The Drivers of Oil Prices: The Usefulness and Limitations of Non-Structural model, the Demand–Supply Framework and Informal Approaches

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Abstract

We discuss three main approaches for analysing oil prices: non-structural models, the supply–demand framework and the informal approach. Each of these approaches emphasizes a certain set of drivers of oil prices. While non-structural models rely on the theory of exhaustible resources as the basis for understanding the oil market, the supply–demand framework uses behavioural equations that link oil demand and supply to its various determinants such as GDP growth, prices and oil reserves. The informal approach, on the other hand, analyses oil price movements within specific contexts and episodes of oil market history. We use the latter approach to identify the main factors that have affected oil price movements in recent years, analysing whether these drivers reflect structural changes in the oil market. We emphasize that although all the above approaches provide useful insights on how the world oil market functions, they suffer from major limitations especially when used to make long-term projections. Thus, pushing hard for policies based on the projections of such models defeats their purpose and may result in misguided policies.

1. Introduction

The behaviour of oil prices has received special attention in the current environment of rapid rises and marked increase in oil price volatility. It is widely believed that high oil prices can slow economic growth, cause inflationary pressures and create global imbalances. Volatile oil prices can also increase uncertainty and discourage much-needed investment in the oil sector. High oil prices and tight market conditions have also raised fears about oil scarcity and concerns about energy security in many oil-importing countries.

Some observers argue that the oil market has undergone structural transformations that have placed oil prices on a new high path. The adherents of this view point to the erosion of spare capacity in the entire oil supply chain, the emergence of new large consumers (mainly China, and India to a lesser extent), the new geopolitical uncertainties in the Middle East following the US invasion of Iraq and the re-emergence of oil nationalism in many oil-producing countries. Others interpret the recent oil price behaviour in terms of cyclicality of commodity prices. Like all raw materials, the rise in oil price stimulates oil production and slows the growth of oil demand. This would cause oil prices to go down which in turn would stimulate demand and increase the oil price. These different views about the oil market clearly reflect divergent expectations about the future evolution of oil prices (Stevens, 2005).

Oil price behaviour has been analysed using three main approaches: the economics of exhaustible resources, the supply–demand framework and the informal approach. Most analysts using the theory of exhaustible resources as the basis for understanding the oil market conclude that oil prices must exhibit an upward trend (see Krautkraemer, 1998 for a review). The insights from this literature have resulted in the derivation of non-structural models of oil price behaviour that do not explicitly model the supply and demand for oil and other factors affecting them (see for example Pindyck, 1999; Dufour *et al*., 2006). In contrast, in the supply–demand framework, the oil market is modelled using behavioural equations that link oil demand and supply to its various determinants, mainly GDP growth, oil prices and reserves (Bacon, 1991; Dees *et al*., 2007). The informal approach is normally used to identify economic, geopolitical and incidental factors that affect demand and supply and hence oil price movements within specific contexts and episodes of oil market history.

These different approaches are frequently used to make projections about oil prices and/or global demand and supply either for the short term or for the very long-term horizon, often over twenty years. Various players such as governments, central banks and international oil companies rely on these projections for planning energy policy, evaluating investment decisions and analysing the impact of various supply and demand shocks hitting the oil market. Although the above frameworks are useful in improving our understanding of how the different elements of the oil market function, any attempt to use these models to predict oil prices or project oil market conditions in years to come would certainly result in errors. It is not only that these models cannot adequately capture the various shocks that influence the oil market, but equally important, these long term projections and long run oil price forecasts are highly sensitive to the underlying assumptions of the model.

This paper is divided into five sections. In Section 2, we discuss oil price behaviour within the context of the economics of exhaustible resources. In Section 3, we discuss the main building blocks of the supply–demand framework and discuss the limitations of using this approach for making projections. In Section 4, we use the informal approach to discuss the main factors that may have affected oil prices in the current context and whether the influence of these factors is transitory or permanent. Rather than listing a wide catalogue of potential factors, we focus our analysis on four factors: the erosion of spare capacity, the role of OPEC, speculation and inventories. Section 5 concludes.

2. Exhaustibility of oil resources and non-structural models

There is a very wide theoretical research that deals with oil price behaviour within the theory of non-renewable resources (Krautkraemer, 1998). An important characteristic of a non-renewable resource is that it is not replaceable or else replaced at a very slow rate such that once it is used or extracted, the resource is no longer available for use or extraction within a reasonable time horizon. Another important characteristic is that the supply of the non-renewable resource is limited relative to demand. Oil has both these features and thus is treated in this literature as a classic example of a non-renewable resource.

The essential implications of exhaustibility are twofold. First, oil production and consumption in one period affect production and consumption in future periods. Thus, the oil market should be analysed within a dynamic context. Second, oil as a non-renewable resource should command a resource rent. Thus, unlike standard goods, the market price for non-renewable resource is not equalized with the marginal cost. This positive premium, also referred to as scarcity rent, is the reward that the resource holders obtain for having kept their stock up until today.

Hotelling's pioneering work (1931) which forms the basis of the literature on exhaustible resources is mainly concerned with the following question: given demand and the initial stock of the non-renewable resource, how much of the resource should be extracted every period so as to maximize the profit for the owner of the resource? Hotelling proposes a very intuitive and powerful theory to address this question. Assuming no extraction costs and given a market price per unit of resource and real risk free interest rate on investment in the economy r, Hotelling shows that in a competitive market, the optimum extraction path would be such that the price of non-renewable resource will rise over time at the interest rate r. This result is highly intuitive. The owner of the resource has two options: either to extract the oil today or to keep it in the ground for future extraction. Any amount extracted today is not available for extraction in the future and any resource left in the ground can fetch a higher price in the future. If the owner extracts the resource today, he or she can use the proceeds and invest them at an interest rate r. If the price of oil is expected to rise faster than r, then the owner has the incentive to hold on to the resource. If all suppliers behave in a similar manner, the supply would go down causing the current market price to rise. Given this equilibrating mechanism, the optimum extraction trajectory is the one in which the oil price increases in line with the interest rate.[1] This theory also has important implications on the exhaustibility of the resource. Specifically, as the price of the resource keeps rising, demand is slowly choked off

[1] This result still holds in the presence of extraction costs. The main difference is that in the presence of extraction costs, the net price (which is the difference between per unit market price and the marginal extraction costs) would increase at the same rate as r.

and eventually when the price reaches very high levels, the demand for the resource would be eliminated. This point occurs when the exhaustion of the resource is complete.[2]

The theory of exhaustible resources has had an influence on many energy economists' view of oil price behaviour. Most analysts using this theory as the basis for understanding the oil market conclude that the oil price must rise over time. Empirically, this means that oil prices must exhibit an upward trend (Berck, 1995). This gradually rising price trend continued to dominate forecasting models even in the 1980s and 1990s, which witnessed many occasions of sharp oil price falls and despite the fact that most empirical studies have shown that mineral prices have been trend-less over time (Krautkraemer, 1998). As argued by Lynch (2002)

> "for many years, nearly every oil price forecast called for such a trend; as the forecasts proved erroneous, the trend was retained but applied to the new lower point…the combination of these theoretical arguments with the oil price shock of 1979 gave credence to these rising price forecasts, and it has proven difficult to convince casual observers that although prices might rise, it is neither inevitable nor preordained by either economic law or geology." (p. 374–375).

