price hikes certainly contributed to the economic downturn from 1973 – 1974. U.S. gross domestic product fell by .5% in 1973 and another 1.3% in 1974 (Adams 2003). Even more staggering is OPEC's 636% increase in oil revenue from 1972 to 1974. In 1972 OPEC oil revenue was only $13.7 billion but by 1974 oil revenue had increased to $87.2 billion (Adams 2003).

The Arab oil embargo lasted until March 1974 but significant structural changes had begun taking place. The realities of high oil prices and tight supplies encouraged conservation efforts, further exploration, and efficiency standards on automobiles. Gasoline consumption fell by 7.7% in the first quarter of 1974 but eventually picked up again following the end of the embargo (Sampson 1975). It is important to note that this decrease in gasoline consumption may have been caused in part by the 55 mph enforcement on American roads and by Americans' reluctance to drive more than necessary. Additionally, it has been empirically shown that generally the price elasticity of demand for oil tends to be inelastic[41] in the short-run. Legislation was also passed in 1974 that permitted construction of a pipeline from Alaska to the lower 48 states. Other legislation enacted in 1975 required automakers to more than double their current fuel efficiency[42] standards from 13 mpg to 27.5 mpg over the next 10 years (Yergin 1991). Sampson (1975) notes that the American public expressed bitter resentment towards the American sisters, particularly Exxon, who posted record profits[43] in 1973. Adams (2003) explains that despite these structural changes[44] U.S. oil demand had risen to new levels by 1978. In the aftermath of the fall of the Shah of Iran in 1979, these tight supply conditions and skyrocketing demand resulted in higher crude oil prices that precipitated sharp economic downturn. Oil consuming countries were at the mercy of OPEC's GSPs or administered prices during this time.

Problems of OPEC Price Administration – Economic Theory and Reality

OPEC-administered price determination differed significantly from OPEC posted price determination. The former was determined solely by OPEC governments and the latter had been previously determined by the collective action of OPEC governments and oil companies. Mabro (1984) argues that increased equity participation led to this method of crude oil price determination. The marker price system proved to be problematic for OPEC because Saudi Arabia's interests often

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[41] Much of the popular literature as well as economic theory suggest that the time lag for structural changes to take effect is usually over the long-term. Gasoline, relatively speaking, had no immediate substitutes in the early 1970s and U.S. automakers could not quickly produce more fuel-efficient vehicles. Although gasoline consumption fell somewhat, demand was relatively inelastic because of the lack of substitutes.

[42] Yergin (1991) indicates that 1 out of every 7 barrels or about 14% of crude oil produced during this time "was burned as motor fuel on America's roads and highways" (Yergin 1991, pp. 661).

[43] Sampson (1975) indicates that Exxon's profits were 81% higher in 1973 than in 1972. Gulf also posted soaring profits of 91% on the previous year. It is important to note, however, that the U.S. dollar was very weak relative to other currencies as the U.S. had recently abandoned the gold standard.

[44] Because of the "hysteresis effect" these structural changes had not fully taken place nor lessened U.S. oil demand significantly.

differed from OPEC's interest: it was not always easy to agree on one marker price. Mabro (1984) discusses the emergence of two other price concepts: the deemed marker price and the actual marker price. The former was set by OPEC and the latter was set by Saudi Arabia. From 1977 until 1981 the deemed marker price *exceeded* the actual marker price. In the absence of OPEC price manipulation these prices would have most likely been determined through the interactions of buyers and sellers of crude oil. It is important to reiterate that these prices, like posted prices, were somewhat *insensitive* to market forces of supply and demand because OPEC governments set these prices based on earning maximum oil revenues rather than market conditions. Mabro (1984) provides an intuitive explanation of the consequences of such a situation within the context of microeconomic theory.

In periods of low demand it is clear that the low-price producer will capture the largest market share, *ceteris paribus*. In a tight market (assuming all producers are at full capacity) no single producer will capture a larger market share; however, Mabro (1984) notes that this is seldom a reality[45]. Revenue losses may occur in a slack market for the producer who follows the deemed marker price but only if the "percentage reduction in exports exceeds the percentage difference between deemed marker and actual marker price" (Mabro 1984, pp. 28). In other words if exports fall due to weak demand by a larger percentage than the percentage difference in prices then the

[45] The situation of deemed marker prices exceeding actual marker prices proved advantageous for Saudi Arabia during the Iranian Revolution between 1978 and 1979. Saudi Arabia possessed excess spare capacity and increased its crude production from 8.5 mbd to 10.5 mbd following the loss of Iranian crude exports of 5.5 mbd in December of 1978 (Yergin 1991, pp. 678 – 685). As a result Saudi Arabia increased its market share (Mabro 1984, pp. 28).

producer will face revenue losses[46]. On the other hand, it may be beneficial for the high-price producer to leave the oil in the ground and save it for future use because "the present value of deferred output …is likely to be greater than zero" (Mabro 1984, pp. 28 - 29). However, the opportunity cost faced by high-price producers may be the loss of customers in the short run. In a tight market where demand exceeds supply (assuming oil demand is inelastic in the short run), the low-price producer will face losses equal to the difference between deemed and actual marker price per barrel sold (Mabro 1984). Producers facing low prices will not have an incentive to increase capacity because of high investment costs and the slow bureaucratic decision-making within OPEC. Falling oil demand in 1981 reinforced the above theories and the problems with OPEC's "dual price" system. "It all ended very painfully and very slowly" for OPEC in October of 1981 (Mabro 1984, pp. 30).

The dual price system hindered OPEC's ability to achieve orderly price administration. Facing declining oil demand in 1981, OPEC attempted price reunification, "but the rift between those countries committed to the [higher] deemed marker price and Saudi Arabia which used a lower reference price, was severe" (Mabro 1984, pp. 30). OPEC members who adhered to the higher deemed price would certainly face revenue losses if they lowered their price per barrel. Following negotiations in October 1981 OPEC members agreed to raise the actual marker price by $2 per barrel and decrease the deemed marker price by $2 per barrel (Mabro 1984). EIA data show that OPEC oil sold at a premium to both U.S. prices and other non-OPEC supplier

[46] For example suppose that the deemed marker price is equal to $10 per barrel, the actual marker price is equal to $5 per barrel, and the high-price producer's exports fall by 55%. The high-price producer would, indeed, face revenue losses since the percentage reduction of exports is greater than the percentage difference in prices: 55% > 50%.

prices in the months following these OPEC negotiations. From October 1981 to October 1983 OPEC oil sold at an average monthly premium of $1.04 to U.S. oil (Energy Information Administration 2008). For the same time period OPEC oil sold at an average monthly premium of $2.04 to non-OPEC oil (Energy Information Administration 2008).

The Iranian Revolution

While the world reeled from the effects of higher oil prices following the events of 1973, Iran experienced massive increases in crude oil revenues. This massive transfer of wealth according to Yergin (1991) was either misspent or completely squandered. Iran's crude oil revenue was "megalomaniacally misspent on extravagant modernization programs or lost to waste and corruption" and resulted in social, political, and economic[47] chaos (Yergin 1991, pp. 674). These ever worsening conditions fueled resentment towards the Shah and eventually led to his overthrow by Ayatollah Khomeini in early 1979[48]. Prior to the revolution the Iranian oil industry, among others, went on strike following the Shah's continued efforts towards "western style liberalization". As OPEC's second largest crude oil producer, Iranian crude production of 5.24 mbd accounted for 8% of total world demand of 64 mbd in 1978 (Energy Information Administration 2008). Following the initial strikes in 1978, Iran's daily production of 5.5 million barrels had fallen to less than 1 mbd by November of the same year (Yergin 1991). The loss of Iranian crude exports lasted from the end of 1978 until the autumn of 1979. Data from the EIA indicate that Iranian production fell by

[47] Specifically, inflation had skyrocketed. Yergin (1991) notes that typical government workers in Tehran spent up to 70% of disposable income on rent alone during these years (Yergin 1991, pp. 674).
[48] The complete history of the Iranian Revolution is beyond the scope of this thesis. For a more thorough treatment the reader should consult Yergin (1991) pp. 674 – 698 or other historical sources.

68% from 2.3 mbd in December 1978 to 730,000 barrels per day (68%) one month later (Energy Information Administration 2008). Crude oil prices skyrocketed by 150% even with Saudi Arabia's increase in production of roughly 2 mbd (Yergin 1991). These events reminded the oil consuming world for a second time that it was at the mercy of OPEC's administered price regime.

The 1970s were extremely significant years in the history of the oil industry. The "structural transformation" of the oil industry stemmed from the loss of access to reserves by major oil companies due to increased OPEC government participation. The major oil companies became more and more dependent on OPEC for supplies as their access to crude reserves declined (Fattouh 2007b). The vertical structure became weak and the major oil companies could no longer send enough crude downstream to meet refining requirements (Fattouh 2007b). EIA data indicate that while non-OPEC crude production increased by 29%[49] between 1973 and 1979, OPEC crude oil production remained relatively flat (Energy Information Administration 2008). Both Adams (2003) and EIA data show that OPEC crude production was approximately 30 mbd[50] in both 1973 and 1979. The concentration of both reserves and power in the Middle East combined with the oil embargos of 1973 – 1974 and the loss of Iranian production following the 1979 revolution encouraged the development of "a proper world market" for oil outside of OPEC (Mabro 1984, pp. 23). Thus the late 1970s and early 1980s are characterized by the emergence of many independent crude oil producers and the development of the spot market for crude oil.

[49] In 1973 non-OPEC production was 24.68 mbd and by 1979 it had risen to 31.73 mbd. See Energy Information Administration 2008.

[50] The EIA shows that 1973 OPEC production was 31 mbd and 30.94 mbd in 1979. See Energy Information Administration 2008.

Chapter 4

Emergence of Independent Producers and a Spot Market for Crude Oil

The most significant oil discoveries outside of OPEC territory were in the North Sea. The United Kingdom and Norway granted the first exploration licenses in 1964 and 1965 respectively and crude oil was discovered in 1969. Modest exploration and crude oil production took place during the early 1970s but by the late 1970s "hefty increases in the price of oil improved the economics of exploration and development in high-cost areas such as the North Sea" (Mabro et al 1986, pp. 1). In other words, the higher crude oil prices provided a better incentive and guaranteed a higher rate of return for time-consuming and costly investment related to exploration, development, and production. The North Sea oil fields yielded a wide variety of crudes. Perhaps the most notable North Sea crude is Brent crude. Brent is similar to West Texas Intermediate (WTI) in its gravity and low sulfur content. Brent and WTI are light sweet crudes and are good substitutes for one another in terms of refining (Adams 2003). Adams (2003) also states that North Sea crude oil markets' proximity to major consuming centers played a large role in non-OPEC suppliers capturing more of the oil market. Mabro et al (1986) provide 10 years of North Sea production data from 1975 – 1985. Production increased steadily each year from approximately 250,000 bpd in 1975 to almost 3.5

mbd in 1985[51]. Non-OPEC suppliers increased their share of world production from 48% in 1975 to 71% in 1985[52]; most of this production came from Mexico, the North Sea, and the Soviet Union (Fattouh 2006c, pp. 50). The North Sea oil supply "came about 'on line' at a time when international oil companies were scampering to acquire access to oil outside OPEC influence" and thus the North Sea spot market became "a central place in the interlocking world network of oil markets (Adams 2003, pp. 36). Facing an oil shortage, oil companies turned to the narrow and illiquid spot market following the Iranian crisis of 1979. Although spot prices[53] were initially bid up, the increase in non-OPEC supply began to have significant effects on the oil industry. Ultimately, the increase in non-OPEC supply transformed the originally oligopolistic oil industry into a more competitive one. The following paragraph summarizes three significant effects of the emergence of non-OPEC crude oil producers as discussed in Fattouh (2006c).

First, each non-OPEC supplier determined its own official price. Non-OPEC suppliers considered the OPEC marker price, other OPEC GSPs, market conditions, and "the possible reactions of major OPEC countries to their 'autonomous' pricing policies" (Mabro 1984, pp. 45). As discussed in Fattouh (2006c) these prices responded to market conditions and were essentially more competitive. The second and perhaps most obvious fact is that the number of producers increased dramatically. Each non-

[51] The data are aggregated and reflect both U.K. and Norwegian crude oil production. It is worth noting that Norway accounted for 50% of production in 1976. By 1985 however, Norway accounted for only 25% of North Sea production. See Mabro et al (1986), pp. 3.
[52] Data provided by the Energy Information Administration, cited in Fattouh (2006c, pp. 50).
[53] Mabro (1984) provides the following definition of spot price: "spot price of a transaction is the price at which a given cargo of crude oil changes hands". It is a "once and for all deal" for a specified crude amount available in one batch at a specified time. See Mabro (1984) pp. 58 – 59 or Glossary of Terms, www.nymex.com.

OPEC producer then had the freedom to adjust his price as he saw fit without consulting his competitors (Mabro 1984). In the event that non-OPEC suppliers produced more crude than required by their contract buyers, they could sell the excess crude oil in the spot market[54] at a discount price to OPEC oil (Fattouh 2006c). Thirdly, non-OPEC producers operating in the North Sea had a great advantage over OPEC producers. Transportation time for delivery of OPEC oil to European markets exceeded that of non-OPEC suppliers in the North Sea. Therefore transportation costs were generally lower for North Sea crude oil and it could arrive at its destination quicker than crude oil shipped from the Middle East. The time dimension posed some other problems for OPEC crude oil as well.

It was not uncommon for OPEC f.o.b.[55] prices to exceed non-OPEC f.o.b. prices upon expiration of a delivery contract (Fattouh 2006c). Longer delivery times can expose the contract holders to price risk. For example, a European buyer may enter into a contract to purchase OPEC crude oil for delivery in one month. The contract locks in the price, sets the loading date, and specifies the estimated date of delivery. If during the contract and delivery period crude prices fall below the contract price then the buyer will have lost money by the amount of the price difference times each barrel purchased. In other words if market prices fell lower than the agreed-upon delivery price then the buyer would end up paying more than he should have. If the buyer had bought crude in the spot market then he would not have faced any price risk. The North Sea markets

[54] Oil sold in the spot market is sold for immediate or prompt delivery.

[55] F.O.B. stands for "free on board". NYMEX defines F.O.B. as "a transaction in which the seller provides a commodity at an agreed unit price, at a specified loading point within a specific period; it is the responsibility of the buyer to arrange transportation and insurance". See Glossary of Terms www.nymex.com.

provided a hedge against the price risk associated with long OPEC contracts and contributed to increased competition in the global oil industry.

The above factors encouraged the further development of a spot market for crude oil outside the territories of OPEC. The Brent market, developed in 1981, provided a crude spot market that was more liquid, transparent, and more responsive to market forces than OPEC marker crudes. Traders, producers, refiners, and other crude oil market participants could hedge their respective risks by taking positions in the spot market[56]. The growth of the spot market as well as the other factors characterizing the economic landscape of the early 1980s led to another structural change in the world crude oil industry. Specifically the decline in world crude oil demand, expansion of non-OPEC supplies, contraction of OPEC supplies, and OPEC's adoption of netback pricing (Mabro 1986, Fattouh 2006c, Mabro 1987, and Fattouh 2007b) contributed to the demise of OPEC's administered pricing system and the oil price collapse of 1986.

Competitive Pressure – OPEC's Declining Market Power

The decline in world crude oil demand began in 1979 and lasted until 1984. Data from the EIA show that total world crude oil demand (including OPEC) was 65.22 mbd in 1979 (Energy Information Administration, 2008) and by 1984 it had fallen to 59.82 mbd; a decrease of just over 8%. In January of 1979 U.S. f.o.b. crude import prices were $14.20 per barrel. By June prices had risen to $19.75 per barrel and by the end of the year prices were just over $27 per barrel (Energy Information Administration, 2008). The high oil prices of the late 1970s "did not initiate" the decline in demand but its effects became more significant in the early years of the 1980s

[56] The development of the spot market also encouraged the development of forward markets and futures markets. These will be discussed in subsequent chapters.

(Mabro 1988, pp. 1). Rather, the high prices had the more immediate effect of encouraging the substitution of coal and gas for crude oil and "provided renewed inducements for energy conservation[57]" (Mabro 1988, pp. 1). It is important to note, however, that the substitution effect did not apply to the transportation industry. There were no substitutes for gasoline or diesel during the early 1980s whereas some industrial facilities were capable of running on both coal and fuel oil[58]. Therefore as crude oil prices went higher it became more cost-effective for industrial facilities to use cheaper coal to produce their necessary energy. However, motorists did not have such options[59] since automobiles ran on only gasoline or diesel fuel. Although demand was declining significantly, crude oil prices continued to rise[60] in the early 1980s. In January of 1980 U.S. f.o.b. crude sold for $29.27 per barrel and by the end of the year the price had risen to $34.11 per barrel (Energy Information Administration 2008). The upward trend continued through January of 1982 when U.S. f.o.b. prices rose to more than $34 per barrel (Energy Information Administration, 2008). The trend slowly began to reverse towards the end of 1982 as more and more crude oil entered the market as a result of increases in non-OPEC suppliers and decreases in OPEC production.

Non-OPEC crude oil production began a significant upward trend in 1975. Crude production of 25.73 mbd reached 32.6 mbd by 1980; an increase of almost 27%

[57] The structural changes that began following the 1973 oil crisis (i.e. fuel efficiency standards, decrease in posted speed limits on U.S. highways, etc) had begun to significantly affect crude oil demand.

[58] Fuel oil is a refined petroleum product used for home heating, industrial boilers, and utility boilers. Fuel oil is divided into two categories: distillate and residual fuel oil. Distillate is used in home heating and light industrial applications. Residual fuel is heavier and used in large industrial boilers. See Glossary of Terms. www.nymex.com.

[59] U.S. motorists in particular faced high fuel costs as many Americans relied on daily automobile use. The burden of high oil prices and therefore gasoline prices was somewhat alleviated as Japanese automakers entered the U.S. market. Toyota and Honda produced smaller and lighter cars than cars produced by Ford or GM. American consumers responded positively to these new transportation options largely due to the increased fuel efficiency.

[60] OPEC attempted to defend the marker price by cutting production a number of times but it ultimately proved to be not only unsuccessful but also disastrous.

(Energy Information Administration, 2008). By 1985, non-OPEC suppliers had increased their average daily crude production by 14% to 37.27 mbd from 1980 levels (Energy Information Administration, 2008). As noted above a significant amount of non-OPEC crude oil supplies came from the North Sea fields. Other increases in non-OPEC supply came from Latin America, Asia, and Eastern Europe[61]. According to Fattouh (2006c) and (2007b) the growth in global crude oil production was the biggest contributor to the demise of OPEC's administered pricing system. It makes economic sense that crude production from non-OPEC suppliers increased so rapidly. Naturally when crude prices exceed per-barrel production costs suppliers will expand output. The rising crude oil prices of the early 1980s provided an incentive for producers to take on costly investment to expand production capacity.

OPEC however began to feel the pressures of growing competition in the oil industry. It was clear by the mid-1980s that "the OPEC-administered oil pricing regime was unlikely to hold for long" (Fattouh 2006c, pp. 51). Saudi Arabia's attempts to defend the marker price for Arab Light became more and more difficult because upward price adjustments[62] "would only result in a dramatic reduction in its oil exports and loss of market share" as competitive non-OPEC suppliers viciously undercut OPEC's marker prices (Fattouh 2007b, pp. 4). Although OPEC countries absorbed massive income transfers during the price hikes following the Iranian Revolution, the demand for OPEC oil fell by almost half from an annual average of 30 mbd in 1979 to an annual

[61] Based on data in Adams (2003) Latin America, Asia, and Eastern Europe increased their crude production from 1974 to 1985, respectively, by 28%, 40%, and 34%. See Adams (2003) pp. 35. Calculations made by author.

[62] Saudi Arabia is often referred to as OPEC's "swing producer" in the popular literature. Saudi Arabia, relative to other OPEC members, is OPEC's largest producer of crude oil. Therefore Saudi Arabia can alter production very quickly depending on OPEC's goals *vis-à-vis* the marker price.

average of 16 mbd in 1985[63] (Fattouh 2006c). The most devastating statistic is that OPEC's own market share of world crude oil production fell from 52% in 1973 to less than 30% in 1985 (Fattouh 2006c)[64]. With falling oil revenues and declining market share Saudi Arabia turned to netback pricing as a means to restore order in the oil markets.

Netback Pricing and the Oil Price Collapse of 1986

OPEC's swing producer[65], Saudi Arabia, had the most to lose from declining market share due to competitive pressures from outside OPEC. Therefore Saudi Arabia adopted netback pricing to support its "market share objective" of mitigating further erosion of market share (Mabro 1987, pp. 4). Netback pricing replaced the existing administered price system where decisions were taken to establish a marker price. Netback pricing in and of itself is quite complex and therefore beyond the scope of this paper. However, Mabro (1987) provides a simple definition of this concept. Netback pricing values crude oil by netting costs from the value of products obtained through refining. Therefore the crude oil netback price is equal to the value of the refined petroleum product at the refinery gate minus transportation and refining costs (Mabro 1987, pp. 6). This system provided oil companies with "a guaranteed refining margin" based on a price formula equal to "*ex post* product realization minus refining and transport costs" (Fattouh 2007b, pp. 4). The guaranteed refining margin was essentially an insurance policy if crude prices were to collapse (Fattouh 2006c). Yergin (1991)

[63] These decreases were felt most heavily by Saudi Arabia whose 1980 annual production average of 9.9 mbd fell by nearly 66% to 3.4 mbd in 1985 (Fattouh 2006c, pp. 51, Energy Information Administration 2008).
[64] Fattouh (2006c) obtained this data from the EIA.
[65] Silvan Robinson (1988) asserts that OPEC gave too much decision-making power regarding production to Saudi Arabia and that "everybody else lived off the fat" (Robinson 1988, pp. 41).

notes that refiners did not have the incentive to raise or lower sale prices on refined products. Rather "[the refiner] would simply want to move as much product as he could because each additional barrel meant guaranteed additional profit" (Yergin 1991, pp. 749).