The paper by Pindyck (1999) is an interesting example on how the Hotelling model has been used to construct forecasting models of energy prices. He suggests that rather than use structural models that take into account a wide array of factors including supply and demand factors, OPEC and non-OPEC behaviour, technological advances and regulatory factors, it might be preferable to use simple non-structural models that examine the stochastic behaviour of oil prices. These models are quite flexible and allow oil prices to be modelled as geometric Brownian motion, or mean reverting process or related process with jumps. Pindyck (1999) considers a competitive model in which real oil prices revert to some long-term total marginal cost. Then, using a simple Hotelling model, he shows that oil price reverts to an unobservable trending long-term marginal cost with a fluctuating level and slope over time. Specifically, assuming constant marginal extraction costs c, an iso-elastic

[2] It is important to note that by following the optimum extraction path, the owner of the resource maximizes the discounted flow of reserves over time.

demand curve function with unitary elasticity and initial level of reserves R_0, the price level at any time t is given by

$$P_t = c + \frac{ce^{rt}}{e^{rcR_0/A} - 1}$$

where A is a demand shifter and r is the real interest rate. The slope of the price trajectory can then be written as

$$\frac{\mathrm{d}P_t}{\mathrm{d}t} = \frac{rce^{rt}}{(e^{rcR_0/A} - 1)}$$

From this equation, it can be seen that the slope is affected by demand factors, extraction costs and the level of reserves. Pindyck (1999) argues that since these factors are likely to fluctuate in an unpredictable manner, the price is also expected to revert to a trend line, which is itself fluctuating over time. He uses a generalized Ornstein-Uhlenbeck (OU) process to capture these features and proposes a discrete time model which forms the basis of his empirical work and forecasting exercise. The forecasting performance of the above model is highly mixed and especially poor for the period 1974–85 where there was wide variation in oil prices. But Pindyck (1999) argues that "putting aside the forecasting performance over the past two decades, the model captures in a non-structural framework what basic theory tells us should be driving price movements" (p. 22).

Since the pioneering work of Hotelling (1931), the theory of non-renewable resources has been developed and a number of simplifying assumptions have been relaxed to make models of non-renewable resources more realistic. More recent models allow for the extraction cost to be a function of cumulative production, introduce perfect substitutes for the non-renewable resource which is supplied at high cost but in vast quantities, permit for marginal extraction to vary over time and allow for varying demand and monopolistic market conditions. By relaxing some of the model's initial assumptions, these studies have shown that oil prices can be revised downward or can even follow a U-shaped path (Slade, 1982; Moazzami and Anderson, 1994). For instance, Khanna (2001) finds that the equilibrium price trajectory can be decreasing, increasing or increasing first and then decreasing, depending on whether the growth in demand is higher than the growth in marginal cost of extraction. Furthermore, although the Hotelling model predicts the net price will rise exponentially, it does not imply that the market price paid by the consumer (known as the user cost) has to rise.

The user cost is the sum of scarcity rent and the marginal extraction cost, and the price trajectory will depend on the interaction between these two variables. If extraction costs fall faster than the increase in scarcity rent, the user cost might decline over a period of time. However, as the resource is extracted, the scarcity rent rises rapidly and will eventually dominate the fall in the marginal extraction costs, causing the user cost to rise. Khanna (2001) considers six different scenarios in her simulation analysis. The oil price declines in only one scenario, but only for a short period of time. Khanna (2001) argues that this scenario fits well with the declining price trend during the period 1975–85.

Slade (1982) finds that the price of a non-renewable resource exhibits a U-shaped path. Technological change that lowers extraction cost generates a decreasing path but continuous resource depletion with diminishing return to technological innovation will cause the price to shift to an upward path. In his empirical exercise, Slade (1982) finds that the minimum point of the U-path occurs during the sample period (in 1978), indicating that oil prices should have followed an upward trend from the late 1970s onwards. However, oil prices did not trend upward after the 1970s. In fact, more recent empirical studies conclude that non-renewable resource prices have a stochastic trend and that the property of increasing prices for most non-renewables is not clear, reducing "the prediction of price increase from near certainty to maybe" (Berck and Roberts, 1996, p. 77). This, however, is not the last word on the issue. In more recent work, Lee *et al*. (2006) find support for characterizing natural resource prices as stationary around deterministic trends but with structural breaks.

Despite its main contributions, many economists consider that the literature on resource exhaustibility does not provide any insights into the oil price issue. The main criticism is directed towards the foundations of the Hotelling model: the concept of exhaustibility of resource and that of fixed stock (Adelman, 1990; Watkins, 1992, 2006). Rather than assuming a fixed stock of the resource, Adelman (1990) suggests that oil reserves should be treated similarly to inventories, which are continuously depleted through extraction but continuously augmented through exploration and development.[3] Thus, according to this view, the issue is not one of exhaustibility but

[3] The reserves issue will be discussed in more detail in Section 3.2.

of investment in accumulating inventories and the costs involved in finding new reserves. An important implication of this view is that there is no such thing as scarcity rent and that models based on such a concept do not provide an accurate description of prices in the real world.

Between these two extreme positions, Mabro (1991) argues that when oil is perceived to be plentiful Adelman's main argument holds. However, there have been few instances in history where oil has been perceived to be in limited supply in which case the Hotelling basic proposition that the price might be influenced by expectations of future price is useful. Mabro (1991) argues that the cycle of perceptions will fluctuate depending on oil price behaviour among other factors. Specifically, an increase in oil prices will stimulate exploration and development, which will shift perception towards abundance. This would cause prices to fall, which would then stimulate demand and eventually would lead to a shift in perception towards scarcity.

In my view, Hotelling's original model was not intended and did not provide a framework for predicting prices or analysing the time series properties of prices of an exhaustible resource, aspects that the recent literature tends to emphasize. Furthermore, the application of Hotelling's model to the entire oil industry reduces its usefulness, especially when there is no clear idea about the size of reserves and what should be included in the reserve base. As Watkins (2006) argues, the application of Hotelling's model to the oil industry "distorts Hotelling's insightful work, work directed more at the firm level where the focus is on a deposit of known, fixed quantity" (p. 512).

3. The demand and supply framework

The most widely used framework for modelling the oil market is the supply–demand framework (Bacon, 1991; Dees *et al*., 2007). After all, it is the interaction between demand and supply for oil that ultimately determines the oil price in the long term. However, the special features of the oil market make the modelling exercise quite complex. There are various types of uncertainties when it comes to projecting future oil demand and supply. Some of these uncertainties are due to unknown future events such as geopolitical factors, supply disruptions, environmental disasters and technological breakthroughs. Even abstracting from these unknown events, uncertainty also arises due to the lack of knowledge about factors such as the long run price and income elasticity of demand, the response of non-OPEC supply and above all, OPEC behaviour. Although the demand function can be modelled in a simple manner as a function of price and income, the uncertainties about short and long run price and income elasticities can generate a wide range of demand curve shapes. On the supply side, the issues are much more complex as there are the role of reserves, technology, depletion effect, lags and leads and market structure.

3.1 The Oil Demand

The starting point of most structural models is the demand for oil equation, which is modelled as a function of world economic activity and oil prices. The hypotheses presented are straightforward: higher economic activity should be associated with higher oil demand while higher oil prices should be associated with lower demand for oil. The bulk of the empirical literature has focused on estimating the price elasticity and income elasticity of demand, both in the short and the long run and across a large number of countries.

3.1.1 Price Elasticity of Crude Oil Demand

The relationship between oil demand and price is usually examined within the context of price elasticity of demand, which measures the relationship between the change in quantity of oil demanded and the change in oil price. A few recent studies are enough to show the wide variation in estimated price elasticity. Table 1 below summarizes some of the studies conducted in the 1990s and 2000 for short and long run price elasticity. As can be seen from this table, the estimates range from 0 to –0.64. Despite this wide variation in estimates, it is possible to draw some general conclusions regarding the price elasticity of demand. First, changes in oil prices have a small (and usually insignificant) effect on demand for crude oil, especially in the short run. Second, the long run price elasticity of demand is higher than the short one due to substitution and energy conservation, but the elasticity is still quite low.

Table 1: Price Elasticity of Oil Demand

Studies	Short run	Long run	Sample
Dahl, 1993	–0.05 to –0.09	–0.13 to –0.26	Developing countries
Pesaran *et al.*, 1998	–0.03	0.0 to –0.48	Asian countries
Gately and Huntington, 2002	–0.05 –0.03	–0.64 –0.18 –0.12	OECD Non-OECD Fast growing non-OECD
Cooper, 2003	0.001 to –0.11	0.038 to –0.56	23 countries
Brook *et al.*, 2004		–0.6 –0.2 –0.2	OECD China Rest of World
Griffin and Schulman, 2005		–0.36	OECD
Krichene, 2006	–0.02 to –0.03	–0.03 to –0.08	Various countries

Recently, there have been some attempts to introduce asymmetry into models of oil demand where it is hypothesized that demand for oil responds in an asymmetric fashion to oil price changes. Gately and Huntington (2002) argue that there is an imperfect price-reversibility mechanism in which the short run price elasticity is dependent upon whether there are price cuts or price increases. For instance, an increase in oil price would reduce demand for oil but it is not necessarily true that the decline in oil demand would be reversed by a decrease in oil price. The increase in price may induce investment and a shift towards a more efficient equipment which reduces the demand for oil and the decrease in price would not reverse these responses. Gately and Huntington also point out that the response of oil demand to an increase in the maximum historical price would not be the same as the increase due to price recovery. In order to test their hypothesis, the authors use the following price decomposition: price increases that lead to new historical prices, price increases returning to observed price levels and price decreases. Using this decomposition, the authors find that price elasticities are significantly different across price falls and prices increases and that the most elastic price response of oil demand is due to new price maxima.

Despite the attractiveness of this explanation, Griffin and Schulman (2005) argue quite convincingly that the asymmetric model has the unintended consequence of creating price volatility, which has the effect of shifting inward the intercept of the demand for oil equation. The authors note that this is observationally equivalent to a shift in the intercept due to an energy-saving technical change. Griffin and Schulman (2005) conjecture that rather than relating an asymmetric response of oil demand to oil price, Gately and Huntington's (2002) evidence of price asymmetry is acting as a proxy for energy-saving technical change. Thus, Griffin and Schulman (2005) opt for a fixed effects model of oil demand, which accounts explicitly for technical change through time dummies. Using a panel of OECD countries, the authors find that the hypothesis of price symmetry cannot be rejected after controlling for technical change. Also consistent with stylised facts about energy saving change, they find a decline in the implied estimates of the long run technical efficiency which strengthen their argument.[4]

3.1.2 Income Elasticity of Crude Oil Demand

The relationship between oil demand and GDP is usually examined within the context of income elasticity of demand, which measures the relationship between the change in quantity of oil demanded and the change in income. As in the case of price elasticity of demand, the estimates vary widely according to the method used, the period under study and whether it is applied to developing countries or OECD. Table 2 below summarizes some recent findings. As can be seen from this table, the variation is quite wide ranging from as low as 0.2 to > 1 in some studies. Despite this wide variation, it is possible to draw the following general conclusions. First, oil demand is more responsive to income than prices. Second, the long run income elasticity for oil demand is higher than the short run income elasticity. Third, there is large heterogeneity in estimated income elasticity across countries and/or regions with

[4] Griffin and Schulman (2005) also point to another limitation of using the price decomposition method. The estimates are highly influenced by the starting point of the data. Specifically, it is possible for a change in oil price to be part of either a price increase or change in price increases, leading to new historical prices depending on the period under examination and the starting date of the data.

developing countries exhibiting higher income elasticity than OECD. Finally, the responsiveness of oil demand to income has been declining over time in OECD.

Table 2: Income Elasticity of Oil Demand

Studies	Long run income elasticity	Sample
Ibrahim and Hurst, 1990	> 1.0	Developing countries
Dahl, 1993	0.79 to1.40	Developing countries
Pesaran *et al.*, 1998	1.0 to 1.2	Asian countries
Gately and Huntington, 2002	0.56 0.53 0.95	OECD Non-OECD Fast growing non-OECD
Brook *et al.*, 2004	0.4 0.7 0.6	OECD China Rest of World
Krichene, 2006	0.54 to 0.90	Various countries

3.1.3 Elasticity of Gasoline Demand

Rather than examining crude oil demand, many studies have modelled different groups of finished petroleum products. In this regard, many have been concerned with estimating the price and income elasticity of demand for gasoline (see Dahl and Sterner, 1991; Dahl and Duggan, 1996; Graham and Glaister, 2002 for surveys). Despite its retreat in most other sectors, crude oil and its by-products (gasoline and diesel oil) remain the dominant fuel in the transport sector. In order to take account of this, many studies have included a measure of vehicle ownership in the demand equation. For instance in a recent study, the IMF (2005) distinguished between different types of oil products: transport fuels (gasoline, jet fuel and gas/diesel oil), fuels for residential and industrial sector use (naphta, LPG and kerosene) and heavy fuel oil. While demand for residential and fuel oil is modelled as a function of GDP, transport demand is linked to the number of vehicles which in turn depends on the level of income as proxied by GDP per capita.

It is not possible to review this very wide literature, but fortunately the study by Espey (1998), which performs an international meta-analysis of elasticities covering a wide array of studies published between 1966 and 1997, can provide us with some useful insights.

First, regarding the magnitudes, empirical studies suggest that short run price elasticity estimates for gasoline demand range from 0 to –1.36 with a mean of –0.26 while long term price elasticity estimates range from 0 to –2.72 with a mean of –0.58. Regarding income elasticity, short run income elasticity ranges from 0 to 2.91 with an average of 0.47 while long run income elasticity ranges from 0.05 to 2.73 with a mean of 0.88.

Second, as expected, the author finds that the estimated elasticities are highly sensitive to the behavioural model underling demand. In this respect, his results indicate that the exclusion of vehicle ownership would bias upwards estimates of short run and long run income elasticity.

Third, he finds that estimates using US data are very different from those using other data sets including OECD and European countries. This is to be expected, as in the US a sparse population and a lesser reliance on public transport render car dependence higher than in other countries. However, the price elasticity of gasoline demand outside of OECD is still very low. This is in large part due to high taxes that most OECD governments impose on oil products, weakening the links between international oil prices and gasoline demand. Since taxes represent a large percentage of the price paid by the consumer for gasoline, a rise in international crude oil prices would increase gasoline prices by only a fraction of the increase.