Most netback deals were arms-length deals (on the spot) in which the price of crude supplied was calculated *ex post* and specified in the netback contract arrangement *ex ante* (Mabro 1987). From a refiner's point of view, netbacks can be advantageous because they bring "long-haul crude into competition with short-haul crude" (Robinson 1988, pp. 42). In the absence of netbacks, transportation time lags can expose a refiner to price risk. Robinson (1988) says it is possible that a refiner who buys spot cargo when product prices are sufficient to cover costs can suffer losses if prices collapse during the contract period. Netback deals "reduced this risk by pricing close to the arrival date" and were priced at levels very close to Brent in order to be more competitive and increase market share" (Robinson 1988, pp. 43).

The economics of netback deals are based on trade-offs among respective economics agents: the seller (OPEC crude oil producer) and the buyer (crude oil refiner). Mabro (1987) explains that a seller's trade-off is between not knowing the price of the refined product at the time of lifting and the knowledge that crude oil is being sold at competitive prices at the time of delivery (Mabro 1987). In other words the producer faces some risk not knowing if the future refined product prices will be adequate to incentivize a potential refiner to buy netback crude. The buyer faces the trade-off of also not knowing the refined-product price at the time of lifting and knowing that the lifted crude will more than likely yield a positive refining margin

(Mabro 1987). For the buyer, his risk is not knowing the amount of the refining margin in which to make an economic decision to enter into a netback arrangement. Netbacks were developed with the idea of increasing producers' market share and "increasing the certainty of a positive refining margin" for a potential buyer (Mabro 1987, pp. 33). For these reasons it seemed logical for Saudi Arabia to promote netback deals and ultimately abandon the business of administered OPEC prices. However, "increasing volume and reduced concern about the selling price would add up to a perfect recipe for falling prices" (Yergin 1991, pp. 749).

The Saudis failed to take into account one particular risk of instituting netback deals: competition from within OPEC, itself. After the adoption of netback pricing in 1985 Saudi Arabia doubled its crude oil exports from less than 2 mbd to close to 4 mbd (Mabro 1987). Other OPEC members quickly adopted netback pricing to increase their crude oil exports as well. Netback prices were not immune from competitive pressures, however. Increased participation in netback pricing by OPEC members eroded netback prices and therefore netback contracts "lost their competitive edge" (Mabro 1987, pp. 33). This strategy was counter-productive to OPEC's overall goal of maintaining price stability. In order to defend the marker price OPEC had to constantly cut production. OPEC production fell by approximately 30% from just under 30 mbd in 1980 to less than 21 mbd in July 1986 (Energy Information Administration 2008). The results were disastrous for OPEC and the entire oil industry.

Despite OPEC's efforts to maintain crude prices at $28 – $30 per barrel, prices collapsed in mid-1986. By July 1986 crude prices had fallen to less than $10 per barrel from more than $25 per barrel a year earlier (Energy Information Administration 2008).

The 1986 oil price collapse marked yet another turning point in the history of the oil industry: crude oil prices from this point would be determined by the market. There was no longer a price-setting structure such as OPEC official prices: prices were set by "thousands and thousands of individual transactions" (Yergin 1991, pp. 751). It is clear that the adoption of netback pricing was not the only harbinger of the oil price collapse. Among the reasons listed above Mabro (1988) also emphasizes the deregulation[66] of the U.S oil industry in contributing to the price collapse, and many others attribute the establishment of the New York Mercantile Exchange[67] and International Petroleum Exchange as significant factors bringing about the price collapse.

Birth of Market-Determined Oil Prices

The years following the 1986 oil price collapse were and still are characterized by market-determined crude oil prices. This "formula pricing" mechanism specifies a marker crude (i.e. WTI or Brent) whose price is determined by the market rather than an organization such as OPEC (Fattouh 2006c, pp. 52). Exchanges such as NYMEX and IPE play a large role in facilitating marker price determination. These exchanges created a forum for buyers and sellers of crude oil to engage in price discovery and to encourage equilibrium between demand and supply. Crude oil price behavior in the market-determined system has been markedly different, however, from price behavior in the posted price and OPEC-administered price regimes. Prices have been subject to

[66] Mabro (1988) notes that deregulation under the Reagan Administration in the early 1980s "strengthened the links between the vast domestic oil market in the USA and world petroleum market". Specifically, spot and futures market trading of West Texas Intermediate and European crudes like Brent became cointegrated; each crude being influenced by price variations of the other.

[67] Oil industry deregulation resulted in the elimination of price controls that insulated the U.S. from activities in the world oil market. In 1983 NYMEX introduced a futures contract for West Texas Intermediate; a light sweet U.S. crude comparable in quality to Brent crude. This resulted in futures market trading which allowed a buyer "to acquire the right to buy the commodity at some month in the future at a specific known price" (Yergin 1991, pp. 724).

much greater volatility and uncertainty than under previous pricing regimes. *Figure 2* below shows the series of log scale prices of WTI since 1946. Clearly, the rate of change in price per barrel was relatively stable from the early 1950s until the early 1970s. The chart also shows the dramatic increase in prices following the first oil embargo in 1973. Finally, the chart shows the collapse of oil prices in 1986 and the subsequent period of volatility.

Mabro (1988) notes that crude oil prices remained fairly stable under both the concession system and OPEC period because oil companies and OPEC each performed a price-stabilizing role. During the concession system oil companies responded to changes in demand by "varying almost automatically the extraction rates from their Middle Eastern fields" (Mabro 1988, pp. 2). The vertically integrated structure of the oil industry facilitated such responses. During the OPEC era excess supplies were "absorbed fairly passively by OPEC member countries" as demonstrated following the first and second oil shocks of the 1970s (Mabro 1988, pp. 2). This power was short-lived of course as OPEC lost its ability to maintain crude oil prices during the oil price collapse of 1986. Today crude oil prices are extremely volatile and often destabilizing. This is clear evidence that there are a number of other factors involved in the determination of crude oil prices.

Conclusions

In order to understand the current pricing mechanisms of the oil industry it is paramount to understand some aspects of its complex and capricious history as detailed above. Under the concession period from the early 1920s until the early 1970s the oil industry was characterized by a very small handful of firms who behaved in many ways like a cartel. The Seven Sisters dominated the world oil industry for so many years largely because of their ability to collude on price fixing and their ability to mostly restrict smaller independent oil companies from accessing Middle East oil reserves. The vertically-integrated and oligopolistic oil industry under the Seven Sisters allowed for the emergence of another non-competitive dominant player: OPEC. OPEC's dominance during the 1970s and early 1980s was the result of highly concentrated crude oil supplies in the Middle East, increasing world crude oil demand, and the inability of the vertically integrated majors to supply enough crude oil to support downstream refining. The emergence of independent producers, development of oil reserves outside OPEC, and the growth of the crude oil spot market led to the demise of OPEC's administered prices and the oil price collapse of 1986.

Posted prices purported to indicate some idea of the supply and demand balance but they were really fiscal parameters used to determine tax revenues and royalties paid to producing countries. Posted prices failed to provide an allocative role as economic agents could not glean any information regarding the scarcity of crude oil and therefore could not make accurate maximizing decisions. OPEC GSPs or administered prices also failed to provide accurate supply and demand information. Administered prices were determined solely by producing governments based on a country's oil reserves. OPEC's attempts to defend a specific price range by increasing or decreasing production was successful during the oil shocks of the 1970s but the increase in non-OPEC oil supplies in the 1980s led to the collapse of the administered price system. Increased competition from outside OPEC reinforced the idea that the market will always prevail in a flawed system. The market-determined price regime, although highly imperfect, responds well to market forces of supply and demand and provides relatively good information regarding crude oil scarcity. Economic agents are better equipped to make individual maximizing decisions because crude oil prices mostly reflect the supply and demand balance. However, market-determined crude oil prices also have their own set of complications.

Since 1986 market-determined crude oil prices have been subject to wild swings and great volatility. During the concession era crude oil prices were relatively more stable than they have been for the past 22 years. Price volatility following the end of the OPEC-administered price regime to the present indicates that there are other factors that affect crude oil prices. There are a variety of supply and demand factors as well as futures market factors which may have significant effects on crude oil prices. The following chapters will examine some of these factors and provide data to illustrate their effects on crude oil prices.

Section II

Introduction

The following chapters will provide a detailed analysis of some of the drivers of crude oil prices over the period beginning January 2002 to December 2007. I will also provide an analysis of the current oil market situation as well as address implications for the industry. My selection of the period 2002 – 2007 is based on a number of factors. 1). While WTI spot prices have exhibited strong volatility since the oil price crash of 1986, the price trend turned sharply upward in 2002 and continued to the end of the series[68]. 2.) The Energy Information Administration provides current data as much as possible but some variables are estimated until such time that they can be finalized. Therefore some crude oil data are published with a significant lag relative to other data. This section will analyze data through December 2007 because at the time of my analysis 2008 data were not yet finalized. 3.) I believe that WTI spot price behavior can be clearly explained based on fundamental economic concepts and future expectations regarding these concepts. 4.) Oil price data from 2008 to the present became available as I completed my analysis of 2002 – 2007. In order to be thorough I will provide a brief analysis of the current period in the global oil market and assess the implications for the oil industry.

[68] Since undertaking this study, crude oil prices increased further to as high as $147 per barrel and subsequently declined to less than $40 per barrel. I will touch upon these facts but the main focus will be the price increases during the stated period.

Chapter 5

Physical and Chemical Properties of Crude Oil

Contrary to conventional wisdom, crude oil is not necessarily a homogeneous commodity (Mabro, 2006). Crude varieties differ by physical properties, chemical properties, and geographical region. Generally, crude oil falls into two categories: heavy/sour and light/sweet. Heavier crude varieties such as Arab Heavy contain a higher percentage of sulfur and other hydrocarbons that make refining more difficult and more costly (Energy Information Administration 2008). Petroleum products refined from heavy crude are usually lower-value products and heavy-crude-refineries typically face higher costs due to the need for more frequent maintenance. Light crude varieties such as West Texas Intermediate and Nigerian Bonny Light contain lower percentages of sulfur and hydrocarbons. When refined, these crudes yield gasoline, jet fuel, and other distillates that are commonly used by consumers worldwide. API Gravity Index measures sulfur content which determines whether the crude is light/sweet or heavy/sour. A higher API indicates low sulfur levels and therefore a lighter crude variety. A lower API reflects higher sulfur content and therefore a heavier crude variety.

Since there are many crude varieties, similar crudes are often priced according to a benchmark crude such as West Texas Intermediate or Brent crude (Energy Information Administration 2008). Because of its high quality, relatively higher API gravity index, and demand for its refined petroleum products West Texas Intermediate serves as the world's benchmark crude. Also, the New York Mercantile Exchange (NYMEX) asserts that WTI futures contracts are the most widely traded and most liquid contracts (Moebert 2007). Additionally, "a model explaining a particular oil grade is directly transferrable to other oil grades as well" (Moebert 2007, pp. 3). It therefore seems plausible that examining the price dynamics of the benchmark crude, in this case WTI, we can gain some insight into the price dynamics of other crudes.

Selection of Variables and Hypotheses

From *Figure 3* one can easily see how WTI spot price trend has been subject to great volatility since 1986 and only recently has followed a deterministic upward trend. However, simply examining the price trend over time does not provide any indication about crude oil prices in the future. As noted in the introduction to this paper there are a number of supply, demand, and futures market variables that are believed to have significant effects on oil price and that may have contributed to the incredible price increases from 2002 – 2007. Researchers including Moebert (2007), Fattouh (2007a), Dees (2008), and Mabro (2006) conducted rigorous econometric studies of oil prices and analyzed specific variables to address reasons for oil price volatility. In order to assess the influence of these variables on oil prices I will utilize the findings of these and other authors, analyze the behavior of each variable relative to oil prices over time, and determine whether or not standard arguments from economic theory can sufficiently explain the behavior of the variables and oil prices.

As shown in *Figures 4*, *5*, and *6* below spare production and refining capacity have significantly decreased in recent years. As spare capacity falls, crude oil producers and refiners operate closer and closer to full capacity. Given long lead-in times, high costs, and financing constraints it is impossible for producers and refiners to augment existing capacity in the short run. Therefore, as firms operate at or near full capacity there is higher a probability of production and refining bottlenecks if there is an exogenous shock that either reduces supply or increases demand. I therefore hypothesize that higher levels of capacity utilization, both upstream and downstream, will tend to put upward pressure on prices and create volatility.

Petroleum stocks are represented by a variable known throughout the literature as days of forward supply. As petroleum stocks increase days of forward supply also increase. Days of forward supply represent the number of days that a country can supply its industries given current demand without access to crude oil imports. Following the oil embargoes in the 1970s many industrialized countries dependent on Middle East Oil imports established strategic petroleum reserves to supply their markets in the event of adverse supply shocks. As days of forward supply increase and therefore stocks increase, I hypothesize that market participants perceive these actions as increases in supply. Any increase in supply above and beyond demand will put downward pressure on prices, *ceteris paribus*.

When a buyer purchases crude oil for immediate refining purposes he purchases it on the spot or at arms length. However, the buyer may not actually receive the crude oil shipment for a month or even two months depending on distance from the production source, mode of transport, or shipping delays in the midstream sector. Therefore, a crude oil buyer may purchase oil at a price today for delivery in the future. Prior to the establishment of futures contracts this type of transaction involved significant price risk. For example, a buyer may agree to buy oil at price X for delivery in 1 month but during the delivery time oil prices may have fallen to $X – Y$ where $X > X – Y$. In other words, a refiner would have lost money on his purchase since refined product prices are derived from crude oil prices. Liquid futures contracts allow buyers of crude oil to hedge against price movements and can therefore mitigate losses due to adverse price movements. In order to trade in futures contracts, futures prices were introduced to provide information and price discovery for future oil deliveries.

Both spot and futures prices provide some information about what the market perceives regarding supply and demand. Periods where spot prices exceed futures prices indicate that it is more profitable for producers to sell oil now rather than storing it for the purposes of selling in the future. Such a period may also indicate that current demand is greater than expectations of demand in the future. It may also indicate that the market thinks that future supplies will be adequate to meet demand. Conversely when futures prices exceed spot prices it may be profitable to store crude oil today with the intention of selling it for a profit in the future. Higher futures prices may also be an indication that demand expectations are higher in the future. It can also mean that the market perceives a supply shortage where oil may be dearer and therefore command a higher price in the future. Therefore, I hypothesize that spot prices will rise during periods when futures prices exceed spot prices. Additionally, if market participants expect prices to be higher in the future then this will encourage stock accumulation because waiting to purchase oil may be costly. Higher futures prices also encourage stock accumulation because those with storage capacity can purchase oil today in the cheaper spot market and sell the oil at a higher price in the future. Therefore, I also hypothesize that stocks will increase during periods when futures prices exceed spot prices and when both are rising.

It is also important to analyze OPEC's role in crude oil price determination. OPEC typically accounts for 40% of the global market and therefore has significant impacts on global oil prices. In the early 1980s OPEC adopted a quota system in which the swing producer, Saudi Arabia, attempted to set production limits for each member based on their reserves and production capacity. It is not a coincidence that Saudi Arabia has the largest spare capacity and the largest known reserves. The popular literature suggests that OPEC sets production quotas based on their price goal: OPEC will cut production if they perceive falling oil prices or they will increase production if prices are too high. These production methods work well with basic supply and demand concepts of economic theory. However, in reality OPEC behavior is far from the simplicity of the static supply and demand model. As crude oil prices increase, OPEC members may have an incentive to cheat on their assigned quotas by producing more crude in order to maximize revenue gains. While Saudi Arabia does not always effectively enforce member quotas, the kingdom has the capacity to punish cheating members by utilizing excess spare capacity to also overproduce. As OPEC supply increases, crude prices will fall resulting in revenue losses for cheating members. OPEC therefore favors high oil prices as it generates higher revenues and, as noted above, crude oil demand is relatively price inelastic in the short run. The popular literature also suggests a back-bending OPEC supply curve. If this is the case then it seems clear that OPEC attempts to artificially fix crude prices through production quotas and other non-market mechanisms. I hypothesize that OPEC production is positively related to prices and that production will increase with higher prices. However, I also think that examining the data will indicate a back-bending OPEC supply curve.

Finally, macroeconomic fluctuations and therefore crude oil demand certainly affect prices. Crude oil is a major input to production for most industrialized economies. Therefore as economies expand there should be proportional increases in demand for oil. In theory as demand increases, crude oil prices will rise but gains to income and GDP may offset the increases in prices and therefore have no negative effects. In reality, however, crude oil demand for developed OECD countries has been relatively flat while crude oil demand from emerging economies such as China and India has increased significantly in recent years. As these emerging economies capture larger global market share and demand Western lifestyles, their crude oil consumption will continue to increase. Additionally, there are growing middle classes in these two countries which most likely contributes significantly to the shift towards Western lifestyles and therefore greater crude oil demand. I believe that rapidly rising oil prices in recent years can be partially attributed to growing demand from developing economies such as China and India. However, it is also important to analyze how demand has behaved in relation to prices.

Given short run price inelasticity of demand, price increases may not have as large a negative effect on demand. It is also possible that due to the lack of available substitutes for crude oil, particularly in the automobile industry, large price increases are somewhat sustainable in the short run. In other words, crude oil and gasoline consumers do not have much choice or sufficient substitutes when oil prices are high.

Also, contrary to conventional wisdom, when oil prices are low due to supply exceeding demand, Say's law may not hold as oil consumers will most likely not increase consumption when prices are low (Fattouh 2007a). Therefore, I hypothesize that, consistent with economic theory, increases in demand will put upward pressure on prices. However, I also hypothesize that after examining crude oil demand data, demand will not exhibit significant fluctuations due to high or volatile oil prices.

Assumptions

In order to provide an intuitive and simple explanation for the recent increases in crude oil prices I will make the following assumptions:

- *Short-Run Price Inelasticity:* $e_{Q,P} = \partial Q/\partial P \cdot (P/Q) < 1$

Studies by Dahl (1993) and Cooper (2003) computed elasticities for crude oil in both developing and OECD countries. Both studies found short-run price elasticity of demand to be extremely low. Dahl (1993) determined the short-run price elasticity was -.07 and Cooper (2003) found the price elasticity to be approximately the same, -.05, ten years later. Clearly, according to these studies crude oil demand is extremely price-inelastic in the short run. This simply means that given a change in price, crude oil demand will change by a smaller percentage than the percentage change in price, *ceteris paribus*. In other words, crude oil demand remains fairly stable in the short-run given a price change. It is also worth mentioning that price elasticity is small for automotive fuels but higher where oil has substitutes (Mabro 2006).

- *Crude Oil is a Normal Good:* $e_{Q,I} = \partial Q/\partial I \cdot (I/Q) > 0$

Crude oil demand and GDP show strong positive correlation over time indicating that periods of higher GDP growth are associated with increasing crude oil demand. This makes economic sense because crude oil is a major input to production. It stands to reason that as industrial production levels increase, the need for crude oil (or refined crude oil products) also increases. More specifically, as personal income increases consumers will purchase more crude oil products according to conventional wisdom. Dahl (1993) found long-run crude oil income elasticity of demand to be 1.32; fairly consistent with what theory indicates the income elasticity of a highly-desired good (with very few substitutes) should be[69]. However, Hamilton (2008) found that income elasticity has fallen somewhat to .47. Additionally, Mabro (2006) notes that price elasticity is small for automotive fuels but higher where oil has substitutes. Although the reasons for this fall in income elasticity are beyond the scope of this paper, I will assume throughout that income elasticity is positive and therefore that crude oil is a normal good.

- *Lack of Short-Run Substitutes*

In recent years there has been a shift towards cleaner and environmentally-friendly energy sources. Markets for ethanol and other biofuels may, indeed, expand in the near future but in the present gasoline will face very little competition. This is simply because refined products such as gasoline have few, if any, substitutes. The EIA indicates that oil refineries refined over 21 mbd of gasoline and almost 24 mbd of distillate fuel oil in 2005 (Energy Information Administration 2008). These two products accounted for half of all the refined crude products in 2005. The majority of automobiles run on unleaded gasoline and distillate fuel is a component of home heating oil and industrial applications (New York Mercantile Exchange 2008). While

[69] Again as noted in Mabro (2006) price elasticity is low where there are few substitutes such as gasoline and higher where there are crude oil substitutes.

coal is an energy source, coal is primarily used to generate electric power and therefore is not a good substitute for crude oil and refined products. Additionally, nuclear energy is not a good substitute for crude oil at this point in time because there are strict federal and environmental regulations on the production and usage of nuclear energy.

Chapter 6

Spare Capacity – Upstream and Downstream

There are 3 components of production in the crude oil industry: upstream, midstream, and downstream. The upstream sector produces or extracts crude oil from sources such as the ground, seabed, or oil shale. The midstream sector consists mainly of transportation such as oil tankers, trucks, pipelines, and other methods of transporting crude oil. The downstream sector refines crude oil into useable products such as gasoline, jet fuel, and heating oil. Therefore refineries make up the entire downstream sector of the oil industry. In this section I will examine the role of spare capacity in both the upstream and downstream sectors. While the midstream or transportation sector is indispensible to the oil industry, a thorough analysis is beyond the scope of this paper.

According to the EIA, the United States typically ranks as one of the world's top three crude oil refiners (Energy Information Administration 2008). As of 2007, the United States' crude oil average refining capacity was over 17 mbd. To put this into perspective, the US accounts for 20% of the world's crude refining and almost 40% of OECD countries' refining capabilities (Energy Information Administration 2008). The United States is in a very advantageous position because unrefined crude oil is virtually worthless; the ability to produce usable products such as gasoline, jet fuel, and heating oil is what makes crude oil so valuable. Refining capacity, or more specifically spare refining capacity, is a very important determinant of crude oil prices. Spare production capacity is also important because the ability of refiners to refine crude oil is dependent on the ability of crude producers to extract crude oil from the ground. According to Fattouh (2006a) both spare production and refining capacity have eroded significantly over the last few years. This has important implications for crude oil prices: lack of spare capacity makes crude oil price spikes more likely in the event of a major supply disruption and increases the potential for downstream refining bottlenecks. In essence, spare capacity and crude oil prices should have an inverse relationship: periods of low spare capacity result in higher prices and periods of sufficient spare capacity result in lower prices. Morse (2006) and Fattouh (2006a) provide data to support this hypothesis. Before examining the time series data let us first turn to some basic concepts of economic theory to determine the validity of this relationship.

In the supply and demand framework a rightward shift of the supply curve indicates an increase in supply. As the supply curve shifts outward, the equilibrium price will fall, *ceteris paribus*, as quantity demanded increases to absorb the increase in supply. In the context of crude oil this simple model seems to work well in the short-run. However, in reality the crude oil market does not operate in such a static fashion. While an increase in supply may reduce spot prices initially, it is important to assess capacity utilization. In general as production increases to capacity levels the market may perceive an over-supply in the short-run, but these expectations may be superseded by fears that producers may not be able to meet future demand or adequately augment production to make up for lost production in the event of adverse supply shocks.

As supply increases, *ceteris paribus*, capacity utilization increases; that is producers utilize a larger portion of their production capacity. If a producer does not increase his production capacity at a rate greater than or equal to the increase in production then it is likely that the producer may not be able to meet future demand resulting from an adverse supply shock or an exogenous increase in demand. Fattouh (2007a) observes that during the 1980s and 1990s "OPEC's spare capacity, chiefly that of Saudi Arabia, helped offset large demand and supply shocks" (Fattouh 2007a, pp. 143). During this same period crude oil prices hovered near historical lows as the emergence of non-OPEC producers helped promote a large spare-capacity cushion. The tradeoff to this scenario is that when oil prices are low producers have little incentive to expand capacity; especially when expectations indicate low prices in the future due to flagging demand. Additionally, the IMF and EIA argue that "the erosion of spare capacity has been the result of world-wide underinvestment in the oil sector" (Fattouh 2007a).

The downstream refining sector is subject to the same results of diminishing spare capacity as the upstream production sector. As refining margins are squeezed due to falling demand and falling oil prices (also gasoline prices) a typical refiner has little incentive to add capacity to current production levels. In periods of higher prices and higher demand for refined petroleum products refiners and producers, indeed, have an incentive to add capacity because the revenue streams may exceed the costs of adding additional capacity. However, holding surplus capacity is costly and "cannot be fully activated at the drop of a hat" (Mabro 2006, pp. 7). In other words, producers and refiners may not be able to ascertain whether a price increase is temporary or permanent. If either a producer or refiner perceives a price increase as temporary he will most likely not add to existing capacity. By the time he raises the necessary financial capital, installs the additional capacity, and employs the new capacity the price trend may have already fallen back to the original level. If a producer or refiner perceives the price increase as permanent then he may be more inclined to take on additional investment to add to capacity. However, it is difficult to determine whether or not periods of sustained higher prices are permanent or transitory. Dees et al (2008) argue that refiners are reluctant to operate at lower rates of utilization because “fixed costs of production are very much greater than operating costs” (Dees et al 2008, pp. 12). In other words refiners have an incentive to expand capacity or utilize existing capacity when the marginal revenue per barrel exceeds fixed costs. The real problem however, is that at high levels of capacity utilization, refiners may be unable to meet demand for refined petroleum products given exogenous events such as refinery outages due to destructive weather.

One example of how low spare capacity in the refining sector can exacerbate price spikes and volatility is the loss of refining abilities in the US following Hurricanes Katrina and Rita in 2005. Mabro (2006) notes that while disasters such as the back-to-back hurricanes are not the cause of under-investment in the refining sector, they “graphically revealed the vulnerability of the system” (Mabro 2006, pp. 8). Because of long lead-in times and general uncertainty of future price levels “relief in the short-term cannot be expected” (Mabro 2006, pp. 7). It should be emphasized that in a short-run static supply and demand model, a leftward exogenous shift of the supply curve may not have a negative effect on demand; particularly when short-run demand has been empirically shown to be very price-inelastic[70]. Dees et al (2008) observe that "as capacity utilization rises beyond normal operating conditions and supplies become tight, inelastic demand implies that large price increases are needed to bring utilization rates back to the normal range" (Dees et al 2008, pp. 13). In other words, only large price increases may result in decreases in demand. This is counter-intuitive to conventional wisdom regarding price inelasticity; however Morse (2006) argues that in 2005 gasoline prices spiked following refinery outages and demand fell significantly in the wake of Hurricane Katrina. Furthermore, Morse (2006) explains that "when price impacts demand, demand is not destroyed but suspended and will return" (Morse 2006, pp. 13).

Figure 4 below shows refining capacity against crude oil production from 1970 – 2005. It is clear that since the early 1980s spare refining capacity has shown almost a 0% net-change. Also, as refining capacity fell, world crude oil production increased significantly from 1986 to the end of the series. Fattouh (2006d) cites a number of implications that can result when low spare capacity becomes a major market force: accelerated rise in average oil prices, increase in volatility, and frequent price spikes (Fattouh 2006d). Let us now examine these conjectures in the context of the available data.

Figure 5 shows the erosion of spare refining capacity from 1995 – 2005 relative to world demand. Clearly in 2004 crude oil demand exceeded refining capacity. According to Fattouh (2006a) these downstream bottlenecks blunt the global system's ability to respond to shocks. In 2004, the refining sector began to feel constraints as spare refining capacity was almost negative 1 mbd. In other words, the world produced

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[70] See Dahl (1993) and Cooper (2003). Both studies concluded that short-run price elasticity of demand (among both OECD and developing countries) was extremely low: -.07 and -.05, respectively.

1 mbd more than could be refined without delay. *Figure 6* provides another picture of how spare refining capacity has gone into negative territory in recent years. *Figure 7* is testament to the claims that diminishing spare capacity has a significant impact on price per barrel. The data indicate that in 2004 and 2005 (when spare refining capacity ventured into negative territory) crude oil prices increased at a greater rate than in the previous years. This conjecture is further supported in Morse (2006) who indicates that "lack of supply cushions mean that upward price pressures persist" (Morse 2006, pp. 5). Additionally, bottlenecks resulting from demand exceeding refining capacity also have been shown to create further upward pressure on prices. From *Figure 5* below, demand for crude oil exceeded daily refining levels in both 2004 and 2005. Moebert (2007) shows that as demand exceeded refining capabilities, this "supply scarcity" of refined petroleum products put further upward pressure on prices and contributed to the recent crude oil price increases (Moebert 2007, pp. 21). Moebert (2007) further reinforces that downstream bottlenecks give rise to crude oil price increases when refining utilization approaches 100%. Furthermore, Dees and Kaufmann et al (2007) show in an econometric model that increases in refinery utilization rates have a positive impact on crude oil prices.

Using annual price and spare capacity data from 1986 – 2005 provided by the EIA, I constructed a simple scatter plot to highlight the inverse relationship between spare capacity and crude oil spot prices as shown in *Figure 8*. Clearly, when spare capacity is low or negative, prices tend to be high. The estimated regression line illustrates the negative relationship. Additionally, a Pearson correlation coefficient of -

.67 corroborates that there is strong negative correlation between spare capacity and price.

Diminishing spare capacity has been empirically shown to have a positive impact on crude oil prices. Predictions from economic theory are also consistent in explaining the inverse relationship between spare capacity and prices. However, spare capacity only partially explains the recent run-up in prices. I will now turn to the role that stocks and futures markets play on crude oil prices.

Chapter 7

Stocks, Strategic Petroleum Reserves, and the Futures Market

Crude oil stocks (also called inventories) represent extracted crude oil available for immediate shipment to refineries, tankers, or pipelines. Countries with storage capacity can quickly release crude to supply their markets in periods of low supply or high demand. In early 1986 the OECD held 3.3 billion barrels of crude oil stocks. Today, OECD crude oil stocks total almost 4.5 billion barrels and the US alone accounts for nearly 25% of the world's stocks; most of which are strategic reserves (Energy Information Administration 2008). The Arab Oil Embargo in October 1973 prompted the US and other crude oil importing nations to establish strategic reserves "as a buffer against severe supply disruptions" (Energy Information Administration 2008).

Moebert (2007) uses OECD stocks to create a variable called days of forward supply. Days of forward supply is an estimation of the number of days that a country can function using its own oil stocks given current demand. This variable indicates an importing country's independence from supply shocks and actions by OPEC (Moebert 2007). In other words, given an exogenous supply shock such as an embargo or loss of upstream production a country can tap into their reserves for a certain number of days in order to not further disrupt other sectors of the economy that rely on crude oil as an input to production. Dees et al (2008) found an inverse relationship between days of forward supply and crude oil prices: as the number of days of forward supply increase there will be a negative effect on crude oil prices. Perhaps, higher stock levels represent a psychological component that tends to keep crude oil prices low or at least stable. Markets may, indeed, view higher stock levels as an extra supply cushion and therefore be less worried about supply disruptions. Accumulating stocks in such a fashion can best be described as the precautionary demand component of crude oil consumption. Dees et al (2007) indicate that "individuals who hold stocks do so to avoid the risk of a disruption" (Dees et al 2007, pp. 19).

In economic theory an increase in stocks can be viewed as an increase in supply. It stands to reason that as stocks increase there would tend to be a negative effect on crude oil prices. As stocks increase there would be less reliance on current production which reduces the risk of higher prices due to supply disruptions (Moebert 2007). Therefore, an increase in stocks should have a negative effect on prices. Additionally, an increase in stocks may send signals to economic agents that markets are well-supplied or even over-supplied given current demand and therefore crude prices should fall, *ceteris paribus*. In the well-known supply and demand framework an increase in stocks shifts the supply curve to the right which causes the equilibrium price to fall, *ceteris paribus*. However, as indicated in Moebert (2007), this static analysis may not always hold. As crude oil stocks increase and prices fall, this may have a stimulative effect on demand therefore putting upward pressure on prices (Moebert 2007). However, as I discussed above the short-run price inelasticity of crude oil may limit short run demand increases due to a reduction in price. Moebert (2007) finds that the opposite may be true as well: as stocks decline this will have the effect of putting upward pressure on prices therefore reducing demand. However, Fattouh (2007a) does not agree with this analysis. While a build-up of crude stocks may be perceived as a sign of oversupply in the market, oil consumers "are under no obligation to absorb the oversupply from oil producers" (Fattouh 2007a, pp. 147). In other words, Say's Law does not hold: supply, in this case, does not create its own demand (Fattouh 2007a). Again, short-run price inelasticity of demand inherent to crude oil may prevent any large changes in demand resulting from a price change.

Regarding precautionary inventories, it does not make economic sense that agents with storage capacity would arbitrarily hold crude inventories for the sole purpose of quickly supplying the market following a supply shock. Petroleum Argus argued in 2006 that the crude oil markets indicated "just-in-time inventories are no longer appropriate" since OPEC's production capacity had declined significantly. (Fattouh 2007a, pp. 147). This implies that it is economically beneficial to store crude oil for future sale and delivery. Fattouh (2007a) disagrees with this assertion due to the fact that holding inventories is costly and therefore this approach to inventory goes against corporate goals of maximizing shareholder value. In other words, lower revenues resulting from lower oil prices may not be adequate to cover the costs of holding inventory. Thus, practices that increase costs and reduce revenues do not tend to maximize shareholder value. Furthermore, Fattouh (2007a) argues that oil companies rely on OPEC's crude holdings, strategic petroleum reserves, and the spot market for immediate deliveries. According to Fattouh (2007a) a more plausible explanation for the recent build-up in inventories is due to the term-structure of oil prices: the dynamics of spot and futures markets.

Before examining the role of futures market activity I will first provide an analysis of stocks and crude oil prices. From economic theory, one would expect that an increase in stocks will have a negative impact on price, *ceteris paribus*. *Figure 9* shows the time series of spot prices and stocks from January 1986 to December 2007. From the chart it is clear that periods of increasing stocks were associated with falling prices. For example, in April 1997 WTI spot prices were $19.70 per barrel and OECD crude stocks were approximately 3.8 billion barrels. Over the subsequent 18 months WTI spot prices fell to as low as $12.51 per barrel and OECD stocks increased to over 4 billion barrels. The data seem to support the theoretical economic propositions. However, the term structure of oil prices may provide a better explanation. As the East Asian financial crisis deepened well into 1998, the global economic downturn put downward pressure on crude oil demand as the crisis affected not only the East Asian countries but also Russia and Brazil as well. The expectation of a worldwide contraction at the time of the crisis and into the foreseeable future reduced demand for crude oil and therefore spot prices. Following the aftermath of the East Asian financial crisis in 1999, the crude oil market entered a period when spot prices exceeded futures prices for nearly 2 years until October 2001. In fact, the spot and futures market showed some divergence in terms of cointegration during this period (Moebert 2007). Generally, spot and futures prices follow the same trend although there is usually a marginal difference, or spread, between the two as shown in *Figure 10* below.

During periods when crude spot prices exceed futures prices the market is said to be normal or in *backwardation*. Conversely, in periods when futures prices exceed spot prices the market is said to be in *contango*. According to Litzenberger and

Rabinowitz (1995) the crude oil market is in backwardation 80 – 90 percent of the time; or the oil forward curve is normal (spot prices exceed futures prices). *Figure 11* below illustrates periods of market contango and backwardation. Positive regions of *Figure 11* indicate periods of backwardation (i.e. $S_t > F_t$) and negative regions indicate periods of contango (i.e. $F_t > S_t$). During periods of backwardation, crude oil producers have a stronger incentive to extract and sell crude oil because "ownership of reserves represents a call-option" (Fattouh 2007a, pp. 147). In other words, crude oil producers will want to produce and sell oil in the present when prices are higher rather than in the future when prices are lower given market backwardation. Additionally, given costs to storing crude stocks, it does not make economic sense for a producer to extract crude, hold it in storage, and sell it in the future at a lower price. Therefore the oil market backwardation will persist. In other words, "weak backwardation is a necessary condition for current production" (Fattouh 2006c, pp. 87). Therefore during periods of backwardation, economic agents with storage capacity will not accumulate crude oil inventories. Fattouh (2007a) also notes that oil producers have the incentive to leave the oil in the ground and sell it in the future if futures prices exceed spot prices or when the market is in contango. "If discounted futures prices are higher than spot prices and if extraction costs grow by no more than the interest rate, then all producers have the incentive to defer production and leave the oil in the ground" (Fattouh 2006c, pp. 87). This strategy will put upward pressure on spot prices if every producer defers production to avoid storage costs.

Hamilton (2008) provides a simple model to illustrate storage arbitrage and how futures markets can affect spot oil prices. Imagine there is an investor with crude oil storage capacity who is considering borrowing money to purchase Q barrels of oil. Assuming that the investor will also pay storage costs for storing the crude oil, C_t, and that he also pays interest on his original loan, i_t, then the investor will profit from storing crude oil today if

$$P_{t+1}Q > (1 + i_t)(P_t + C_t)Q.$$

Making such a bet requires examining future expectations. If it were the case that drilling rigs were expected to go offline in the future for maintenance then it is quite possible that futures prices will exceed spot prices and the investment would be profitable, *ceteris paribus*. The reasoning behind this is that a decrease in production capacity relative to current demand (i.e. less drilling rigs extracting less oil) may send signals to market participants that the oil industry is less capable of supplying adequate amounts of oil following an exogenous shock. However, if a new oil field was discovered today and it was expected that active production will take place in the future then this investment may not be profitable. The reasoning is that oil market participants may perceive new production as an increase in supply and therefore conclude that the oil industry is more equipped to augment production in order to mitigate the risk of exogenous supply shocks.

Clearly, most people do not have the capabilities of storing crude oil. The alternative is to enter into a futures contract where an investor agrees to buy oil at some point in the future at a certain price that he and the other party agree upon today. In the event that an investor agrees to buy oil in the future at price F_t, then he will make a profit whenever $F_t < P_{t+1}$ because he can sell his contract to another investor at P_{t+1} any time before the expiration of his contract. Therefore it is clear from this example that spot and futures prices tend to follow the same price path. Time series data also corroborate this claim as shown in *Figure 10* below. As mentioned above, expectations about the future may move the market into contango or backwardation. Again, the market is in a contango when $F_t > S_t$ and the market is in backwardation when $F_t < S_t$. As shown in *Figure 11* below the oil market is generally in backwardation or under normal conditions. While it is generally accepted that futures prices tend to cause spot prices, let us now examine another model to show how causation may run the opposite direction.

A number of researchers including Carol Dahl of the Colorado School of Mines introduce a variable called convenience yield. Convenience yield is a non-financial or non-pecuniary benefit to holding crude oil inventories. Dahl (2004) explains that inventories can be used to offset unexpected increases in demand or augment supply when conditions become tight. Clearly, when oil is dearer it will command a higher price and therefore holding inventories will be a profitable endeavor (see Hamilton's equation above). In the following equation, Dahl (2004) subtracts the convenience yield from storage costs to further elucidate the relationship between spot and futures prices. In the equation,

$$F_t^T = S_t e^{(r + \mu - \delta)(T - t)},$$

F_t^T indicates the future price at time t for delivery at some time T in the future, S_t is the spot price at time t, r is the interest rate associated with cost of borrowing, μ is the cost of storage, and δ is the convenience yield to holding inventories.

If the convenience yield of holding inventories is smaller than storage and interest costs, given by

$$r + \mu > \delta,$$

then the market will be in contango where futures prices are greater than spot prices. This means that inventories are high and that holders of these inventories do not anticipate supply shortages in the short term. In this case, holders of oil inventories do not anticipate having to sell portions of their stock to satisfy demand or augment supply shortages in the short run. Therefore the convenience yield to holding crude stocks in the short term falls; which increases the future price. If convenience yield is greater that the sum of interest and storage costs, given by

$$r + \mu < \delta,$$

then the market will be in backwardation or spot prices exceed futures prices. In this case, inventories will tend to be low. When spot prices exceed futures prices this is an indication that current demand for crude oil exceeds current supply. Therefore, higher demand now commands a higher price than selling oil in the future. Given a supply or demand shock, the benefits to holding oil inventories will be much greater in the short term as inventory holders can easily sell their oil for a higher price now than in the future. As we can see, supply and demand balances now and expectations of future balances have a significant effect on convenience yield and therefore futures and spot prices.

The following provides a real example of how spot and futures prices are affected by convenience yields. The reader will recall from Chapter 4 that Saudi Arabia adopted netback pricing in 1985 to mitigate loss of market share and falling oil prices which therefore led to the oil price collapse of 1986. As inventories rose, this signaled to market participants and futures contract traders that the market was, indeed, well if not over-supplied. As spot prices fell following large supply increases, convenience yields also fell. Historically low spot prices encouraged accumulation of inventories (albeit not increases in demand for consumption purposes). As OPEC scrambled to reach a production agreement in March of 1986, convenience yields fell again and averaged $.03 per barrel for the next 2 years (Dahl 2004). As markets tightened in 1988 following OPEC's decision to cut production, both spot prices and convenience yields rose. It is also worth noting that the impacts of OPEC's production decisions are contingent upon market participants' "understanding of their implications and their perceptions about the credibility of the policy" (Fattouh 2006c, pp 91). In other words, OPEC production decisions are often ambiguous and may be interpreted in different ways by oil market participants and therefore have different effects on spot and futures prices.