3.1.4 Projections

The relationship between oil demand, prices and income has been used extensively to project global or regional oil demand growth. Table 3 below summarizes some of the widely used projections. As can be seen from Table 3, the differences are widespread. First, the projections are highly sensitive to the assumptions made about economic growth. Second, they are highly sensitive to the income and price elasticity used. Third, the projections are sensitive to the oil price path chosen.[5]

Table 3: Projected Oil Demand (Millions of Barrels per Day)

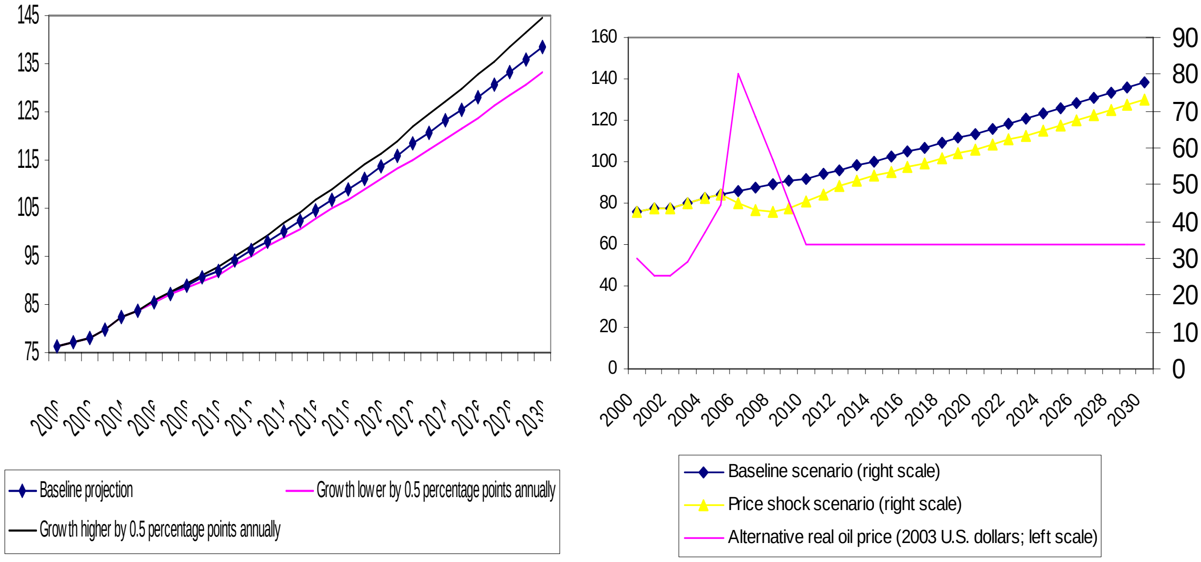
	2003 (Actual)	**2010**	**2015**	**2020**	**2025**	**2030**
IMF, 2005	79.8	92	102.42	113.5	125.5	138.5
EIA, 2006	80	92	98	104	111	118
IEA, 2006	82.5 (2004)	91.3	99.3			116.3

Source: IMF (2005), World Economic Outlook, April 2005, Table 4.5; Energy Information Administration (EIA), International Energy Outlook 2006, Figure 26. International Energy Agency, World Energy Outlook 2006, Table 3.1.

To appreciate the sensitivity of the results to some of these assumptions, Figure 1 below plots the IMF (2005) projections under different growth and price assumptions. The graph on the left shows that lowering growth by 0.5% annually would cause the global oil demand to decline by 5.2 million barrels per day (mbd) from the baseline demand projection. The graph on the right shows that an oil price shock at the beginning of the projection period can cause oil demand to decline by almost 8.5 mbd from the baseline scenario. Fourth, there is the issue of endogeneity of prices and income. Most studies implicitly assume that the price is exogenous, probably set by OPEC, but as argued later this is not a realistic assumption. Finally, most empirical studies ignore the potential relationship between oil price shocks and growth. A wide literature on oil price shocks and growth suggests a feedback mechanism in which oil prices can have a large and significant impact on growth (see for example Jones *et al.*, 2004; Barsky and Kilian, 2004 for a review of this literature). However, the insights and results from this literature have not been so far integrated into the empirical studies on income and price elasticity and these two trends have grown independently from each other.

[5] In the case of IMF (2005), the baseline price path used is that forecast by the World Economic Outlook, from the simple average of WTI, Brent and Dubai prices. In the case of EIA, the high and low oil prices are based on different assumptions about supply of reserves and the cost of producing them.

Figure 1: Sensitivity to GDP Growth and Oil Price Increase assumptions



Source: IMF (2005)

3.2 The Oil Supply: Non-OPEC Supply, Reserves, OPEC Behaviour

Modelling oil supply is much more complex because of the issue of reserves and the behaviour of various suppliers. Concerning the latter, it is useful to distinguish between OPEC and non-OPEC. While it is widely assumed that non-OPEC behaves competitively, OPEC behaviour is much more complex and there are many diverse theories in the literature about its behaviour (see Gately, 1984; Crémer and Salehi-Isfahani, 1991 for reviews). There are many different and diverse suppliers outside OPEC ranging from national oil companies, the large international oil companies and the smaller independents. However, empirical studies do not make the distinction between these various players and usually tend to aggregate oil production outside OPEC or aggregate production in individual countries.

3.2.1 Non-OPEC Supply: The Hubbert Approach

There are two main general approaches to modelling oil supply: the geophysical and economic-based models. The geophysical approach, which is mainly based on the work of Hubbert (1956), stresses geophysical factors in determining non-OPEC oil supply. According to this approach, production is governed by historical cumulative production and the size of ultimately recoverable reserves (URR). Since reserves govern oil production, the eventual depletion of reserves would cause a decline in oil production. According to Hubbert, the production profile of an oil region follows three phases: continual production increase ('pre-peak'), production becomes stagnant ('at peak' or 'plateau') and continual declining production ('decline'). Specifically, based on a particular logistic curve that defines the time path of cumulative production, it is possible to fit symmetrical bell-shaped curves for the annual rate of production. These curves are known as production curves and can be used to generate long-term forecasts of oil production. For constructing these bell-shaped curves, one only needs to estimate ultimate cumulative oil production and the remaining volume to be produced as a percentage of cumulative production.

Hubbert's approach to modelling the oil supply received wide popularity in the 1970s (mainly because of its success in forecasting the annual production of the lower 48 US states) but has recently been widely criticized (see for example Lynch, 2002; Watkins, 2006). A major criticism is Hubbert's treatment of URR as a static variable, while in reality URR is dynamic and has expanded over time due to economic and technological advances. Another weakness is the tendency of the Hubbert model to overestimate the depletion effect. Lynch (2002) reviewed various predictions and found that most of these forecasts have overstated the depletion effect. Thus, far from being symmetrical the Hubbert curves are skewed to the right, indicating other factors such as new investments, the discovery of new fields or a combination of both help offset the decline in production.

3.2.2. Oil Reserves

As can be implied from the above discussion, assumptions made about reserves are central to modelling oil production. The issue of reserves, however, is highly contentious where there is a wide disagreement on the size of global reserves. The estimates vary considerably, ranging from very low estimates of less than 2 trillion barrels of oil equivalent (TBOE) (Campbell, 1989; Campbell and Laherrère, 1998) to moderate estimates of reserves between 2–4 TBOE (USGS, 2000) and high estimates of reserves of excess of 4 TBOE (Odell and Rosing, 1983; Shell 2001)[6]. These widely varying estimates arise due to a number of factors including the different methodologies used, the vested interests, whether studies take into account conventional and unconventional oil and the adoption of different definitions.