Economic theory also provides sound explanations for the above concepts of convenience yields, spot prices, and futures prices. Dahl (2004) and Mabro (2006c) indicate that energy futures enhance price discovery through price transparency and the providing of information regarding future expectations. Therefore, we arrive at the efficient market hypothesis described in Dahl (2004) which indicates that spot prices are a function of futures prices and risk premia:

$$St = F_t^T + RP_t$$

During the 2002 – 2007 period, crude oil speculators were often demonized as the key contributors to the dramatic price increases. Speculators continuously and consistently bet on higher crude oil prices in the future and from the above equation it would seem that increases in spot prices directly resulted from higher futures prices (see extended market contango in *Figure 11*). However, increased speculation may have not been the direct cause. Fleming and Ostdiek (1998) found an inverse relationship between crude oil futures contracts and spot market volatility. In their interpretation of these findings, the use of futures contracts contributed more to increased market depth and liquidity rather than price volatility. *Figure 5* and *Figure 6* below show that during this period spare capacity declined significantly and crude oil demand exceeded refining capacity in 2004. These supply conditions most likely contributed to future expectations of a tight market and therefore led to higher futures prices. As mentioned above market contango encourages inventory accumulation. Hamilton (2008) argues that a continuous speculative bubble, such as the one seen in recent years, would have to result "in continuous inventory accumulation" which, as he explains, is highly unrealistic (Hamilton 2008, pp. 14-15). He then argues that cuts in production are the cause of the speculative behavior and therefore the rise in futures and spot prices.

Economically speaking, Hamilton's argument makes sense. As future expectations point to less crude oil due to production cuts or underinvestment in production and refining capacity then market participants may perceive oil as dearer in the future. From economic theory, a decrease in supply of a commodity such as oil results in an increase in equilibrium price, *ceteris paribus*. Given that the price elasticity of demand for crude oil has been empirically shown to be low (i.e. inelastic in the short run) an increase in the price per barrel may not result in a decrease in demand. Demand and supply expectations, however, are not the only factors that affect futures prices.

Events not directly related to the oil industry may also affect future expectations regarding supply and demand balances which may also affect prices. Geopolitical tensions, wars, terrorist attacks, politically unstable oil-exporting governments, and destructive weather can disrupt current oil markets and, depending on the expectations regarding these events, add a large premium to futures prices. For example, in the event that a country wages war against an OPEC nation, market participants may bid up oil futures contracts due the risk of supply disruptions resulting from the destruction of production facilities. Futures prices may rise even further if it unclear as to the length of time and outcome of the conflict. Such a situation may send signals to the market that oil supplies could be significantly less in the future and for an unknown length of time. It therefore seems logical that there will be a significant risk premium built into futures prices. It is clear that these and other non-economic factors can have significant effects on expectations regarding future supply and demand balances. Futures market participants most likely weigh both economic and non-economic factors when making investment decisions. However, measuring the effects of non-economic variables is difficult because of the qualitative nature of these variables.

The following figures provide support for the claim that futures prices cause spot prices and that stocks and prices have a positive relationship. *Figure 12* below shows a scatter plot of spot price and OECD stocks. Clearly there is a positive relationship indicated by the upward sloping regression line; which implies that inventories will rise as futures prices (and therefore spot prices) rise. A Pearson correlation coefficient of .68 indicates a strong positive relationship between stocks and crude oil prices. *Figure 13* shows the relationship between U.S. SPR stocks and spot prices. Clearly there is an even stronger positive relationship given by the steep upward sloping regression line. The Pearson correlation coefficient of .85 indicates strong positive correlation between U.S. SPR stocks and spot prices. Again, the reader should refer to *Figure 10* to observe the movements of spot and futures prices for the 2002 – 2007 series. Clearly, the two price series exhibit strong correlation as they closely follow the same trend although with some divergence from one another. *Figure 14* shows the scatter plot of 4-month futures prices and spot prices which shows a positive and very stable relationship. The regression line is positive and near linear. Additionally, a Pearson correlation coefficient of .99 indicates that spot and futures prices are highly correlated.

While correlation does not necessarily imply causation, “if one variable is the primary causal factor in determining the value of the other variable, then a high correlation must be observed” (Glahe 1973, pp. 325). In other words, while my correlation observations do not prove that one variable caused the other, higher correlation values do imply the possibility of causation. As noted in Glahe (1973) low correlations prove lack of causality. Finally, high correlation is a necessary condition for causality but not a sufficient condition.

Chapter 8

OPEC's Production Behavior, its Role in Determining Prices, and the Inherent Complexities of Modeling Supply

Perhaps the most difficult aspect of constructing oil price models is determining how to model supply. It is nearly impossible to cast either non-OPEC or OPEC producers[71] into a single category that adequately describes the entire supply side of the crude oil market. Much of the popular literature attempts to classify OPEC as a cartel and non-OPEC producers as competitive or monopolistically competitive. Yet researchers such as Alhajji (2000) find that the cartel, Cournot, and dominant firm[72] models are not plausible for OPEC. Additionally, Alhajji (2000) does not find evidence to support non-OPEC producers as competitive because the oil market is "dominated by Saudi Arabia" (Alhajji 2000, pp. 52). In economic theory cartels are characterized by very few perfectly-colluding firms who attempt to set prices, set marginal revenue equal to marginal cost, and earn monopoly profits. Additionally, barriers to entry make it very difficult for other firms to enter the industry and earn monopoly profits.

DeSantis (2003) also provides convincing evidence that OPEC behavior cannot be adequately explained by the theory of oligopoly. In microeconomic analysis oligopoly price mark-ups are a function of marginal costs, price elasticity of demand, and market share. DeSantis contends that these variables are somewhat stable in the

[71] Refer to Chapters 2 and 3 above for a detailed historical account of the transformation of the oil market from the 1970s to the oil price collapse of 1986.
[72] Alhajji (2000) did find that Saudi Arabia acts as a dominant producer

short-run. Due to menu costs associated with changing prices, risks associated with misperceiving permanent and transitory price changes, and misperceptions of changes in relative and general prices, DeSantis (2003) argues that “crude oil price fluctuation in the short run is unlikely to be explained by an oligopoly theory” (DeSantis 2003, pp. 156). These arguments are well-founded because it is difficult to assess whether price changes in the short run are permanent or temporary. If OPEC were to perceive a price increase as permanent due to a positive demand shift then they may in fact increase production to keep prices stable or not alter production so that the increase in demand may put upward pressure on prices and therefore increase oil revenues. However, it may be difficult in the short run to assess a permanent increase in prices due to a positive shift in demand. If they chose to reduce output to capture larger revenue gains then this may encourage exploration of alternative energy sources which may erode future OPEC market share. Indeed, these arguments are theoretical in nature, however, they do provide some explanation of why oil prices tend to overshoot and therefore exhibit volatility as supply and demand attempt to come back into equilibrium.

In addition to the varying opinions regarding OPEC’s structure, there are also numerous opinions about the degree of influence that OPEC has on world crude oil markets. After collecting OPEC production data and constructing a scatter plot that relates quantities to prices I found OPEC’s supply curve to be back-bending. *Figure 15* below shows this relationship. Spot prices and OPEC production are highly correlated as the Pearson correlation coefficient is .83; indicating a strong positive relationship. Dees et al (2007) argue that the back-bending nature of OPEC’s supply curve indicates that OPEC may base production decisions on non-competitive behavior. OPEC has an incentive to increase production as prices increase; as indicated in economic theory. However, this back-bending supply curve also indicates that OPEC may have an incentive to reduce production in order to maximize revenue gains. Since the oil price collapse of 1986 OPEC resorted to establishing and enforcing production quotas on each of its members. Leading up to the price collapse in 1986, the arrival of independent oil producers severely eroded OPEC's market share and greatly reduced their ability to influence the world oil market. As noted throughout the popular literature, OPEC established quotas to make up the difference between world crude oil demand and non-OPEC supply. Moebert (2007) argues that OPEC simply impinges upon the oil market by establishing production quotas to push up prices during periods of slack demand and that market participants indicate their expectations *vis-à-vis* OPEC announcements through their behavior in futures markets.

Hamilton (2008) notes that if OPEC operated as an effective cartel then it "would try to set the marginal revenue for the group equal to the marginal cost" (Hamilton 2008, pp. 21). Therefore, since individuals are a fraction of the entire group of OPEC producers, the marginal revenue for an individual member always exceeds that of the whole (Hamilton 2008). If this is the case then, as noted ubiquitously throughout the literature, OPEC members have an incentive to cheat on production quotas. Specifically, each OPEC member agrees to certain production quotas. OPEC administers set these quotas based on "its assessment of the market's call on its supply" (Fattouh 2007b, pp. 6) which is "the hypothetical amount that OPEC needs to produce to close the gap between oil demand and non-OPEC supply" (Fattouh 2007a, pp. 139). In order to produce where marginal revenue exceeds marginal costs, OPEC members have an incentive to cheat; "producing a little more for themselves than the group agreed" (Hamilton 2008, pp. 21). Depending on how well OPEC officials enforce quotas, OPEC is restricted to influencing "price movements towards a target level" (Fattouh 2007b, pp. 6). Additionally, OPEC quotas are difficult to ascertain because crude oil data sources such as the EIA, IEA, and Platts "all have different estimates of what [OPEC's] actual production numbers are" (Hamilton 2008, pp. 22).

Dees et al (2007) also argue that OPEC members generally increase production in response to higher crude oil prices. This makes economic sense and may also indicate that OPEC can behave in a somewhat competitive manner even though they often exhibit more cartel-like behavior. However, OPEC members who increase their production to levels above their assigned quotas are cheating. According to Dees et al (2007) OPEC production decisions Granger-cause crude oil prices. In other words, OPEC production is found to be highly significant in its influence on crude oil prices. These findings are in stark contrast to opinions that OPEC has lost a considerable degree of its market share and ability to influence world oil markets. *Figure 16* below shows crude oil spot prices and OPEC production from January 2002 – December 2007. Clearly, OPEC production did not change substantially over this period as the average production was 30.99 mbd. However, in percentage terms, OPEC production increased by a total of 21.73% from January 2002 to December 2007. In absolute terms, production increased by less than 6 mbd.

Regarding cheating by individual members, we can examine the microeconomic cartel model to explain the incentive to cheat. A cartel will attempt to raise the market price (equilibrium price determined in perfect competition) by restricting output. If an individual member decides to produce beyond the production restriction then he will increase his revenue by the additional quantity sold while the other members suffer from selling at the lower price level (Molchanov 2003). If a cartel has an efficient and effective quota-enforcing mechanism then output will not exceed that amount dictated by the production quota. It is well-known but perhaps not as well-documented that OPEC lacks an effective quota-enforcement mechanism as its members have consistently cheated on production quotas. Saudi Arabia, OPEC's largest producer and *de facto* quota enforcer has "both the willingness and ability to rapidly boost output in the face of substantial overproduction by fellow members, precipitating a global supply glut and price collapse" (Molchanov 2003, pp. 9). Saudi Arabia's ability to produce extra crude oil to reduce prices stems from its substantial surplus capacity. However, Saudi Arabia can be adversely affected through revenue declines following decreases in crude oil prices. As suggested in Molchanov (2003), Saudi Arabia has the requisite power to reduce the benefit to cheating but "it does not eliminate the basic incentive to modestly overproduce" (Molchanov 2003, pp. 10). In other words, Saudi Arabia may turn a blind eye to cheating on quotas until it directly affects their revenue stream.

Kaufmann et al (2004) also found that OPEC's decisions exhibit considerable influence on world oil markets. Using quarterly data from 1986 – 2000, the authors found strong co-integrating relationships between real oil prices, OPEC capacity utilization, OPEC quotas, and adherence to these quotas. He claims that the above variables Granger-cause real oil prices. This study refutes the argument that OPEC is no longer a dominant player in global markets for crude oil. His regression results indicate that as the days of forward supply increase, the effect on crude oil prices will be negative. As discussed above, an increase in stocks will reduce the real oil price as it reduces reliance on current production "and thereby reducing the risk premium associated with a supply disruption" (Kaufmann et al 2004, pp. 77). Kaufmann et al (2004) also concludes that as increase in OPEC quotas and therefore cheating will tend to have a negative effect on prices. Again, this conclusion is consistent with economic theory as an increase in supply, *ceteris paribus*, will decrease the equilibrium price. The study also found OPEC capacity utilization and prices to be positively related. As noted above, higher rates of capacity utilization send signals to market participants that suppliers may not be able to augment production is the event of exogenous supply disruptions. This is also consistent with economic theory in that at full capacity, shocks to supply can only be absorbed by rising prices. Kauffman (2004) also notes that during 1986 – 2000 OPEC behaved as marginal producer. In other words, OPEC attempted to set production levels equal to the difference between non-OPEC supply and global demand.

During the early 1980s oil discoveries outside of OPEC territories encouraged the growth of non-OPEC producers. During the period from 1975- 1985 non-OPEC producers increased their share of world production from 48% to 71% (Fattouh 2007b). In essence, the number of firms increased dramatically, which as economic theory dictates should have a negative effect on price. Non-OPEC producers flooded the market with crude oil and therefore "secured the sale of all their production by undercutting OPEC prices in the spot market" (Fattouh 2007b, pp. 4). OPEC could not compete with the new suppliers and lost a significant share of oil revenues and market share[73]. With the increasing numbers of non-OPEC producers and the adoption of netback pricing by Saudi Arabia in 1985, OPEC lost its ability to control oil prices. In 1986, world oil prices collapsed to less than $10 per barrel from over $26 per barrel a year earlier[74].

As indicated above, assessing OPEC's influence on the current oil market that is characterized by a quasi-cartel and quasi-competition among non-OPEC members is fraught with difficulty and numerous pitfalls. However, gaining a general understanding of OPEC's clout is of vast importance since OPEC accounts for over 40% of crude oil market share. As indicated in Chapter 4, Saudi Arabia acts as a swing producer when markets become tight in order to fill the gap between non-OPEC supply and global demand (Fattouh 2006c). It is worth noting that Kauffman et al (2004) found that only Saudi Arabia and Venezuela augment production in response to prices. This makes sense due to their capacity utilization and their dominance of OPEC production. This further corroborates Molchanov's (2003) claim that Saudi Arabia can rapidly increase or restrict output depending on the current spot price. Regarding OPEC production quotas, Fattouh (2006c) argues that they are signals to market participants about OPEC's preferred prices. Essentially, OPEC quota decisions send a clear message about the future supply and demand balance. If OPEC decides to cut production, it is usually to keep the market price from falling or to increase prices if revenues are falling. When OPEC indicates that future production cuts are a possibility, futures prices tend to increase as future supply will certainly be less. As discussed

[73] In 1973 OPEC's market share was 52%. By 1985 it was less than 30%.
[74] Refer to Chapter 4 above for a discussion of the 1986 oil price collapse.

above, this may result in inventory accumulation with the intention of selling futures contracts for a profit.

It does seem somewhat plausible (and perhaps easier) to classify the non-OPEC side of the market as competitive. Mabro (1992) notes that while many researchers discuss the competitive nature of non-OPEC producers, the competitive paradigm is “rarely investigated in depth” (Mabro 1992, pp. 5). Mabro (1992) further discusses efficient resource allocation, optimal investment *vis-à-vis* price signals, and whether excess depletion will result in “feasts followed by famine because of inadequate investment due to the low prices” (Mabro 1992, pp. 5).

Regarding the conflicting interpretations of OPEC behavior, Kauffman et al (2008) argue that the fact that OPEC does not neatly fit into any one model is a function of real world complexities. Additionally, Kaufmann (2008) dismisses the idea that a simple model exists to explain production behavior of an organization made up of several sovereign nations which have different resource endowments, industry structures, and political ideologies. These conclusions are well-founded given that over 30 years of research has been devoted to modeling OPEC behavior.

Ultimately, there are varying opinions regarding the supply-side structure of the crude oil market *vis-à-vis* OPEC and its ability to influence prices. One thing, however, is quite clear: crude oil prices have been subject to dramatic and often destabilizing volatility as more and more firms entered the market following the oil price collapse of 1986 when it was first believed that OPEC lost significant market power. *Figure 3* below is testament to this claim. While a thorough analysis of OPEC is beyond the scope of this paper the above analysis provides adequate detail regarding OPEC’s role in the global oil market and explores its ability to influence prices through production quotas. Additionally, OPEC is difficult to analyze because statistics and production quota numbers for each member are not reliable. Again, despite varying views of OPEC, oil prices have been much more sensitive to market forces in the last 23 years than when OPEC dominated global oil markets in the 1970s and early 1980s.

Chapter 9

Crude Oil Demand and Macroeconomic Fluctuations

In 1970 the world consumed 46.8 mbd of crude oil. In 2007 the world consumed 85.8 mbd of crude oil; nearly twice the amount consumed in 1970 (Energy Information Administration 2009). From *Figure 17* below, consumption data from 1970 – 2007 indicate that the OECD countries are the largest consumers of crude oil and show how global oil consumption has increased significantly in the last 39 years. From *Figure 17*, one can also see how OECD oil consumption has been relatively flat since about 2000 and that world consumption has increased significantly relative to the OECD trend line. In short, demand for crude oil by developed countries such as the United States has grown only very slowly and has not increased greatly for the last 15 years (see *Figure 18* below). U.S. demand for crude oil increased by just over 4 mbd[75] from 1995 - 2007. Many analysts and researchers attribute the increase in world oil consumption to the explosive growth of developing economies such as India and China.

In 1986, China consumed on average 2 mbd and in 2007 China's consumption nearly quadrupled to 7.58 mbd (Energy Information Administration 2009). This reflects an overall increase in consumption of 379%. India's consumption increased from less than 1 mbd in 1986 to 2.72 mbd in 2007. This reflects almost a 300% increase in crude oil consumption. See *Figure 19* below. According to Moebert (2007)

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[75] While this represents a 27% increase from 1995 to 2007, it is not that much when viewed in absolute terms.

this explosive growth points to the strength of these developing economies and points to higher future demand. China and India have both become significant players in the global economies and compete with highly industrialized economies in many sectors. Morse (2006) forecast that in 2006 demand from emerging economies such as China and India would grow by 2.8% - 3.5%. According to EIA data, Chinese oil demand grew by over 7% in 2006 and Indian oil demand grew by more than 5% (Energy Information Administration 2009). These increases in demand reflect the strong growth of middle classes in China and India who demand goods such as automobiles. As these middle classes grow, they will demand more goods such as cars which will, indeed, add to their existing consumption of crude oil. The important distinction between developed countries such as the U.S. and developing countries such as China is that the U.S. is not expected to see large increases in its crude oil consumption because its middle class is mature and is not expected to grow significantly in the future. China, on the other hand, is expected to see large increases in the number of people who are described as middle class and who can afford to purchase commodities such as cars and who desire a western lifestyle.

Let us now turn to how prices have behaved in relation to crude oil demand. *Figure 20* below shows the spot price trend and crude oil consumption for both OECD and non-OECD countries. From the graph it does not appear that price had any effect on demand. Morse (2006) argues that in the short run, it is difficult to reduce demand with small price changes. He further argues that it takes large price spikes to significantly erode demand. This makes economic sense given the low price elasticity of demand in the short-run. Since most consumers use refined petroleum products such as gasoline, an increase in oil prices and therefore gasoline prices may not significantly curb consumption. The short run inelasticity is largely due to the fact that people (mostly in the United States) rely on driving automobiles to get to and from work. Additionally, transportation substitutes such as subways, buses, and trams are not available in all areas of the United States.

As discussed above crude oil serves a variety of purposes mostly related to producing fuel that can be burned for energy. Crude oil is also used as an input to production or "feedstock" to create products such as petrochemicals, plastics, polyurethane, solvents, and many other goods (Energy Information Administration 2009). In order to better understand crude oil price dynamics we must further explore the nature of short run price inelasticity. As discussed above, Dahl (1993) and Cooper (2003) computed elasticities for crude oil and found short-run price elasticity of demand to be extremely low: -.07 and -.05 respectively. Again, low price elasticities simply mean that demand is not very responsive to price changes. Low price inelasticity of demand also implies that crude oil has very few substitutes or that "low elasticity is the inescapable reflection of constrained substitutability" (Mabro 1992, pp. 7). It is not enough, however, to look at elasticities in order to make intuitive assumptions about price behavior *vis-à-vis* demand.

Hamilton (2008) argues that demand at any given time responds to a number of other variables besides price. According to standard economic theory demand may change due to a number of non-price determinants such as changes in consumer tastes, number of consumers in a given market, income, and availability of substitutes. Hamilton (2008) argues that the previous year's price is a significant determinant "since it can take many years for the fleet of existing cars to reflect changes in purchasing habits" (Hamilton 2008, pp. 16). Additionally, long lead-in times are required for research, development, testing, and eventually production. A current example is the dramatic change in consumer preferences regarding hybrid and energy efficient cars. "Green" initiatives and life styles have moved to the forefront for many Americans and over the past few years automobile companies have abandoned production of trucks and SUVs in favor of hybrid models and other more fuel-efficient cars. It may be a coincidence that rising oil prices which led to higher gasoline prices occurred around the same time that many Americans demanded more environmentally-friendly transportation methods. Regarding price elasticities, Hamilton (2008) provides data that further corroborates his argument that using elasticities to gauge changes in demand may not always be accurate and reliable.

Using logarithmic transformations of crude oil consumption and U.S. real GDP from 1949 to 2007, Hamilton (2008) illustrates how crude oil consumption rarely deviated from its long run trend over the series. However, there are a few exceptions worth noting. As discussed in Chapter 3, following the fall of the Shah of Iran, Iranian production fell from 5.5 mbd to less than 1 mbd. Prices ratcheted upward to almost $40 per barrel and U.S. oil consumption fell by 16% (Hamilton 2008). Despite the fall in oil consumption, U.S. real GDP increased by 5.4% (Hamilton 2008). These numbers seem to indicate that crude oil price elasticity of demand was highly elastic as demand quickly responded to a leftward shift of the supply curve. In the time period of interest for this thesis, crude oil prices also increased significantly. Prices rose by 361% from $19.71 in 2002 to over $90 in December 2007. During this time period U.S.

consumption of crude oil increased by 4.5% (Hamilton 2008). This may reflect the fact that there are very few substitutes for crude oil and that American motorists had no choice but to continue filling up their gasoline tanks in order to drive to and from work. In summary, oil price increases and GDP responses can be somewhat asymmetric; higher oil prices may result in GDP contraction but lower prices may not have a proportional stimulative effect on output (Regnier 2006).