[6] This classification is based on Ahlbrandt (2006).

Regarding the latter, the World Petroleum Congress (WPS) and the Society of Petroleum Engineering adopted new definitions for reserves which build on the SEC definition. The new approach introduces elements of probability allowing it to distinguish between proved and unproved reserves. Proved reserves are quantities of petroleum that can be commercially recoverable from known reservoirs given current economic and regulatory conditions, with a 90% probability that the quantities recovered will be equal to or greater than the estimate based on the analysis of geological and engineering data. The definition of unproved reserves is also based on similar geological and engineering data of proved reserves, but there might be contractual, economical, regulatory or technical factors that prevent such reserves from being treated as proved. Unproved reserves can be divided into probable reserves (unproved reserves where there is 50% probability that quantities of petroleum actually recovered will equal or exceed the estimate) and possible reserves (unproved reserves where there is 10% probability that quantities of petroleum actually recovered will equal or exceed the estimate) (Ahlbrandt, 2006; Seba, 1998).

Identifying the underlying assumption about the size of reserves is important because it forms the basis of various projections of future oil supply. Some pessimists predicted that oil would peak in the 1990s (Campbell, 1989). The inaccuracy of such predictions led to a series of revisions and to model modification (for instance, introducing the retardation effect which has the effect of generating a multimodal rather than a unimodal production curve). Other studies based on the USGS data predict the peak in non-OPEC to occur between 2015 and 2020 (Cavallo, 2002). Studies with high estimates of reserves suggest peaks further into the future. For instance, Odell (1998) estimates 3 trillion barrels of conventional oil and 3 trillion barrels of unconventional oil and suggests a peak in 2020 for the former and a peak in around 2060 for the latter (see Ahlbrandt, 2006).

It is important to stress that despite regular discussions of looming oil shortage, the proved reserves to production ratio has increased over the last thirty years indicating strong growth in reserve volumes. Table 4 below shows that although total production has increased from 59 mbd in 1973 to 77 mbd in 2003, reserve additions over these thirty years have risen by more than 500 billion barrels. Thus, not only have reserve additions replaced total production during this 30-year period, but they have become more plentiful compared to 30 years ago (see Watkins, 2006 for a more detailed discussion). The bulk of this growth is not due to new discoveries but mainly due to reserve (or field) growth.[7] For instance, Ahlbrandt (2006) reports that in the last fifteen years reserve growth has added 85% to reserves in the US. The reserve growth can be explained by initial conservative estimates and the application of new technology to exploration and development activity and the new drilling technologies. Regarding the latter, Verma (2000) emphasizes the importance of enhanced oil recovery where new technologies such as water flooding and more complex techniques such as injecting gas has lead to dramatic improvements in recovery rates with some fields achieving 50% or more of original oil in place. Studies of world reserve growth also show that the contribution of reserve growth from adding reserves to existing fields has been more important than the discovery of new fields.

Table 4: Oil Reserves and Production Data

	1973	1983	1993	2003
World Reserves (billion barrels)	635	723	1024	1148
World Output (mbd)	59	57	66	77
World R/P ratio (years)	30	35	42	41

Source: Watkins (2006), Table 1.

3.2.3 Economic-Based Models

Many have argued that since the Hubbert approach is based on the wrong concept of ultimate recoverable reserves, it should not be used for modelling oil supply functions. Hubbert's model has also been criticized for its neglect of the role of economic factors and technology. Economic-based supply models have emphasized that economic factors such as real oil prices and costs, regulatory factors such as the fiscal system and the concession terms and technology play an important role in determining investment and hence oil supply. In this respect, various studies have attempted to estimate price elasticity for non-OPEC oil supply. These studies have shown that the response of non-OPEC production to oil prices, especially in the short run, is very low. On the one hand, producers do not necessarily increase production in the face of a price rise. On the other hand, a reduction in oil prices does not induce

[7] Reserve growth is defined as an increase in estimated sizes of field over time as these are developed and produced.

producers to reduce production. For instance, during the 1970s prices soared and production did not rise as fast. But in the 1980s, prices fell dramatically but production continued to increase. This suggests negative price elasticity of non-OPEC supply during this period.

Although the long run price elasticity is found to be positive, the estimates are quite low but not necessarily in all studies. Krichene (2006) reports a very low long run price elasticity of 0.08 for non-OPEC supply. Alhajji and Huettner (2000) report a long run price elasticity of non-OPEC supply of 0.29. Gately (2004) reports a wide band of price elasticity varying from 0.15 to 0.58 by 2020 while Dahl and Duggan (1996) report a price elasticity of 0.58.[8]

Other more elaborate attempts to estimate supply functions have also been made. Watkins and Streifel (1998) estimate a model in which reserve additions are regressed on some inferred price of discovered but undeveloped reserves, and a time variable which is expected to capture a range of factors including net impact of changes in prospectivity, depletion effects, cost efficiency and technology. The main purpose of their exercise was to test whether the supply function has been moving outward (i.e. expanding) in response to new discoveries and cost saving technologies or moving inward (i.e. contracting) due to depletion effects. Their results indicate that outside North America, non-OPEC supply has been expanding while in North America it has been contracting. The authors warn that the latter result does not indicate that reserves will not be added in North America, but that the diminishing returns on exploration have not been offset by technological or efficiency advancements. It is clear that in such economic-based models, ultimate recoverable reserves play no role in determining the oil supply and are treated as “irrelevant non-binding constraint” (Adelman, 1990).

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[8] In this respect, it is worth noting that the way price enters into the equation depends on whether oil is treated as an exhaustible resource. If oil is treated as an exhaustible resource, then supply is determined by inter-temporal optimization. Thus, the amount supplied will not only depend on current prices, but also on future prices. In this case, whether production will respond to current higher oil prices depends on whether the increase in the expected future price is larger or smaller than the increase in current price. If the former effect is higher, producers would have the incentive not to produce today. If the price increase is expected to be temporary, then the supply curve would have the usual upward sloping curve (Crémer and Salehi-Isfahani, 1991).

3.2.4. Hybrid Models

In general, economic models of oil supply that focus on price elasticity did not prove very successful not only when applied to OPEC production but also when applied to non-OPEC production, where it is assumed that producers are competitive and take prices as given. This is mainly due to complex interaction between geological factors (reserves, depletion and discovery), economic factors (oil prices and technical change), regulatory factors (the fiscal system) and political factors (sanctions and political turmoil). There have been a number of attempts to construct models which combine geophysical with economic factors, referred to as hybrid models (Kaufmann, 1995; Moroney and Berg, 1999; Kaufmann and Cleveland, 2001). An early attempt was made by Kaufmann (1991), who calculated the difference between the actual and the predicted production curve based on Hubbert's model. The difference was then regressed on a number of economic and regulatory variables. In a more recent empirical study, Moroney and Berg (1999) use an integrated model which includes both economic and geophysical factors. Specifically, they model oil supply as a function of the stock of reserves, the real price of oil and dummy variables to account for regulatory factors. They use a partial adjustment model to account for the fact that producers react gradually to changes in the environment. For the US, Moroney and Berg (1999) find a wide band of price elasticity estimates ranging from 0.057 to 0.19, depending on the model used. Their results also indicate a unitary long run elasticity of production with respect to lagged reserves.