According to the conventional wisdom GDP growth generally leads to higher oil prices as more oil is demanded for both fuel production and feedstock to increase production of non-fuel commodities. However, the conventional wisdom also indicates that higher crude oil prices will result in GDP contractions. According to data provided by the IMF, World Bank, OECD, and Department of Energy an increase in $10 per barrel will reduce OECD GDP by .4% for 2 years (Morse 2006). It follows from this theory that inflation and unemployment will also rise. This may be true at very high oil prices (i.e. high oil prices of the summer months of 2008) but according to data from the Federal Reserve Bank of St. Louis U.S. GDP increased each year between 2002 and 2007 and oil prices rose by over 300% (Energy Information Administration 2009). Again, these numbers may reflect the short-run price inelasticity of demand for crude oil or that consumers simply chose to afford these price increases because of positive expectations about economic growth.

On the economic theory side, it is important to discuss possible substitution effects[76] resulting from low or high oil prices. In the short run, low oil prices may encourage substitution of fuel oil for coal power in power stations with double burner

[76] Implications of current oil prices *vis-à-vis* substitution for alternative energy sources will be discussed in Chapter 10 below.

capabilities (Mabro 1986). It is important to note that at the time of Mabro's writing, oil sold for $10 – 12 per barrel and coal fetched $50 a ton. However, implementing the substitution of fuel oil for coal power requires substantial lead-in times to assess costs of capital, install new capital, and implement new methods of production. Substitution effects may thus depend on perceptions of changes in crude oil price changes. Specifically, price changes may be perceived to be permanent or transitory. For example, if the recent decline in oil prices is perceived to be permanent, then substitution effects may not be realistic because cheaper crude oil will crowd out energy sources that are more costly and less efficient. However, if the decline is perceived as temporary (which it most likely is) then substitution of other energy sources may occur as oil prices rise again to levels that make substitution of other energy sources more economically feasible.

Finally, from the basic supply and demand analysis an increase in demand will cause the demand curve to shift to the right and the equilibrium price to rise, *ceteris paribus*. The equilibrium price will remain elevated and perhaps rise further if supply is not increased to meet the increase in demand. One other strong possibility for the sharp increases in crude oil prices from 2002 – 2007 is that demand exceeded supply beginning in late 2005. Additionally, in 2006 crude oil demand exceeded crude oil production and this gap widened for the remainder of the year and continued to the end of the series. *Figure 21* below illustrates this phenomenon. Such a situation will, indeed put upward pressure on oil prices. Since we assume that short-run crude oil price elasticity is very low then a supply reduction shifts the supply curve inward and the price per barrel rises, *ceteris paribus*. Given the low price elasticity of demand,

demand actually increased (no good substitutes for crude oil) causing the price to rise even more. Producers clearly have the advantage here as consumers (in the short run) are price takers and cannot switch to cheaper alternatives when crude prices climb. As noted above, much of the increase in demand most likely came from developing economies and this demand is forecasted to increase significantly over time. Regarding production, OPEC supplies approximately 40% of the world's crude oil and enforces quotas to rein in excess production to keep prices stable. Given the short-run price inelasticity of demand, OPEC has an incentive not to increase production when demand is high because higher crude oil prices result in greater oil revenues in the short run. Non-OPEC producers who behave more competitively may increase production to sate demand and hopefully capture higher revenues as well. *Figure 22* below shows how production growth has increased only slightly but tends to move in tandem with prices. Economic theory supports this trend.

Section III

Chapter 10

Oil Prices Today

When I began this research in December 2007 a barrel of WTI sold for approximately $91. On 3 July 2007 oil prices peaked at $145.31 and subsequently fell to $30.28 just before Christmas 2008. *Figure 23* below shows daily WTI prices beginning in January 2008 to the end of March 2009[77]. This series seems to indicate a gradual downward trend of crude prices. Viewing this downward trend relative to the original WTI price series tells quite a different story, however, as shown in *Figure 24* below. Clearly, crude oil prices have fallen much faster than they had previously risen. The worldwide economic downturn has undoubtedly contributed to the current demise of oil prices. It is still too early to accurately assess the impact of the recession on oil prices but the EIA forecasts that world consumption of crude oil will fall by 1.35 mbd in 2009; which may keep prices from rising significantly (EIA Short Term Energy and Summer Fuels Outlook 2009). The EIA also expects that if fiscal and monetary actions improve the outlook for economic recovery then crude oil prices should stabilize and eventually rise with the economic upswing. However, the decline is daily world consumption of crude oil is expected to reduce 2009 world GDP by .8% (EIA Short Term Energy and Summer Fuels Outlook 2009). The EIA forecast world oil consumption to grow by 1.1 mbd in 2010 if the global economy grows by 2.6%. In addition to the recession, this current period of low prices relative to the high prices

[77] These data recently became available hence my discussion and analysis in this final section of the paper.

during the summer of 2008 has important implications for the oil industry in general but particularly for OPEC.

Underinvestment and the Implications of Price Volatility

In 2005 Ali Naimi, Saudi Petroleum and Mineral Resources Minister, argued that the problem within the oil industry "is not one of availability; it is a problem of deliverability" (Mabro and Fattouh 2006, pp. 101). Ali Naimi argued further that the upstream and downstream sectors face infrastructure constraints and bottlenecks "that are causing market volatility and restricting [OPEC's] ability to bring oil from the ground" (Mabro and Fattouh 2006, pp. 101). In other words, insufficient investment has been a significant contributor to volatile oil prices. Volatile prices make it very difficult for firms to make investment decisions about adding extra capacity, installing more oil rigs, or adding more downstream refineries. Wildly fluctuating prices make it next to impossible for firms to calculate return on investment and history has shown that oil prices do not follow any particular deterministic trend. Additionally, volatile oil prices and fluctuating demand contribute to low investment "by blurring the distinction between transitory and permanent price movements and hence permanent cash flows" (Kochhar, Ouliaris, and Samiei 2005, pp. 3). In other words, it is difficult to determine whether or not short-run changes in prices will be permanent or transitory. Sustained higher oil prices ensure that a producer's costs are covered by the associated revenue from oil sales while "sudden and assumed short-lived price hike[s] [are] not sufficient to bring a large field into production" (Ringlund et al 2007, pp. 342). Therefore, declining prices squeeze profit margins and cannot justify additional investment outlays.

In addition to the above economic explanations for underinvestment in the oil industry, a brief review of recent history also provides an intuitive explanation. Following high oil prices in the early 1980s many non-OPEC producers responded to these higher prices by increasing exploration, production, and production capacity. OPEC did not actively pursue exploration or attempt to install new capacity as its excess capacity was around 12 mbd (Mabro and Fattouh 2006). Economically, OPEC had no incentive to increase capacity because new capacity would have remained idle; which is costly. Following the Iranian Revolution and the subsequent oil price spikes, global oil demand began trending downward until 1984 as shown in *Figure 17* below. Mabro and Fattouh (2006) argue that this "demand pessimism" also contributed to low oil prices in the late 1990s as well. This period of weak demand and low prices "threw the industry into a deep recession"; which reduced the attractiveness of investment in the oil industry (Mabro and Fattouh 2006, pp. 106). In short, expectations of weak demand and therefore lower prices could not justify additional investment because it was not certain that returns would exceed costs. These potential problems were not unknown, however. Following the price collapse of 1986, Mabro (1986) accurately and prophetically forecast that low oil prices would hinder exploration and development of new oil fields, reduce additions to refining capacity, and therefore contribute to lower crude oil output in the 1990s. Combined with relatively flat demand for crude oil, there was very little change in crude oil production until the late 1990s. Additionally, prices remained flat and did not exhibit any extreme volatility in either direction[78].

[78] The exception of course is the period beginning in August 1990 when Iraq invaded Kuwait and the subsequent Gulf War. The distinct spike in *Figure 1* around 1991 indicates the loss of Kuwaiti and Iraqi supply.

According to Baker Hughes, the number of active rotary rigs is a leading indicator of demand for products used in drilling, completing, producing, and processing hydrocarbons (Baker Hughes 2009). The number of rotary rigs is also a good measure of upstream investment in the crude oil industry[79]. From *Figure 25* below it is clear that the number of active rotary rigs from January 1982 to March 2009 exhibits a direct relationship, albeit with a slight lag, with WTI spot prices. The Pearson correlation coefficient of .226 indicates a positive relationship between rig count and WTI spot prices. The data and Pearson correlation coefficient show that new investment (i.e. installation of new rotary rigs) is sensitive to price movements but the relationship is not very strong given the correlation coefficient of .226. This can be explained by oil producers' reluctance to install new capacity or put existing capacity online in the short run when it is difficult to assess whether a price change is permanent or transitory. According to Ringlund et al (2007) oilrig activity tends to increase with oil prices in the long run. This study and the data support the above analysis that periods of lower prices will tend to reduce new investment because the low prices may not result in revenues high enough to justify the costs of new investment. Additionally, weaker outlooks for demand will curb investment spending on new production and capacity.

Mitigating Price Volatility Through Government Intervention

In general, uncertainties with regard to demand, world economic growth, technological developments, the role of substitutes, and environmental policies may also hinder investment in upstream and downstream capacity (Mabro 2006). These

[79] Mabro and Fattouh (2006) point out that a declining rig count may not necessarily mean that active rigs have been uninstalled or taken offline. The authors say that the use of horizontal drilling rigs is increasing which reduces the number of wells needed for producing crude oil.

uncertainties present challenges to making prudent investment decisions and highlight the risks to both over- and underinvestment. On the one hand, overinvestment may permanently depress prices so that oil exporting countries will face significant revenue losses. As discussed above, underinvestment may exacerbate price volatility which may then prevent further investment projects. In the previous oil price regimes, prices were relatively more stable, but oil prices were at the behest of governments and oligopolistic cartels. In today's market regime, oil prices are not only determined by both buyers and sellers of crude oil but also by agents who never actually come in contact with a physical barrel of oil.

Speculators, hedge funds, and other market participants play a key role in price determination but were ubiquitously labeled as the scapegoats for driving oil prices to $147 per barrel in July 2008. This run-up of oil prices created a frenzied clamor for government intervention in the U.S. to enforce strict regulation on traders in order to rein in and control oil prices. Even though oil prices declined more quickly than they rose, it would not be surprising to hear such calls if prices were to rise again in the future. However, government regulation of trading futures contracts may hinder the allocative signals that futures prices send to economic agents regarding supply and demand.

Oil market participants adopted futures prices because of the problematic decline in the physical base of marker crudes. This problem "increases the vulnerability of these markets to squeezes" (Fattouh 2006c, pp. 94). Futures markets are much more effective in price determination than the spot market because of the large volume of transactions. Additionally, futures prices are determined by these transactions through the interaction of buyers and sellers; not by arbitrary price-making mechanisms designed by governments. Therefore, futures prices paint a very clear picture of the global oil market and enable market participants to make well-informed allocative decisions. As noted in Hamilton (2008), oil speculators respond to supply and demand factors such as production cuts, capacity utilization, stock levels, and consumption. It is therefore fallacious to assert that futures market participants arbitrarily bet on higher futures prices without any regard for oil market conditions. Limiting or regulating futures market transactions through government intervention could disrupt the price-discovery process and blur the picture of supply and demand.

While governmental actions may discourage oil speculators from entering the market and thus limit price volatility to some degree, there are larger and perhaps more severe long term implications. Preventing market participants from the price-discovering process could also contribute to underinvestment in the oil industry. Artificial prices determined by governments do not send allocative signals to agents regarding supply and demand and therefore create uncertainty. When making capital-budgeting decisions, firms adjust their required rate of return according to various risks associated with investment decisions. Not knowing the market price or the supply and demand balance can inhibit crude oil producers and refiners from making decisions regarding capacity additions. Governments, however, may be more effective in preventing destabilizing oil price volatility through indirect means such as sound monetary policy and prudent spending.

Ultimately, creating a stable economic environment with no limits on the flow of information may significantly curb speculative bubbles and lead to modest oil price appreciation, revenue gains, and stable costs. However, Mabro (2006) argues that "Western governments are not in a position to address oil issues with sufficient knowledge and competence". Following the period of low oil prices in the 1980s and 1990s due to excess supply and weak demand, many Western governments reduced the size and scope of their energy departments (Mabro 2006). This led to oil industry deregulation which provided more autonomy for markets to determine prices. In a 2007 interview, Mabro emphasized the importance of developing technology to increase reserves because he believes that oil investors base their decisions on a firm's access to reserves (Swartz 2007). Additionally, Mabro believes that oil companies should collaborate with countries endowed with oil resources "to improve access to oil acreage and increase reserves" (Swartz 2007, pp. 1). While Mabro is not necessarily arguing against government regulation of the oil industry, he is arguing that oil markets will stabilize with increased access to reserves and therefore a larger supply cushion.

Substitution Effects and Alternative Energy

As noted above, sustained periods of higher oil prices may result in substitution effects; particularly in alternative energy sectors. Conversely, periods of sustained lower prices may not encourage substitutes because it may not be economically feasible to do so. In recent years there has been a strong push towards energy-efficiency, independence from politically-unstable oil exporting nations, and increasing concern for the environment. These concerns have led to the research and development of alternative energy sources including solar power, wind power, nuclear, hydro-electric, and bio-fuels such as ethanol. Proponents of these alternative energy sources cite their renewability, efficiency, and limited environmental damage as the benefits to substituting them for traditional petroleum energy. During the summer of 2008 when oil prices topped out over $140 per barrel investment in these alternative energy sources looked both promising and lucrative. However, as shown in *Figure 24* below the high oil prices during the summer of 2008 were not sustainable and crashed by Christmas 2008; thus eliminating the economic feasibility of substantial investments in alternative energy sources. Additionally, given the financial crisis, governments of developed countries such as the U.S. are allocating enormous amounts of money to stimulate demand and hopefully revive the economy. In essence, governmental actions have "already revised the priorities surrounding alternative energy sources" as the funds allocated to shoring up the economy translate into less funding and subsidies for alternative energy production (Henderson 2008, pp. 2).

This does not mean, however, that investment in alternative energy will never be a lucrative undertaking; nor does it mean that crude oil prices are the only determinant to investment in alternative energy. As noted above and as fully acknowledged among policy makers, economists, and industry leaders oil is a finite resource and *at some point* there will be no choice but to substitute into alternative fuels. The main barriers to substituting completely into alternative energy sources, as posed by Kaufmann (2007), are determining with precision the year that oil production will peak, the quantity of alternative fuels needed to sustain the global economy, and "how this uncertainty affects firms' willingness to provide alternatives in a timely fashion" (Kaufmann 2007, pp. 405). In the short run, however, growing acceptance of the need to explore alternative energy sources poses certain problems for countries whose main export is crude oil; namely OPEC.

New Challenges for the OPEC Cartel

Throughout its history, OPEC has impinged upon the global oil markets by cutting production when prices are low and increasing production when prices are too high. These actions ensure that oil revenues will either remain stable or not fall as much. Clearly, due to production and transportation costs, OPEC's oil revenue per barrel must be greater than or equal to its cost per barrel in order for the cartel to remain profitable. In essence, OPEC ministers most likely scheme to keep oil prices within a certain band in order to ensure stable revenue flows. However, as the global economy embraces alternative energy solutions in lieu of traditional petroleum energy sources, OPEC will have to collude to keep oil prices from spiraling to unsustainable heights such as $140 per barrel. In other words, OPEC in the 21st century must fight a two-front battle in the global oil market: on the one hand they must prevent oil prices from collapsing in order to keep revenues stable but on the other hand they cannot drive up oil prices through production cuts because this may further fuel the demand for alternative energy. Clearly, a global abandonment of petroleum energy in favor of alternative energy will severely curb demand for OPEC oil and could effectively destroy the cartel.

To illustrate, Iran and Venezuela are economically vulnerable to crude oil prices less than $70 per barrel (Henderson 2008). Essentially, these two countries depend on oil revenues in which per-barrel prices are greater than $70. Therefore in the face of falling prices, these two countries would most likely push for large production cuts to drive oil prices towards $100 (Henderson 2008). In Q4 2008 OPEC cut production by 1.1 mbd and by 2.1 mbd in Q1 2009 (Short Term Energy and Summer Fuels Outlook, 2009). These cuts reduced OPEC's daily output to 28.5 mbd which is significantly less than average daily production of 32.1 mbd in 2007 (Energy Information Administration, 2008). Since the announcements of these OPEC production cuts, WTI spot prices have, indeed, risen from $33 per barrel in late December 2008 to just over $50 in late March 2009 (Energy Information Administration, 2009). However, it is not yet clear that the increase in prices can be completely explained by OPEC production cuts; further study must be undertaken over the next few months to accurately determine this. Current oil prices are still well-below the $70 per barrel benchmark for Iran and Venezuela as the average price in March 2009 was $47.93 per barrel (Energy Information Administration 2009). At best, OPEC can only hope to keep oil prices from further collapses as long as the global recession continues with little prospects for a quick recovery.

Falling oil prices may not necessarily be such a bad thing, however, for OPEC. Falling oil prices may in fact stimulate demand and help revive the sluggish economy thus generating strong oil revenues for OPEC. Cheap oil is "the equivalent of a trillion-dollar stimulus package" according to Nobuo Tanka, head of the International Energy Agency (Petroleum Economist 2009). However, as noted in Fattouh (2007a) oil consumers are under no obligation to consume excess oil above and beyond their immediate needs even if oil is offered at fire sale prices. On the other hand, higher oil prices in the current global financial downturn may not help OPEC either. It is possible that rapidly rising fuel prices could exacerbate the recession. Rising fuel costs will adversely affect the global transportation industry whose performance is a leading indicator of global economic health. Even though short-run price elasticity of crude oil is very low, it is not certain that oil demand will adhere to the theoretical underpinnings of elasticity given a price change as seen in Hamilton (2008). If OPEC opted for further production cuts crude prices would certainly rise, but given the global recession this does not seem like a logical step to guarantee higher oil revenues. The other danger is that if OPEC adopts retaliatory measures to drive up oil prices they also run the risk of encouraging substitution into alternative fuels.

Periods of sustained high crude oil and fuel prices will make alternative energy sources more attractive. In addition to the growing clamor for environmental awareness and clean reliable energy, consumers may simply get tired of volatile energy prices as a result of OPEC market manipulation. Furthermore, large investments into alternative fuel sources will erode the world's dependence on OPEC oil. Therefore, OPEC economies cannot live above their means since their economies are completely dependent on crude oil exports. According to Petroleum Economist (2009) OPEC did not have an incentive to invest in other industries in their economies when oil prices and therefore revenues were high during the last 7 years. Now that prices are low OPEC nations may, indeed, favor investments in other sectors but this task will be much more difficult given anemic oil revenues (Petroleum Economist 2009). While OPEC's oil revenues may continue to weaken in the global recession, the cartel will not face market share loss from alternative energy companies in the short-run. As noted above, periods of sustained low crude oil prices will certainly not encourage substitution into alternative energy sources.

Recently OPEC has taken to talking down renewable energies such as bio-fuels. OPEC correctly argues that renewables "are too expensive, unreliable, and too small to provide a genuine power-sector alternative; let alone for transportation" (Petroleum

Economist 2009). However, OPEC's statement may be more reflective of their inability to cope with a change in demand to renewable energy as well as their inability to profit from this change in demand. Additionally, OPEC expects another oil price spike over the next two years once economic recovery begins. However, OPEC's secretary general, Abdalla El-Badri indicated recently that the cartel has abandoned 35 upstream investment projects going into 2014 "that are not viable at today's oil prices" (Petroleum Economist 2009). If investment is contingent on rising prices then it seems counter-intuitive that OPEC plans to cancel 35 projects even though it expects another spike in oil prices. Petroleum Economist (2009) notes that while Canada's oil sands industry will most certainly see curtailed investment projects they will weather economic downturns better than OPEC because the Canadian "economy has successfully diversified into other areas such as manufacturing and financial services" (Petroleum Economist 2009).

With regard to alternative energy sources, it may seem logical for OPEC to overproduce in order to drive down crude oil prices therefore stonewalling the prospects of substitution into alternative fuels. The tradeoff of course is significant revenue losses. However, there is no evidence at this point that OPEC will pursue this method of market manipulation as recent data indicate that OPEC has made significant production cuts. On the other hand, OPEC cannot make large production cuts that drive up oil prices as this may certainly lead to increased investment in alternative energy and large losses in market share. Less than 24 years ago OPEC faced significant competition from non-OPEC producers who undercut their prices in the then burgeoning spot market and captured significant market share. Today, OPEC faces the challenge of losing market share due to high oil prices that may encourage substitution into alternative fuels. Therefore, in order for OPEC to remain a dominant player in the global oil market it must prevent prices from venturing to either extreme of too high or too low.

Chapter 11

Peak Oil Theory – An Alternative Approach to Modeling Oil Price Behavior

There are a handful of other theories that may also explain crude oil price behavior. One particular theory that has gained considerable ground is the theory of peak oil which originally began as the theory of exhaustible resources. In a seminal paper[80] published in 1931, Harold Hoteling called attention to crude oil's great abundance and cheap prices. Hoteling argued that scarce resources are "being selfishly exploited at too rapid a rate, and in consequence of their excessive cheapness they are being produced and consumed wastefully…" (Hoteling 1931, pp. 281). In essence Hoteling's paper ignited awareness and interest in responsible resource conservation. Hotelling makes the case that profit-maximizing firms base their decisions on the quantity of recoverable oil, production (extraction) costs, and the market demand curve for oil. To simplify Hotelling's assumptions, rents should increase proportionally as the rate of interest and can be used to "generate optimal price and production paths" (Kaufmann 2007, pp. 410). According to Fattouh (2007c) many economists who support Hoteling's theory believe that oil prices must rise over the course of time and that demand would eventually be eliminated as prices become too high. The peak oil theory therefore bases its assumptions on the idea that oil production will eventually peak (i.e. the rate of change will continue to increase but at a decreasing rate).

[80] *The Economics of Exhaustible Resources* (1931) by Harold Hoteling of Stanford University.

In 1956, geophysicist M.K. Hubbert introduced a symmetrical bell-shaped curve to illustrate the production trends of crude oil. Hubbert's model explained the concept of peak oil which refers to "the future decline in world production of crude oil and to the accompanying potentially calamitous effects" (Holland 2008, pp. 61). In essence, Hubbert predicted that given then current reserves and technology oil production would increase, peak or stagnate, and then decline until the resource was completely depleted. His appraisal of then current reserves and predictions of peak production received both accolades and criticisms. Hubbert's approach was very popular among both petroleum engineers and economists well-into the 1970s because of the model's ability to accurately forecast production in the lower 48 U.S. states (Fattouh 2007c). However, his static treatment of ultimately recoverable reserves (URR) and technological advancements drew criticisms from economists. According to Lynch (2002) and Watkins (2006) the static treatment of URR overstated or overemphasized the effects of resource depletion. This argument is well-founded because holding URR constant while allowing variables such as demand and production to be dynamic will, indeed, tend to overstate the explanatory power of the model. Additionally, Fattouh (2007c) indicates that factors such as new investment and discovery of new fields "prevent – or postpone - the decline in production" (Fattouh 2007c, pp. 136). This also makes economic sense because the discovery of new fields or the advancement of technology used to discover new fields may have the effect of increasing reserves and therefore alleviating pressure on current supplies. Furthermore Bardi and Yaxley (2005), while generally supportive of the validity of Hubbert's model, qualify their support by arguing that the model's success is largely derived from regional cases, specific historical cases but “is not yet generally accepted as being [valid] for all cases” (Bardi and Yaxley 2005, pp. 1).

The size of global reserves is also a major point of contention. Because of the differences in defining reserves, using this approach has been shown to be even more problematic. For example, proved reserves are known, commercially recoverable, and have a 90% probability that the quantity of recovered reserves will equal to or greater than the estimation of proved reserves (Fattouh 2007c). Unproved reserves are estimated based on geological and engineering data and have a probability of less than 50% of recovery. Therefore, the difficulty arises in estimating actual recoverable and known crude oil reserves. Data in Watkins (2006) indicate that the ratio of proved reserves to annual production increased from 30 in 1973 to 41 in 2003. These numbers indicate that crude oil reserves have increased significantly over the last 30-plus years.

Holland (2008) is also critical of non-economic studies of peak oil because they fail to account for the role that prices play in allocating scarce resources. He indicates that many of these studies such as Lovins et al (2005) present policy solutions that will supposedly reduce the demand for oil while still allowing for oil companies to operate profitably. Holland (2008) argues that any policy that reduces demand will presumably decrease the price of oil and therefore decrease the profitability of oil companies. Fundamental economic theory supports this argument. Additionally, Holland (2008) argues that most economic models of resource depletion “do not explicitly generate a peak in production” (Holland 2008, pp. 62). Using 4 peak production models, Holland (2008) identifies 4 possible causes of increases in crude oil production: increases in demand, technological advances that reduce costs, cost reductions through exploration, and increases in production resulting from further site development. His models show that crude oil scarcity leads to a decline in production but that peak production is the result of "efficient intertemporal optimization" rather than market failures (Holland 2008, pp. 75). He concludes that prices are a better indicator of resource scarcity than production.

According to Mabro (2006) reaching peak production does not indicate that the world's oil supplies will dry up. Rather, Mabro (2006) argues that at the peak of production, it will be difficult if not impossible to supply increases in demand "if *ex ante* oil consumption wants to grow at prevailing prices" (Mabro 2006, pp. 9). Predictions of peak oil pointed to 2000, 2005, and are now somewhere between 2010 and 2015. One of the strongest criticisms of the peak oil theory is that it fails to account for new oil discoveries and the role that technology plays in expediting the oil recovery process (Mabro 2006). Due to geological and seismic factors it is very difficult to assess exactly how much oil is left underneath the earth's crust or embedded in the ocean floor. Additionally, ultimate recovery of reserves has increased and Mabro (2006) argues that they are likely to continue increasing. However, all researchers do agree on one important point: that crude oil in a finite resource. The main disagreement tends to be a question of when. Kaufmann (2007) admits that forecasting the exact date in which oil production will peak is difficult simply because of the uncertainty regarding the amount of crude oil that remains to be produced.

While strong arguments for and against the theory of peak oil abound throughout the literature, the peak oil theory and its foundations are beyond the scope of this paper. Providing a cogent, sophisticated, and complete analysis would be better suited for a geologist, physicist, or petroleum engineer. It is apparent that further extensive research is needed to determine the usefulness and limitations of the peak oil theory.

Conclusion

I have examined a number of different supply, demand, OPEC, and futures market variables and assessed their influence on crude oil prices using available data and economic theory as a guide. While this study is non-technical in nature and does not rely on advanced econometric modeling to show causation, the behavior of prices and the representative variables can be adequately explained using fundamental economic theory.

Periods of low spare production and refining capacity have exhibited strong upward movements of crude oil prices. As production reaches near capacity, producers' ability to respond to exogenous supply shocks is blunted due to long lead-in times and high costs to install new capacity. Therefore, high levels of capacity utilization add a risk premium which puts upward pressure on crude oil prices. Inventory and stock levels also have predictable effects on prices. Increases in inventories are widely viewed as increases in supply and signal to market participants that producers are adequately equipped to respond to supply disruptions. Therefore prices and inventories should exhibit an inverse relationship. However, inventories may not be a direct cause of prices; causation has been shown to run the other direction. Higher prices encourage inventory accumulation as market participants buy crude oil with the anticipation of selling it for a profit in the futures market. This is intuitive as well in the sense that those with capabilities to store crude oil, given expectations of higher prices in the future, may want to buy it cheaper today in order to meet supply needs in the future and to make a profit.

The futures market is a liquid and transparent mechanism that allows investors and holders of crude oil inventories to hedge against crude oil price changes. Expectations play a large role in determining the spot and future price spreads. When supplies are expected to be lower in the future this may encourage accumulation of inventories and result in market contango where futures prices exceed spot prices. In the event that market demands exceed current supplies then backwardation will take place where spot prices exceed futures prices. As noted above, backwardation is necessary for increases in current production. Other factors such as storage costs, the interest rate, and convenience yield also affect spot and futures prices and therefore determine market contango or backwardation.

OPEC, in which Saudi Arabia acts as a swing producer, behaves in many ways as an oligopolistic cartel. OPEC attempts to restrict output to keep prices high or from falling in order to generate large revenue streams. This endeavor is achieved through member production quotas. Due to OPEC's inability to effectively enforce quotas on individual members, some members have an incentive to cheat by overproducing. Overproduction is characterized as an increase in supply which, when production greatly exceeds quotas, can bring prices down very quickly. However, Saudi Arabia possesses the necessary surplus capacity to offset cheating by overproducing, themselves, so that the cheaters suffer significantly through decreases in revenues. These behaviors indicate that OPEC, and particularly Saudi Arabia, can be characterized by the dominant firm model and that individual behavior is somewhat competitive in nature. Ultimately, however, no single model exists that sufficiently explains OPEC's behavior. While OPEC's influence waned considerably following the emergence of independent producers and the adoption of netback pricing in the early 1980s, OPEC is still a considerable force in the global oil market as futures markets respond decisively to OPEC production announcements.

The global demand for crude oil has shown an upward trend in recent years; largely due to the economic growth of developing countries such as China and India. These countries are expected to continue their robust growth and thus consume more crude oil over time. The short-run price elasticity of demand has been empirically shown to be very low which indicates that crude oil demand is very price inelastic. This makes economic sense because there are very few substitutes for refined crude oil products such as gasoline, jet fuel, and other distillates. However, the rules of price elasticity as dictated by economic theory do not always hold in reality. Low crude oil prices may result in substitution effects if falling prices are perceived to be permanent. On the other hand, price changes that are perceived as transitory may not result in substitution effects.

Crude oil prices have, indeed, shown great volatility since the oil price collapse of 1986 as prices began to respond to market forces rather than artificial mechanisms developed by OPEC. However, OPEC is still a dominant force in global crude oil markets. While crude oil price volatility better reflects fundamentals such as supply, demand, and expectations, price volatility presents problems and has implications for the crude oil industry. In short, price volatility has contributed to severe underinvestment in the oil industry.

This thesis has shown that crude oil prices are directly related to their corresponding price regimes. Prices remained relatively stable when there were very few large firms (i.e. the Seven Sisters) controlling supply and access to that supply. During the OPEC regime when the cartel attempted to artificially control crude oil prices there were often large and destabilizing price spikes. In the subsequent period of market-determined prices, crude oil prices have exhibited great volatility *vis-à-vis* supply and demand factors and have both risen and fallen to incredible extremes.

This thesis has been successful in utilizing an informal approach to analyzing crude oil price behavior because it provided critical insight to the interaction of oil prices and corresponding variables. My oil price analysis is significant because I identified supply, demand, futures market, and OPEC variables that influenced oil prices during the 2002 – 2007 period using fairly simple techniques. In addition, these variables most likely had a significant impact on the oil price collapse in late 2008. I believe that my methods would be highly useful in analyzing other periods of oil price history because my methods can help the researcher make *a priori* assumptions regarding oil price determinants and behavior. Furthermore, my research elucidated the problem of severe underinvestment in the oil industry and that prolonged periods of price volatility curbs new investment in the upstream and downstream sectors. Finally, further research should be undertaken in order to assess whether or not underinvestment is directly responsible for oil price volatility and to what degree oil price volatility is both the cause and effect of underinvestment.

It is difficult to remember that less than 1 year ago, a barrel of West Texas Intermediate sold for $147. It is even harder to imagine that oil prices fell so precipitously following the summer of 2008 and that today a barrel of West Texas Intermediate sells for just over $50. While it is nearly impossible to accurately forecast crude oil prices, this thesis has shown that fundamental economic concepts are very useful in determining how crude oil prices react to changes in supply, demand, and futures market variables. Furthermore, the above analysis utilized a fundamental but practical approach to explaining some of the determinants of crude oil prices.

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Appendix A - List of Figures

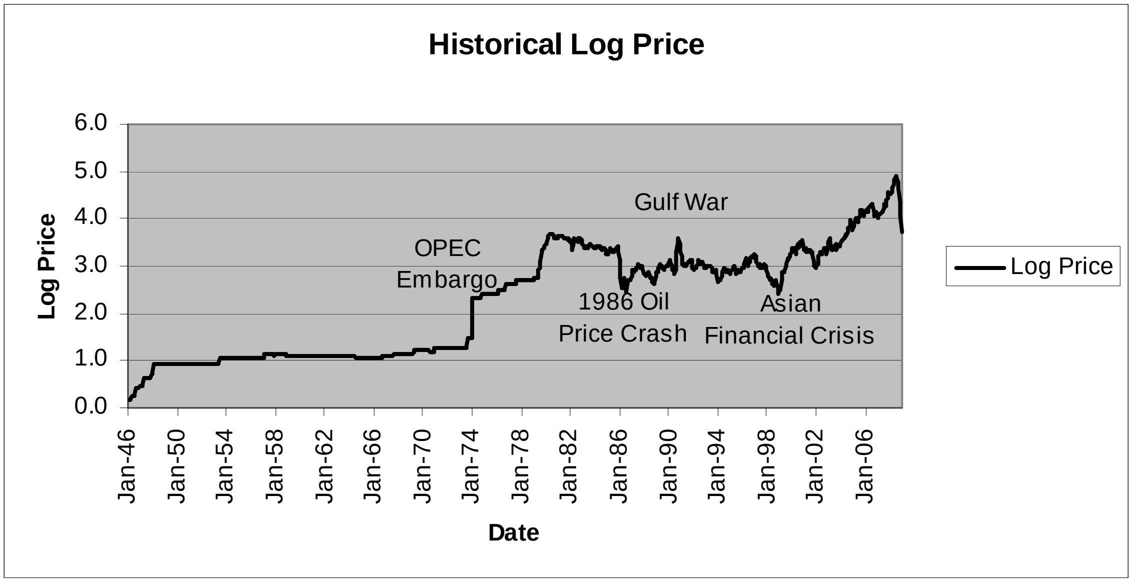

Figure 1 - Historical Log Price 1946 – 2008. Data provided by the Federal Reserve Bank of St. Louis. Chart constructed by author.

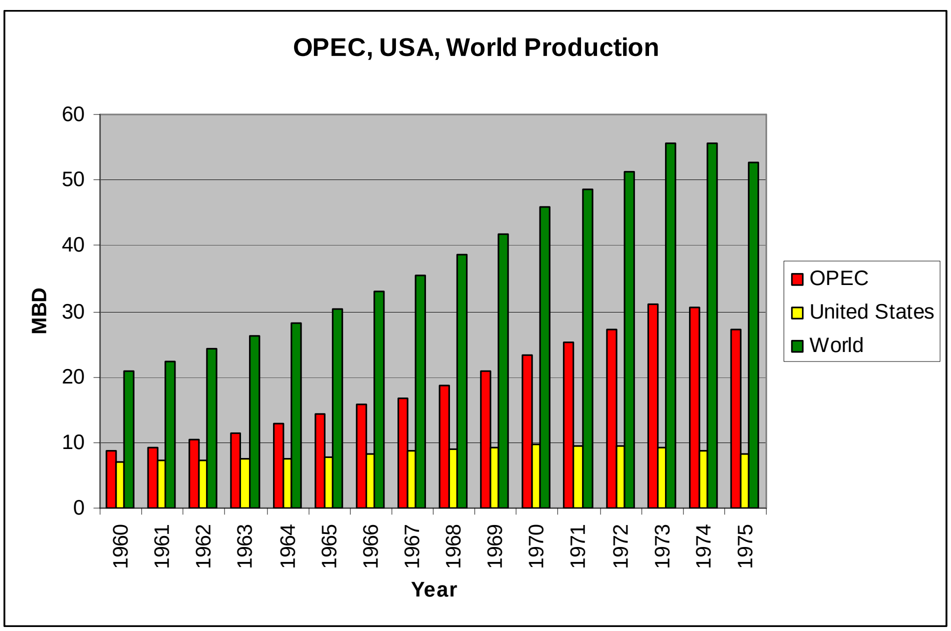

Figure 2 - OPEC, USA, and World Crude Oil Production 1960 – 1975. Data provided by the EIA (www.eia.doe.gov). Chart constructed by author.

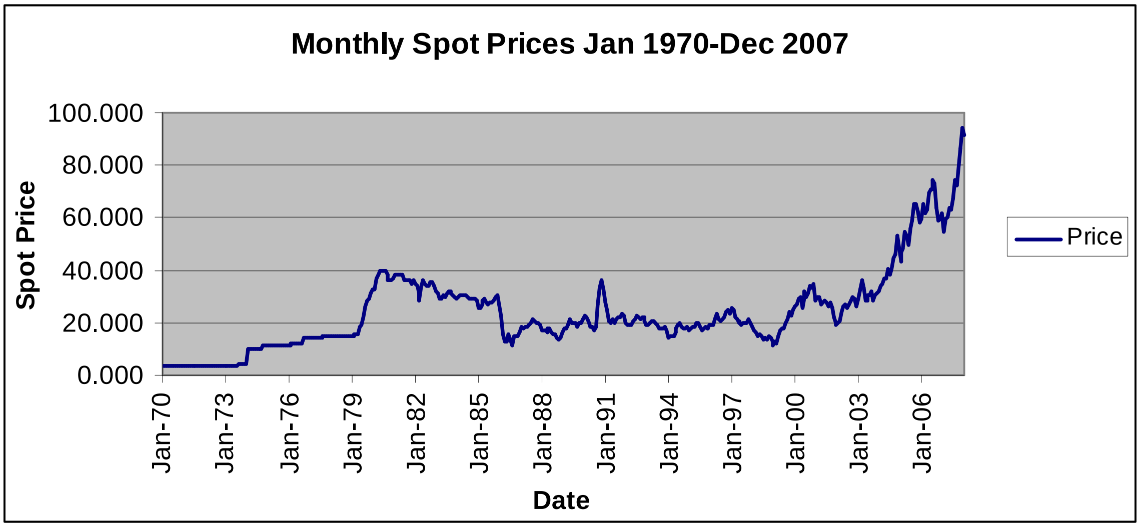

Figure 3 – Monthly Nominal Spot Prices Jan 1970 – Dec 2007. Data source: Federal Reserve Bank of St. Louis. Chart constructed by author.

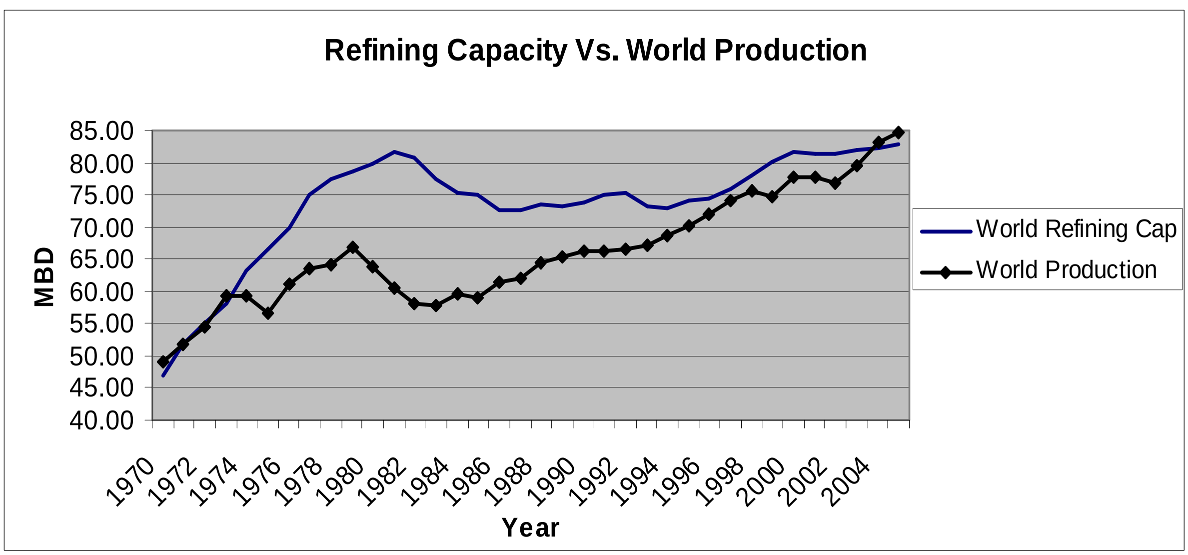

Figure 4 – Annual World Refining Capacity and World Production January 1970 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

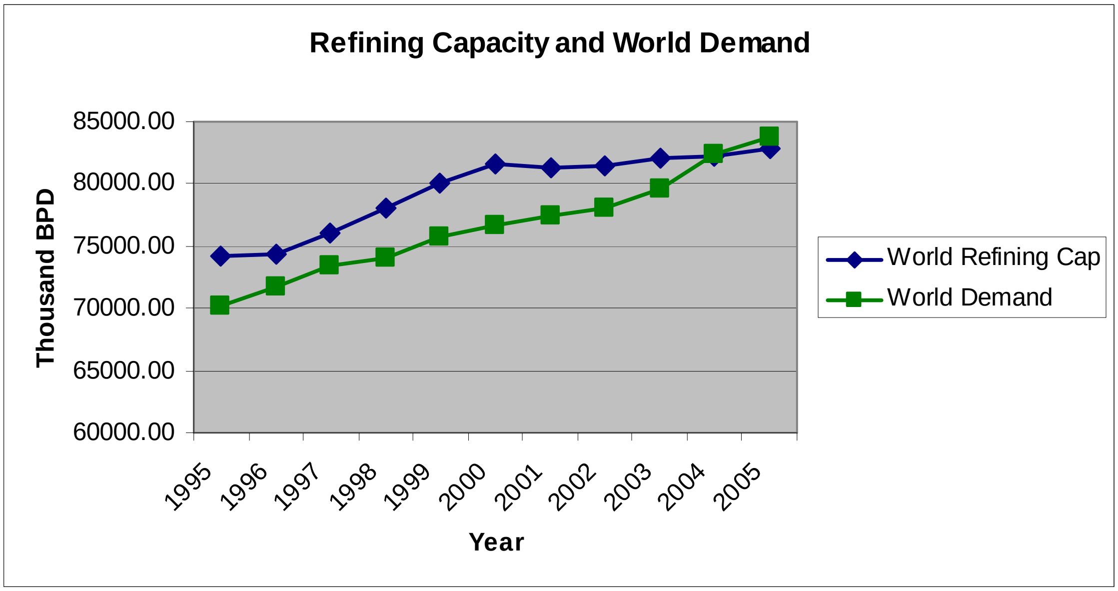

Figure 5 – Annual Refining Capacity and World Crude Oil Demand January 1995 – December 2005. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