3.2.5 Projections of Non-OPEC Supply

Given the different models and the wide range of elasticity estimates, it is no surprise that non-OPEC supply projections differ considerably across studies and over time. Table 5 below reports the EIA and IEA projections of non-OPEC supply. As can be seen from this table, while the EIA expects a relatively high non-OPEC supply growth, the IEA is more conservative about the potential contribution of non-OPEC. The large difference in the projections is mainly due to differences in the estimates of the responsiveness of non-OPEC supply and unconventional liquids to oil prices and whether non-OPEC oil supply reaches a peak during the projection period. In fact, the large EIA revision in 2006 is partly due to the more optimistic view about the potential of unconventional liquids, which would become highly economical at the projected high oil prices. The IEA (2006) predicts that unconventional supplies will reach 9.7 mbd in 2025 and 11.5 mbd in 2030. This is a substantial upward revision from its 2005 Annual Energy Outlook where unconventional supplies were estimated to reach 5.7 mbd in 2025.

Table 5: Non-OPEC Oil Production Projections

	2010	2015	2030
EIA, 2006	54.4	58.6	72.6
EIA, 2005	56.6	61.7	66.2
IEA, 2006	53.4	55.0	57.6

3.3 OPEC Supply

Studying OPEC supply behaviour is crucial for understanding the oil market and long run oil prices. However, OPEC behaviour is very complex to model (see Fattouh, 2007a for a recent review). Many conflicting theoretical and empirical interpretations about the nature of OPEC and its influence on world oil markets have been proposed. The debate is not centred on whether OPEC restricts output, but the reasons behind these restrictions. Some studies emphasize that OPEC production decisions are made in reference to budgetary needs, which in turn depend on the absorptive capacity of the members' domestic economies (Teece, 1982). Others explain production cuts in the 1970s in terms of the transfer of property rights from international oil companies to governments, which tend to have lower discount rates (Johany, 1980; Mead, 1979). Others explain output restrictions in terms of coordinated actions of OPEC members. Within this literature, OPEC behaviour ranges from classic text book cartel, to two-block cartel (Hnyilicza and Pindyck, 1976), to clumsy cartel (Adelman, 1980), to dominant firm (Salant, 1976; Mabro, 1991), to loosely co-operating oligopoly, to residual firm monopolist (Adelman, 1982) and most recently to bureaucratic cartel (Smith, 2005). Others suggest that OPEC oscillates between various positions but always acts as a vacillating federation of producers (see for instance Adelman, 1982; Smith, 2005). The existing empirical evidence has not helped narrow these different views.

There has been an extensive debate on the usefulness and limits of the various models. This debate is beyond the scope of this paper. What is important to emphasize, however, is that each of these theories implies a different OPEC behaviour and hence supply decisions and pricing rule. We use two theories to clarify this point. In models that consider OPEC as a monopoly owner of an exhaustible resource, the organization's behaviour is highly predictable: it would choose prices or quantities such that the marginal revenue minus marginal extraction cost increases at the rate of interest (Pindyck, 1978). The target revenue theory hypothesizes that OPEC responds to rising oil price by cutting production, and to a fall in oil prices by expanding output i.e. a negative price elasticity of supply. The underlying intuition behind this theory is simple. Supply decisions are determined by a country's national budget requirements: a function of the economy's ability to absorb productive investment. This is defined as the ability of the country to attract investments within a period of time at a certain rate of a return. Thus, rises in oil prices entail holding production constant or reducing production in order to meet the target revenue. If many countries follow the target revenue rule, then simultaneous cuts in production could increase oil prices even without any coordination from OPEC members (Teece, 1982).

Modelling OPEC supply creates a serious challenge for the supply–demand framework. Simply put, it is not possible to describe OPEC as a cartel or oligopoly while at the same time use a competitive supply–demand framework for analysing the long run behaviour of the oil market. In a recent study by Dees *et al*. (2007), the model is closed by considering OPEC to act as a swing producer, equilibrating demand and supply with optimal prices/quantity levels. To consider the implication of this assumption, consider the impact of a permanent increase in the price of oil. Based on their simulation model, this would cause oil demand to fall, non-OPEC production to increase (although the response is quite inelastic) and OPEC to cut its production to balance supply and demand.

A more standard way to close the model has been to treat OPEC supply decision as a residual, often referred to as the 'call on OPEC', which is the hypothetical amount that OPEC needs to produce to close the gap between oil demand and non-OPEC supply. In other words, projections about OPEC supply are not based on behavioural analysis but derived from a simple accounting formula that balances world demand after taking into account various factors. This approach has been widely used to project OPEC supply.[9] Table 6 below presents various projections on the call on OPEC. As can be seen from the table, the projections vary widely, with the difference between the lowest and highest estimate in 2030 reaching 29.1 mbd. Also notice the wide divergence between the upper and lower bounds, which in some instances can reach more than 20 mbd.

Table 6: Projections of OPEC Call

	2010	2020	2025	2030
EIA, 2006 (Upper bound–Lower bound)	32.9–37.9	29.3–43.3	29.8–46.9	30.9–51.0
IMF, 2005 (Upper bound–Lower bound)	30.6–32.7	43.5–49.2	51.6–61.0	61.3–74.4
IEA, 2006 (Baseline scenario)	35.9			56.3

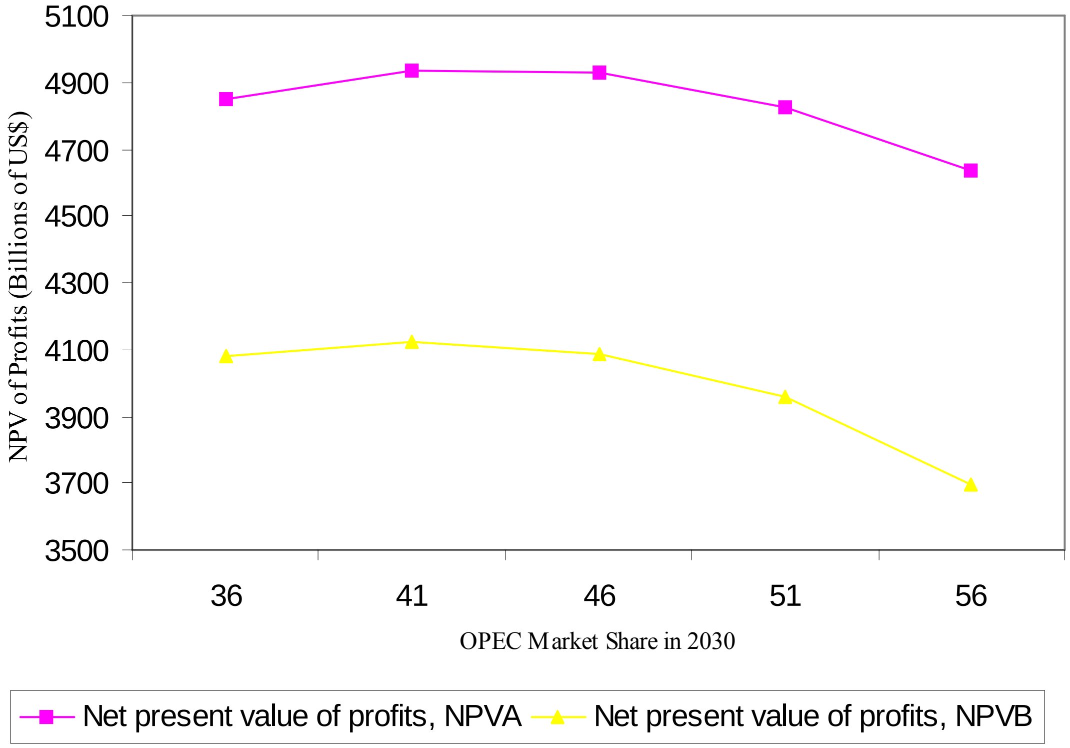
Although calculating OPEC supply as a residual overcomes the problem of modelling OPEC's complex behaviour, this approach suffers from two major limitations: it assumes that OPEC has the incentive to expand output and that the necessary investment to increase capacity would materialize.

The above projections implicitly assume that OPEC has the incentive to increase market share without any regard to oil prices. Rather than calculating the OPEC supply as a mere residual, Gately (2004) calculates OPEC's net present value (NPV) of profits for different choices of OPEC's market share. His main finding is that the NPV of the discounted profits are relatively insensitive to higher output growth. In fact, aggressive plans to expand output can yield lower payoff than if OPEC decides to maintain its market share. This result is quite intuitive. Given certain assumptions about the model parameters, the increase in discounted expected profit from higher

[9] In addition to long-term projections, the demand and supply framework has been used to study the impact of various shocks on oil prices. For instance, Dees *et al*. (2007) consider a model which incorporates a pricing rule generating various types of shocks. These shocks include demand, supply, stocks and OPEC output decisions. For instance, in their model a 10% increase in OPEC quota decreases the price of oil, causing the demand to increase. After a series of oscillations in which demand and oil price react to each other, the price of oil goes down by 10%. Using a similar oil market model, Brook *et al*. (2004) examine the impact of a serious supply disruption on oil prices. In the bad case scenario, they find that a 7% oil supply shock would raise the oil price by around $20 in the first year and prices would fall back to the baseline relatively quickly. These types of exercises are very useful, but they are highly sensitive to the various parameters and the way the model is closed.

output would be more than offset by lower prices as a result of a rapid output expansion. Gately (2004) thus concludes that the projections made by EIA and IEA of rapid increases in OPEC output and rapid increase in market share for its current level are implausible and "are likely to be contrary to OPEC's own best interests" (p. 88). He notes that the incentive to increase capacity at a rapid pace might exist only under the assumptions of high price elasticity of world oil demand and if non-OPEC supply is more responsive to high oil prices.[10]

Figure 2: Profitability of Various OPEC Market Strategies



Notes: NPVA corresponds to the NPV of discounted profits in the baseline scenario with the IEA non-OPEC supply path. NPVB corresponds to the NPV of discounted profits in the baseline scenario with US DOE non-OPEC supply path. Source: IMF (2005).

Figure 2 above shows that the optimal strategy for OPEC is to maintain a market share between 41 to 46%. This is well below the shares projected by IEA, EIA or the IMF. For instance, in the IMF baseline scenario, the call on OPEC is predicted at 61.3–74.4 mbd. Given oil demand at 138.5 mbd, this implies a market share of 54% in 2030. This is much higher than anticipated if OPEC capacity expansion is analysed within the profit maximization framework.

[10] In a separate paper, Gately (2001) reaches the same conclusion regarding Persian Gulf oil producers.

Furthermore, even if OPEC has the incentive to increase market share, the investment needed to attain those shares is quite substantial. This investment, however, may not materialize for a number of reasons such as uncertainty, unfavourable geopolitical factors and sanctions, the relationship between the government and the national oil company and the relationship between the governments and/or national oil companies and the international oil companies (see Fattouh and Mabro, 2006 for a detailed analysis of the causes of under-investment in the oil sector).

3.4 Conclusion

The supply–demand framework explains oil market behaviour in terms of factors that determine demand (income and price) and supply (price, reserves and OPEC behaviour). Although this approach is useful for gaining better understanding of the oil market, using this framework to project oil prices is likely to result in mistakes for a number of reasons. First, they are highly sensitive to the assumptions made about income and price elasticity of demand, the price elasticity of supply, the role of reserves and OPEC behaviour, which is essential to close structural models. Second, the above framework cannot capture the impact of unexpected shocks. These shocks are central to understanding the behaviour of oil prices, since evidence suggests that shocks can be persistent (Cashin *et al.*, 1999). One important implication of shock persistency is that "it is incorrect to view shocks to commodity prices as generally being a temporary phenomenon that largely reflect short-lived variability in supply interacting with relatively unchanging demand". Instead, these shocks are long lived and have enduring effects and in some instances may shift oil price to a new path. Third, the above framework does not take into account the general geopolitical context and market conditions in which oil prices are determined. It is true that demand and supply determine the oil price in the long term, but they do so in a specific context. Unfortunately, the supply–demand framework analyses oil prices and makes projections in a 'neutral context'.

4. Drivers of Oil Prices in the Current Context: An Informal Approach

The rise in oil prices and the increase in oil price volatility experienced in the last three years led many analysts to argue that factors other than changes in elasticities or reserves can also influence oil market developments, at least in the short run. In analysing the recent rise in oil prices, researchers have resorted to a wide list of drivers including strong demand (mainly from outside OECD), lack of spare capacity in upstream oil, distributional bottlenecks, OPEC supply response, geopolitical and weather shocks and the increasing role of speculators and traders in price formation. In this section, we discuss some of the factors that can explain the recent behaviour in oil prices and whether the influence of these factors on the oil market is temporary or permanent. We focus on the role of OPEC, the erosion of spare capacity, the role of speculation and inventories. The analysis in this section falls within the informal approach which analyses oil price behaviour within a specific economic and political context. Although this approach is essential to understanding current and past developments in the oil market, it can only provide a cursory view about how the oil market and oil prices might develop in the future, and hence is of limited use to making projections.

4.1 OPEC and Oil Prices

As in any other issue related to OPEC, there are divergent views regarding OPEC pricing power. There seem to be switches in perception, shifting from one extreme where OPEC is perceived to play no role or a very limited role in pricing to the other where OPEC is perceived to be a price setter. These switches in perception became very apparent in the events that surrounded the oil price collapse in 1998 and the oil price hike in 2004. In 1998, when the Dubai price approached the $10 per barrel, many observers claimed that OPEC had lost its ability to defend oil prices with many of them predicting its demise. This view of ineffective OPEC, however, was reversed only a few months later, with many observers in the media considering the events of 1997 as inducing great cooperation among OPEC members and ushering in a new era for OPEC.[11] In the high oil price environment of 2004, there was another switch in perception where doubts re-emerged about the pricing power of OPEC.

In 1986 OPEC abandoned fixing the reference price in favour of a system in which OPEC sets production quotas. By altering production quotas, OPEC is bound to have an influence on oil prices. OPEC sets production quotas based on its assessment of the market's call on OPEC supply, and oil prices fluctuate partly according to how well OPEC does this calculus and how the market responds to OPEC signals.