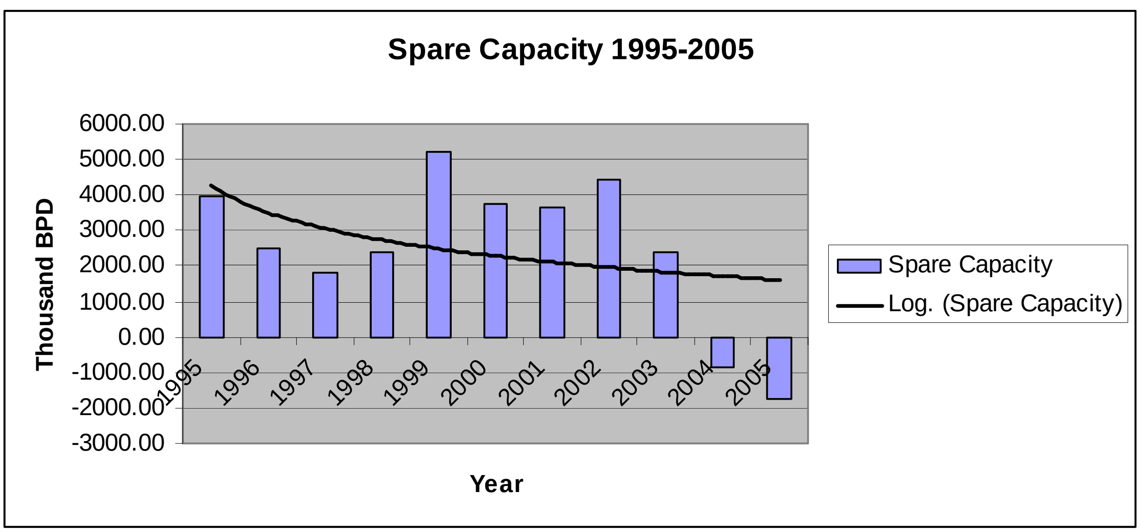

Figure 6 – Annual Refining Capacity January 1995 – December 2005. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

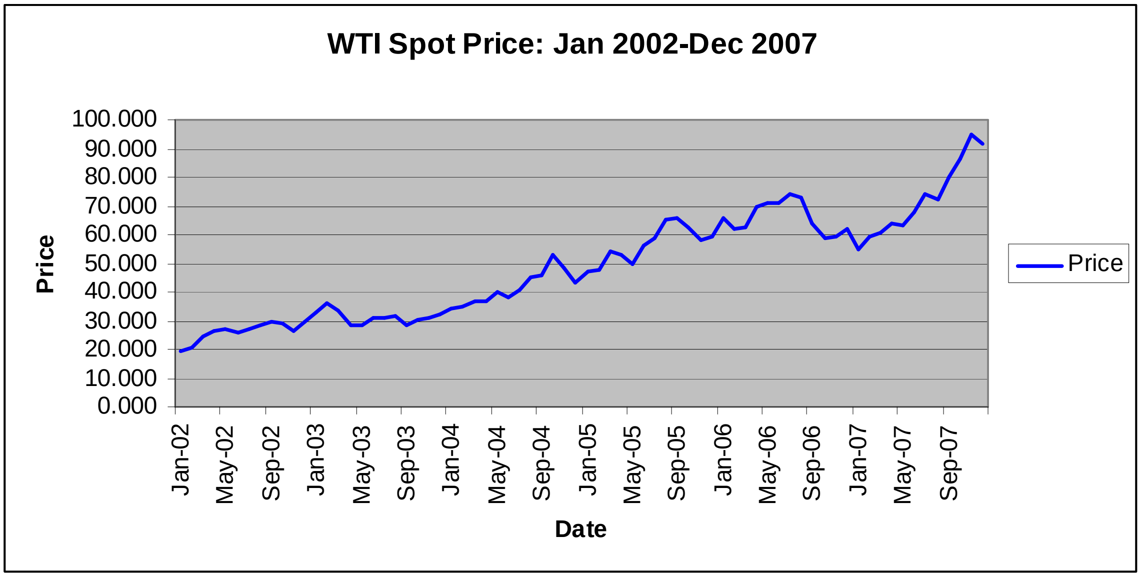

Figure 7 – Monthly Crude Oil Spot Prices January 2002 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

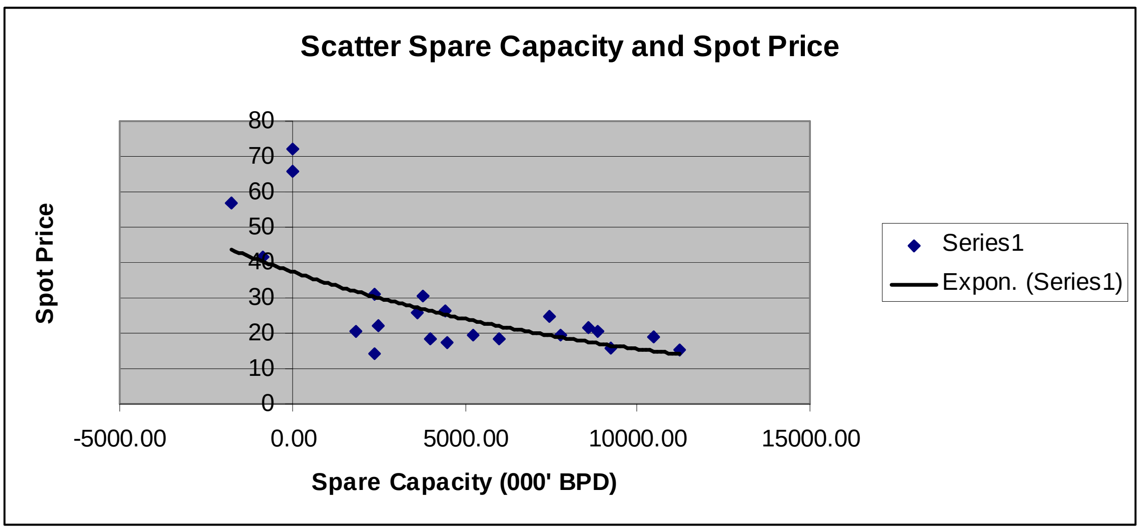

Figure 8 – Scatter plot of crude oil spot prices and spare refining capacity January 2002 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

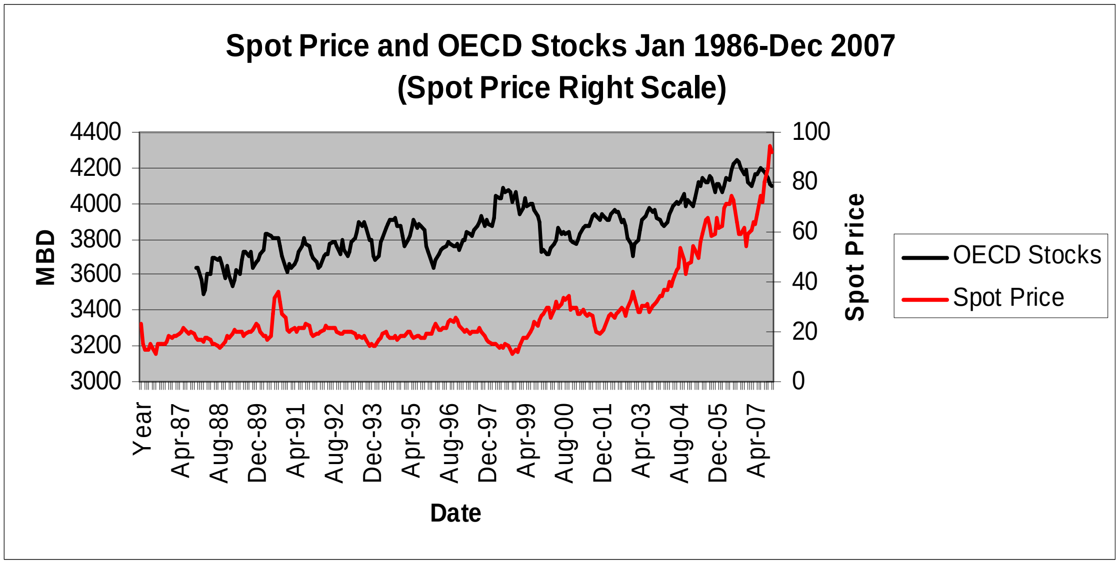

Figure 9 – Crude Oil Spot Price and OECD Stocks January 1986 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

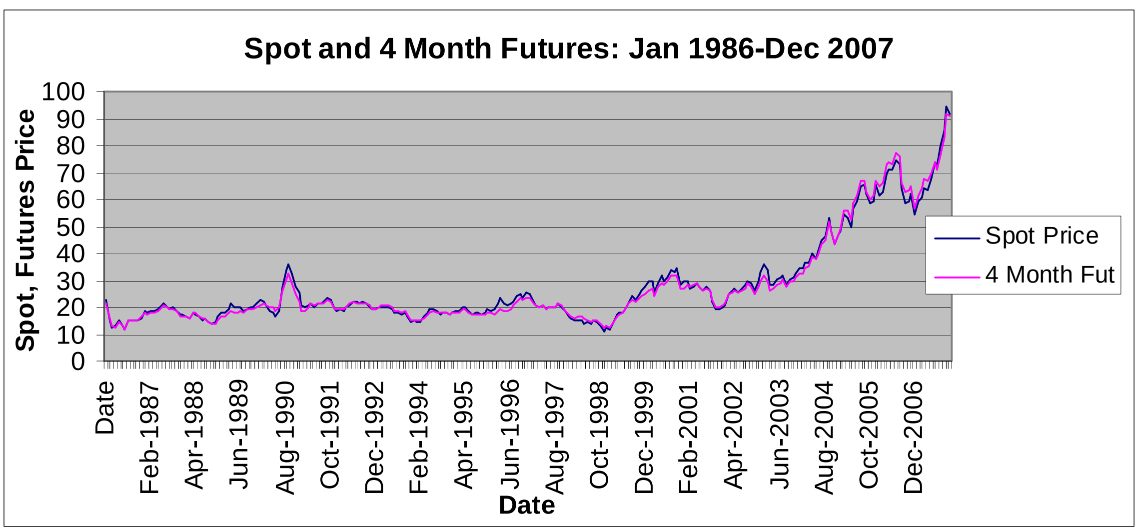

Figure 10 – Crude Oil Spot and 4-Month Futures Prices January 1986 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

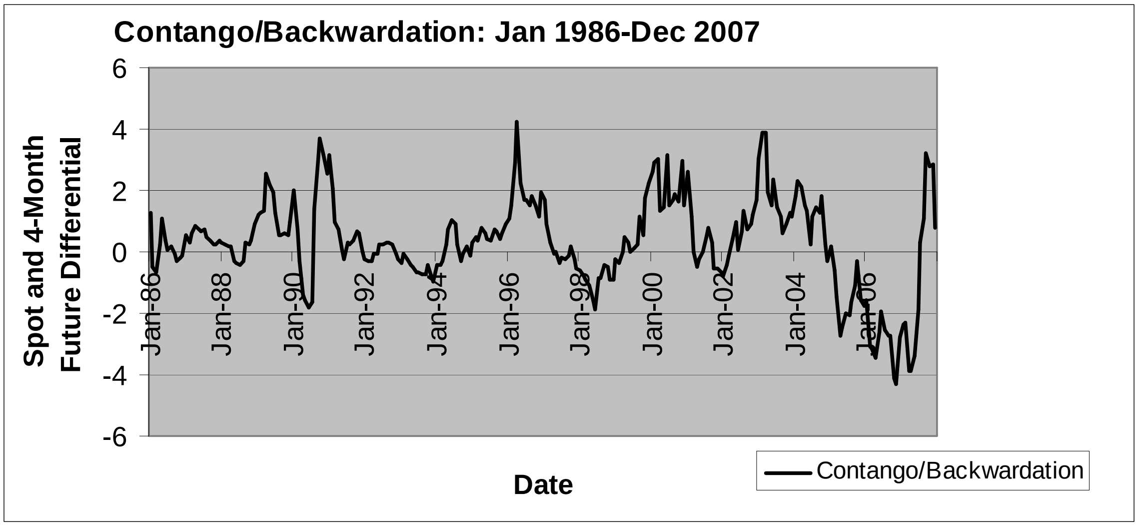

Figure 11 – Spot and 4-Month Futures Price Differential January 1986 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

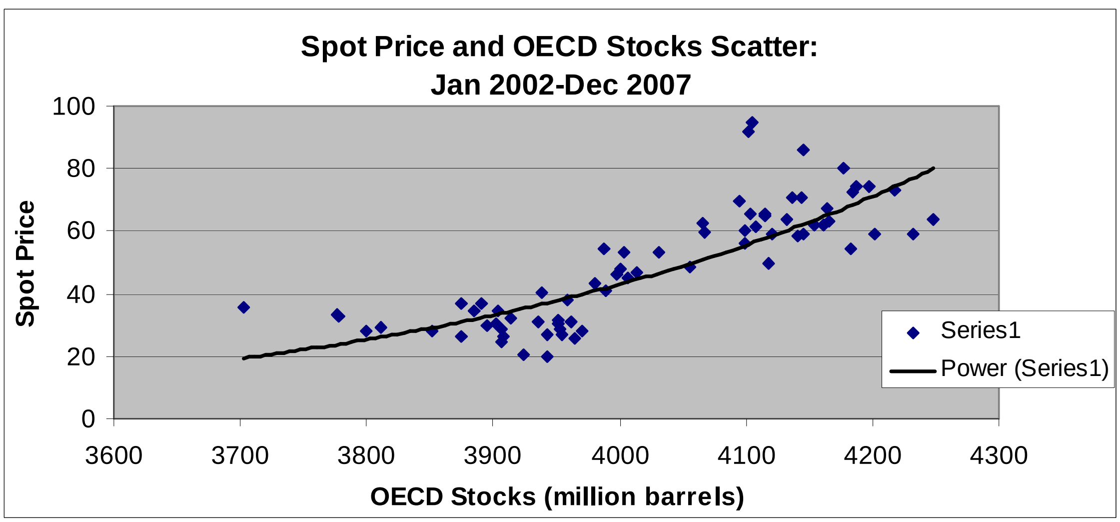

Figure 12 – Scatter plot of spot prices and OECD crude oil stocks January 2002 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

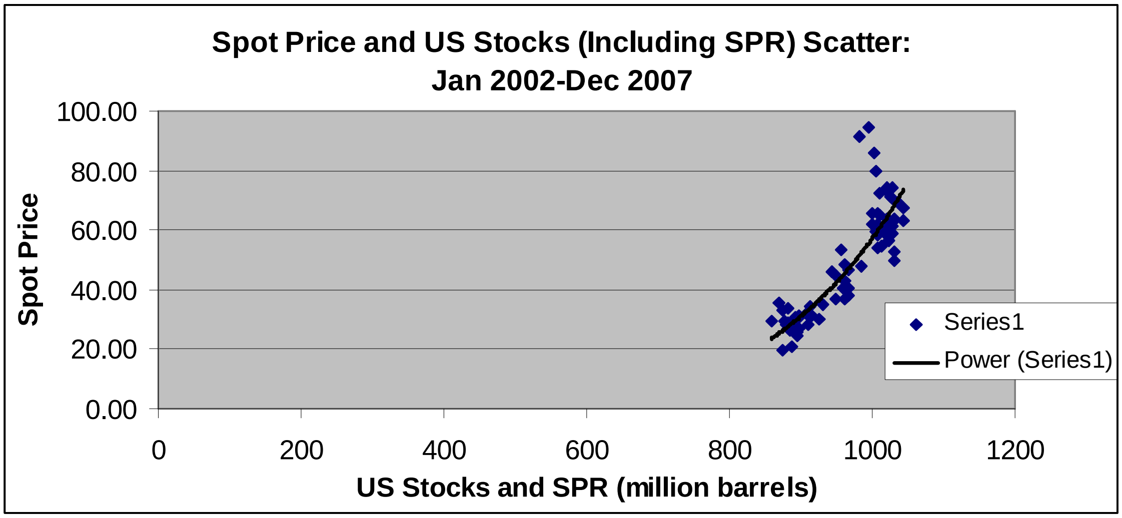

Figure 13 – Scatter plot of spot prices and U.S. SPR crude oil stocks January 2002 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

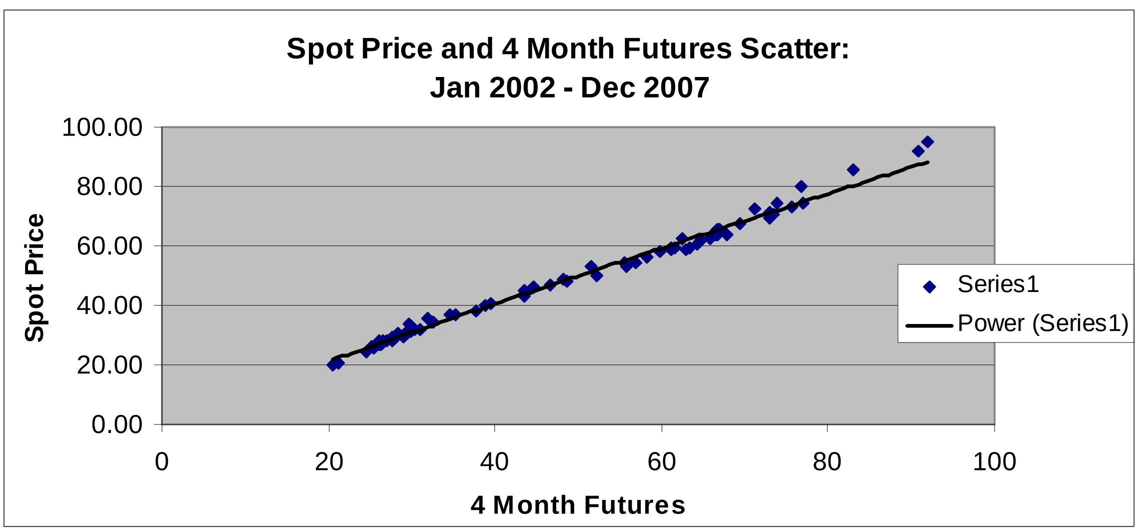

Figure 14 – Scatter plot of spot and 4-month futures prices January 2002 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

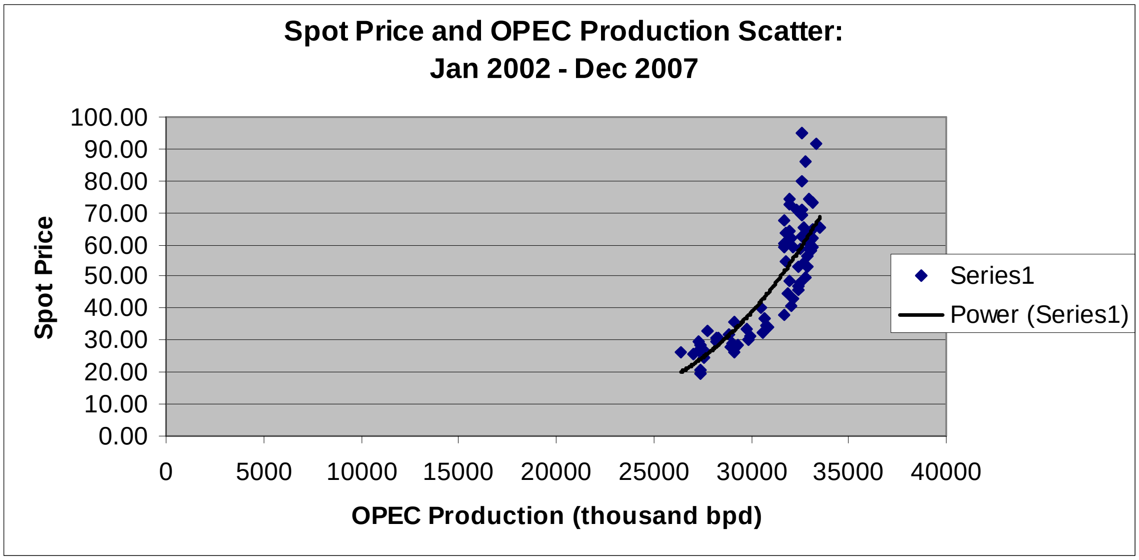

Figure 15 – Scatter plot of spot prices and OPEC production January 2002 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

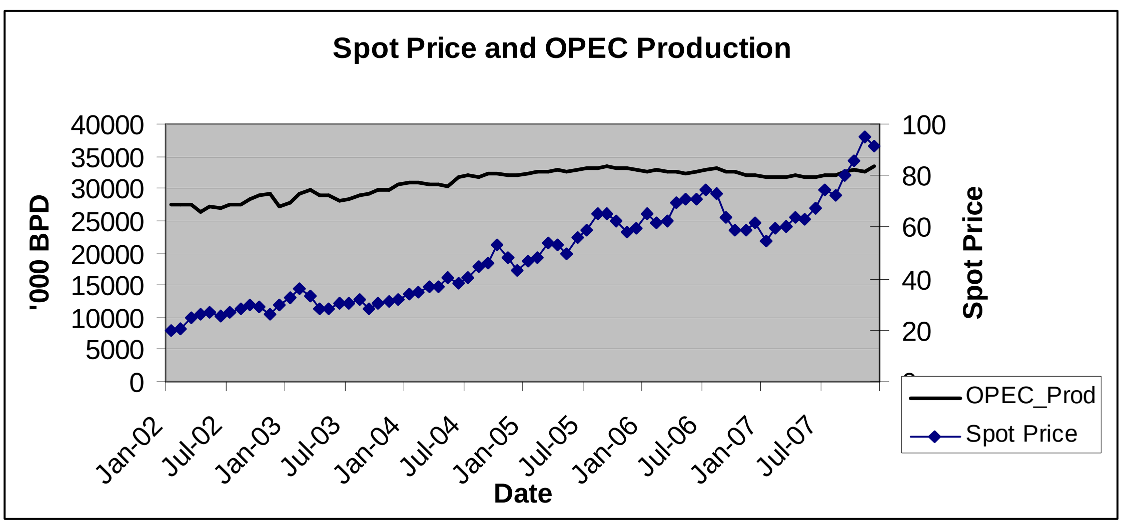

Figure 16 – Spot Prices and OPEC Production January 2002 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

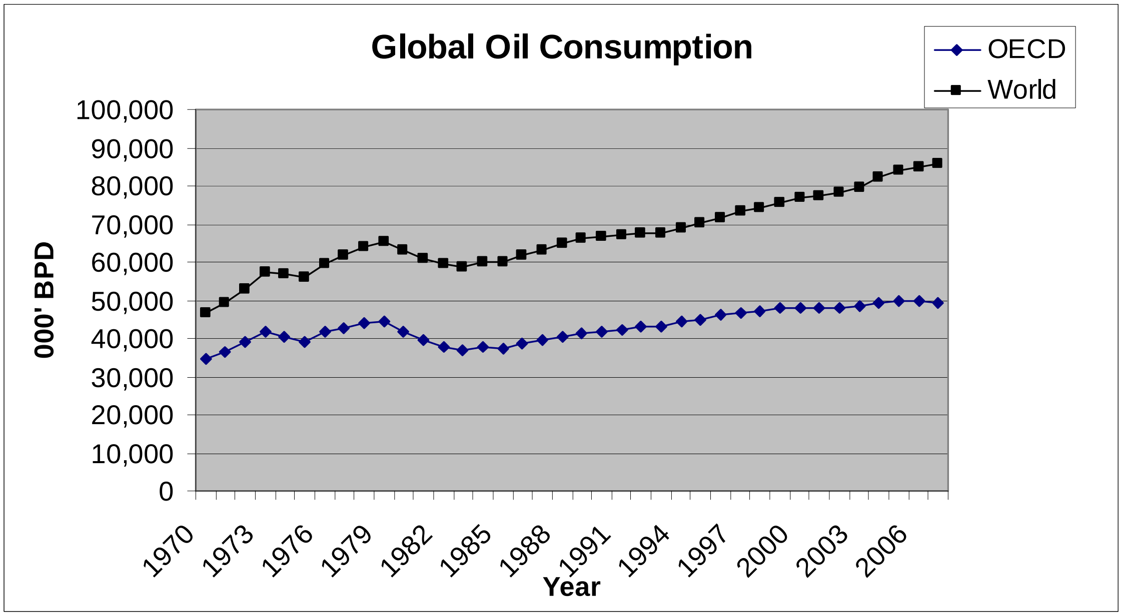

Figure 17 – World Crude Oil Consumption 1970 - 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

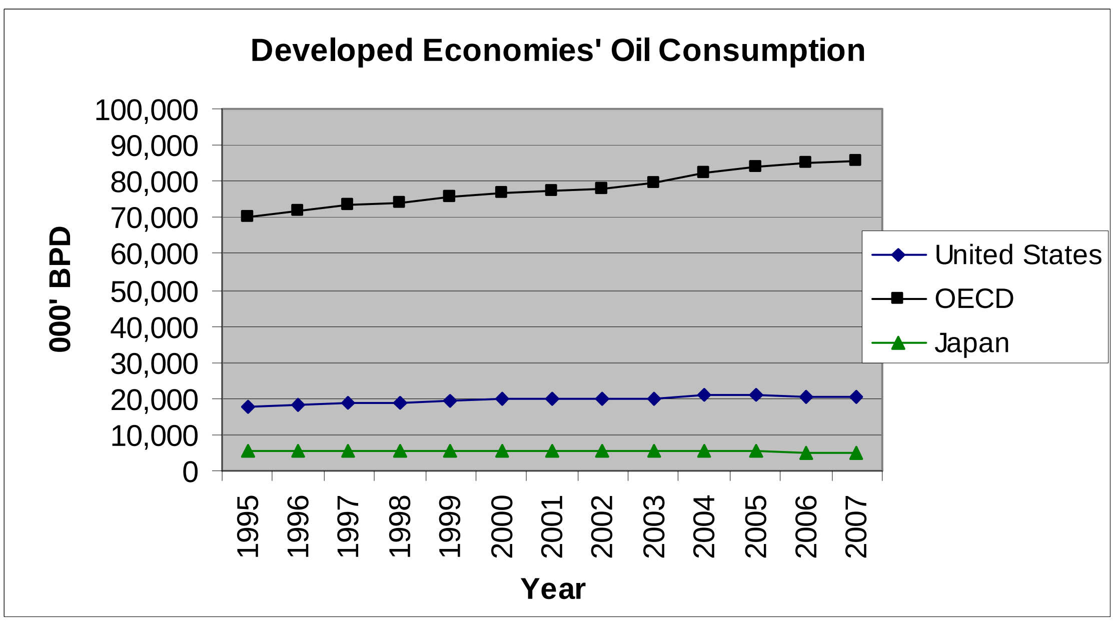

Figure 18 – OECD, US, and Japan Oil Consumption 1995 - 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

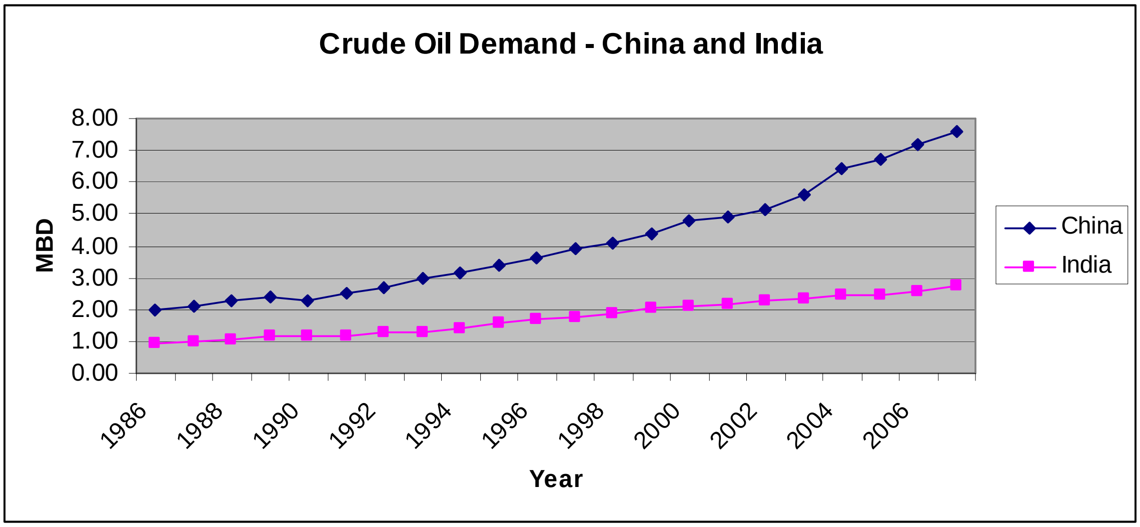

Figure 19 – China and India Oil Consumption 1986 - 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

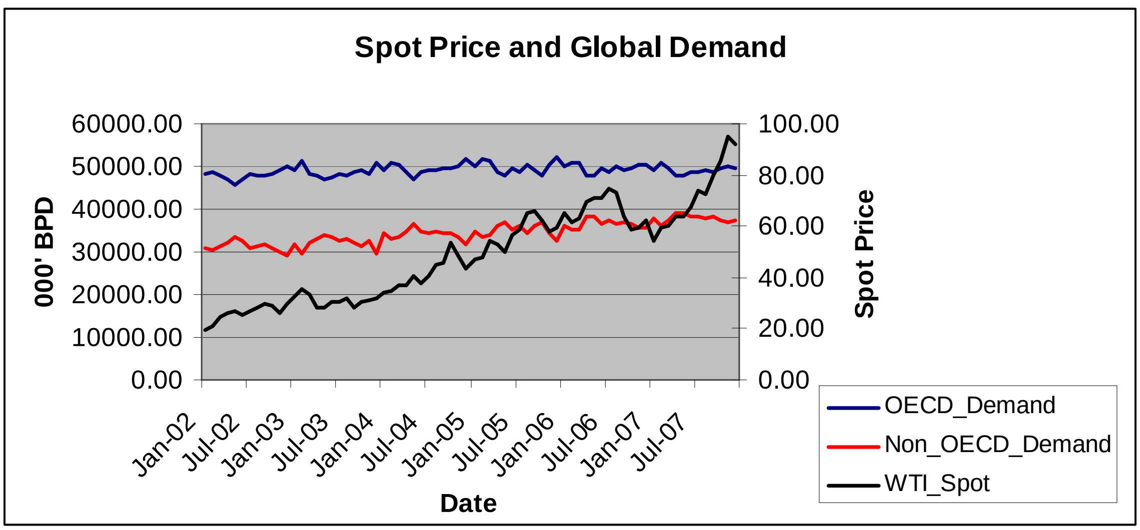

Figure 20 – Spot Price and Crude Oil Consumption January 2002 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

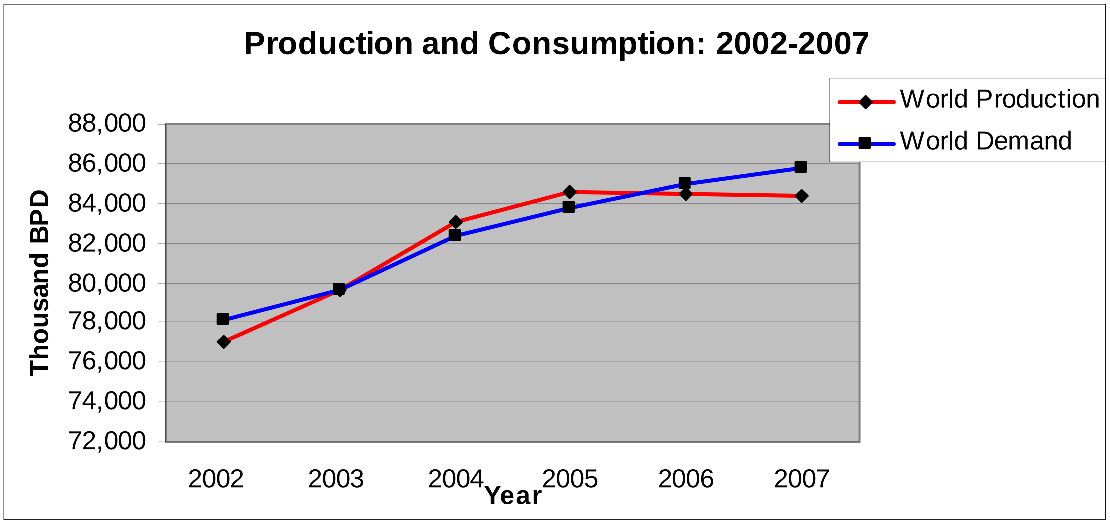

Figure 21 – Crude Oil Consumption and Production January 2002 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

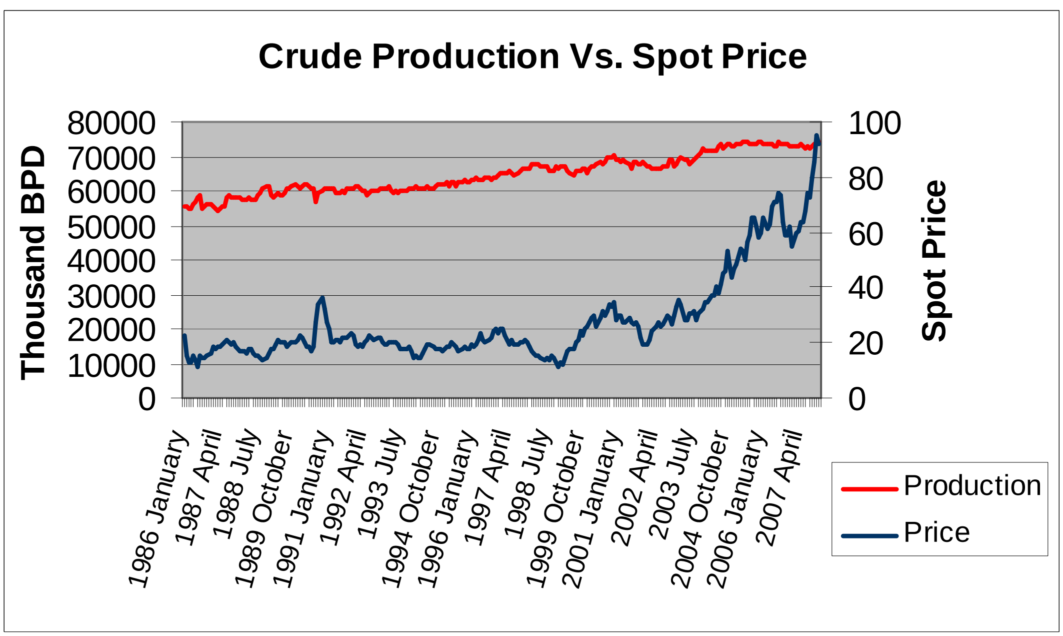

Figure 22 – Crude Oil Production and Spot Price January 1986 – December 2007. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

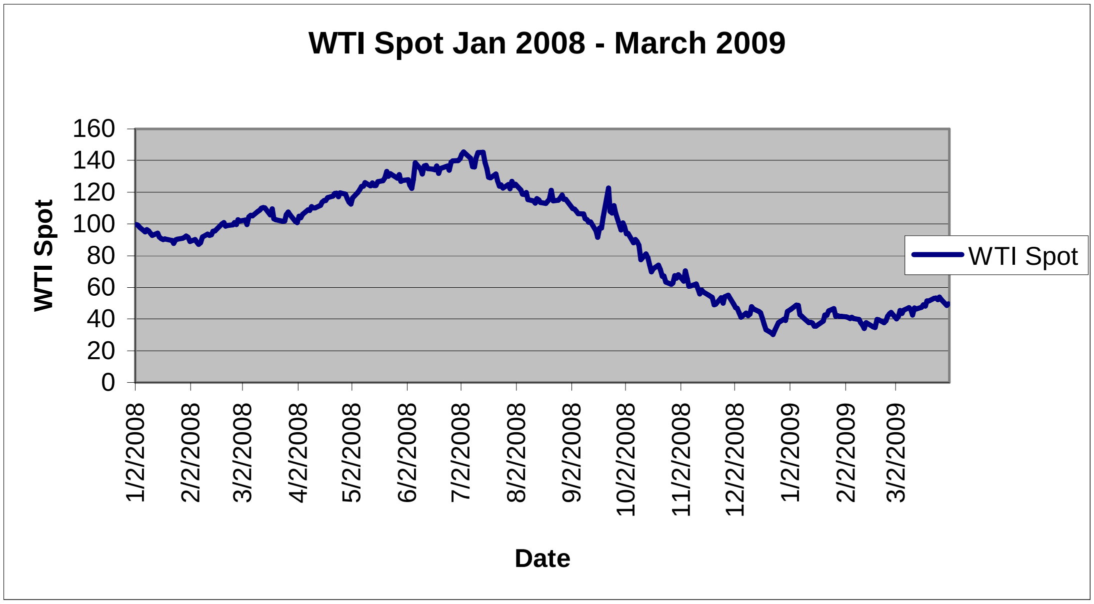

Figure 23 – Daily WTI Spot Prices January 2008 – March 2009. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

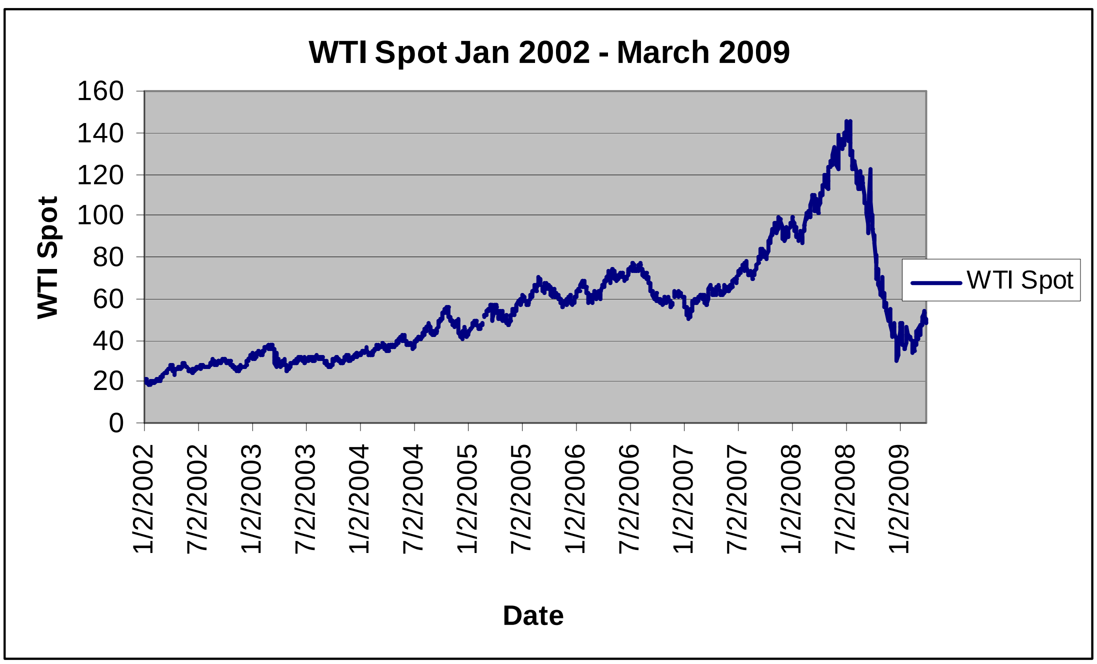

Figure 24 – Daily WTI Spot Prices January 2002 – March 2009. Data source: EIA website (www.eia.doe.gov). Chart constructed by author.

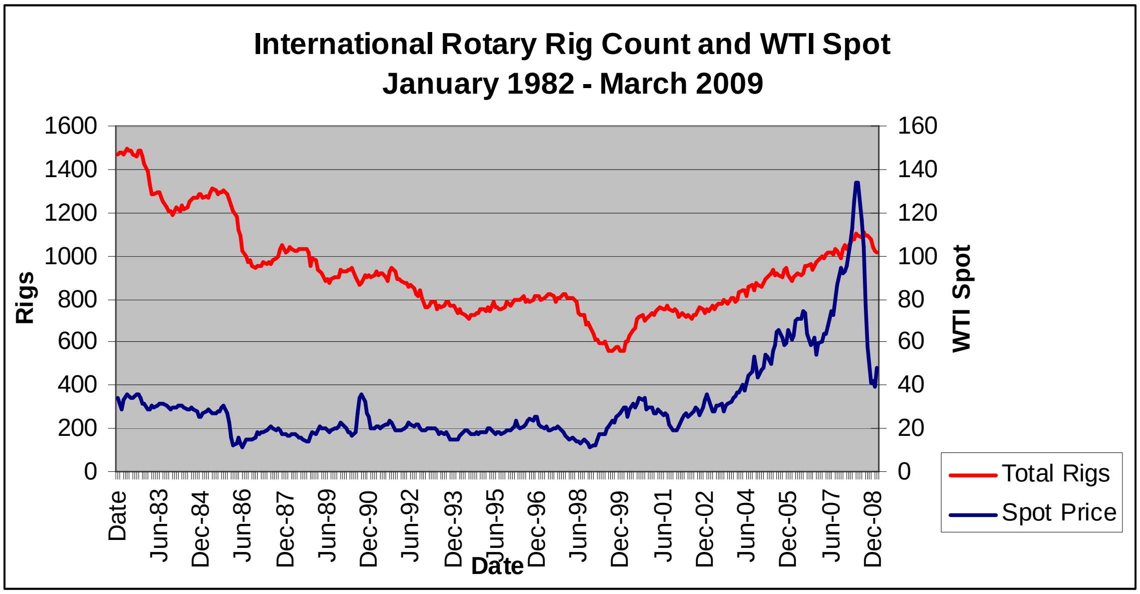

Figure 25 – International Rotary Rigs and WTI Spot Price January 1982 – March 2009. Data source: EIA website (www.eia.doe.gov) and Baker Hughes website (www.bakerhughes.com). Chart constructed by author.