Although OPEC has on many occasions succeeded in defending the oil price, adjusting output downward has sometimes proved to be unsuccessful. Because of the different features, needs, bargaining power and divergent interests of member countries, OPEC cannot usually reach an agreement on the allocation of production cuts (e.g. Kohl, 2002; Libecap and Smith, 2004). These problems become more acute when the required cuts are significant. In these circumstances, market participants would doubt the credibility of OPEC's decision to cut production and may decide to ignore the signal. Adjusting output in the face of growing global oil demand can also be problematic, but for different reasons. Although agreements to increase quotas are easier to reach and implement when global demand is rising, OPEC may not respond fast enough to this upward trend in an environment of imperfect information and uncertainty about future demand. The rise in global demand for oil can have an impact on OPEC pricing power through another channel: the erosion of spare capacity. This became very evident in 2004 when doubts about the ability of the dominant producer, Saudi Arabia, to supply the market with additional supplies of the required quality of crude rendered any OPEC announcements of production increases ineffective.

The pricing power of OPEC is therefore not straightforward. First, its pricing power varies over time. Second, the change in pricing power is induced by market conditions and can occur both in weak and tight market conditions. Third, pursuing output

[11] See for instance, Stanley Reed, "Cheap Oil? Forget It", Business Week. 3/8/2004, Issue 3873 and Weston and Christiansen (2003).

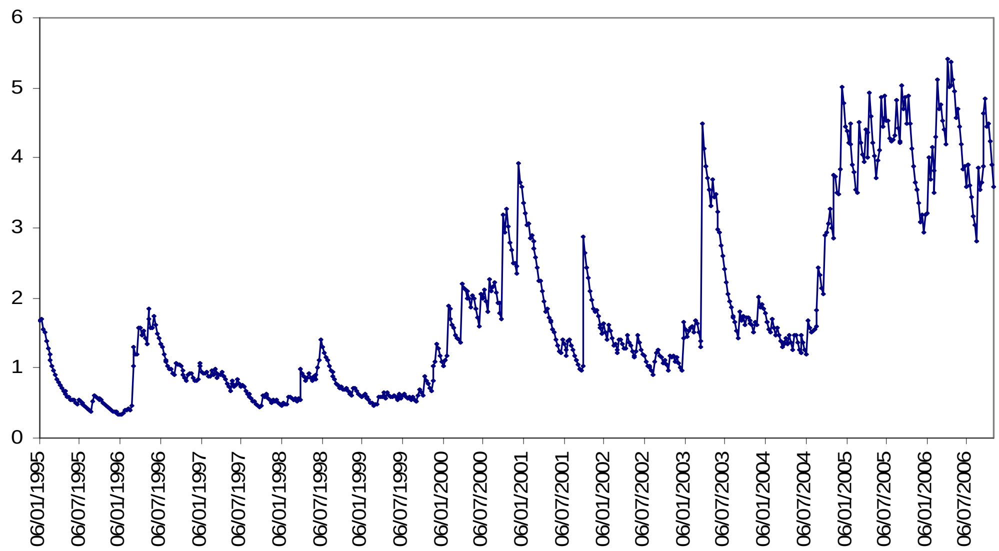
polices has become more complicated with the growing importance of the futures market in the process of oil price discovery (Fattouh, 2007b).

4.2 Erosion of Spare Capacity and Oil Price Dynamics

The oil price hikes in 2004 and 2005 revealed an oil market that had lost a great deal of its flexibility and capacity to deal with supply shocks or large unexpected (or even expected) increases in global oil demand. For most of the 1980s and 1990s, OPEC's spare capacity (chiefly that of Saudi Arabia) helped offset large demand and supply shocks. Spare capacity, however, has witnessed a gradual decline since the early 1990s. Many observers argue that the conditions responsible for the emergence of a large spare capacity cushion in the mid 1980s, mainly the surge in non-OPEC supply accompanied by a decline in global demand, cannot be repeated therefore spare capacity is a thing of the past. For advocates of peak oil, spare capacity is a myth. International institutions such as the IMF and IEA argue that the erosion of spare capacity has been the result of worldwide under-investment in the oil sector and hence they call for removing barriers to investment in order to restore spare capacity in all parts of the supply chain. Others such as Goldman Sachs (2005) are more pessimistic about the realization of investments, arguing that "demand destruction will be needed to recreate a spare capacity cushion in order to return to a period of lower energy prices". Saudi Arabia's declared policy of maintaining a volume of spare capacity of around 2 mbd could be achieved, but this spare capacity is too little compared to global demand. It is interesting to note that although these views are fundamentally different, they all seem to agree on one thing: we have entered a 'new era' in which the oil market's ability to rely on spare capacity to absorb shocks has greatly diminished.

This situation, if it turns to be correct, would have strong implications both on price levels and the dynamic behaviour of crude oil prices. Given that the crude oil market is characterized by low price elasticity of supply, any increase in demand cannot be met by an increase in oil supply, especially in the short run. Thus, in the absence of spare capacity, demand shocks would require large changes in prices to clear the market. In particular, when capacity constraints become the driving force in the market, the following price dynamics are likely to emerge: an accelerated rise in the average level of oil prices, more frequent spikes in crude oil prices and an increase in the volatility of oil prices. The behaviour of oil prices in the last three years is consistent with these price dynamics where we witnessed an accelerated rise in oil prices and many frequent oil price hikes. Volatility has also increased and reached high levels in the last two years. We use a GARCH (1,1) model to compute conditional volatility for weekly oil price (spot WTI) returns from January 1995 to November 2006. Figure 3 plots the estimated conditional variance. As can be seen from this graph, volatility rose markedly, especially in 2004, and remained high until the end of our sample, especially when compared to the mid and late 1990s.

Figure 3: Crude Oil Price (SPOT WTI) Conditional Volatility



Weekly Data (January 1995–November 2006)

4.3 Speculation and Oil Prices

In a number of articles in energy publications and international policy reports, many observers have raised concerns about the possible impact of speculators on the recent rises in oil prices.[12] It is often argued that in recent years, a large number of speculators have entered the oil market, lured by high returns. The BIS Quarterly Review (2004) notes that "the rapid increase in oil prices in recent months has focused attention on the role of speculators in the oil market. With prices in most major equity, bond and credit markets moving sideways or even declining, investors in search of higher returns have reportedly turned to commodity markets, oil in particular" (p. 6). In a similar vein, Greenspan has noted that "when in the last couple of years it became apparent that the world's industry was not investing enough to expand crude oil production capacity quickly enough to meet rising demand, increasing numbers of hedge funds and other institutional investors began bidding for oil".[13] Tight market conditions, geopolitical uncertainties and a thin spare capacity have made laying a wager on potential supply shocks extremely attractive. For

[12] See for instance the recent Staff Report prepared by the US Senate: "The Role of Market Speculation in Rising Oil and Gas Prices: A Need to Put the Cop Back on the Beat", June 2006.

[13] Statement of Alan Greenspan before the Committee on Foreign Relations United States Senate, June 7, 2006, http://foreign.senate.gov/testimony/2006/GreenspanTestimony060607.pdf

instance, although the probability of a supply shock might not have changed compared to previous years or might have increased slightly, the upside potential in the event of such a shock can be extremely high in the absence of large spare capacity. Although inventories have risen, investors believe that in the case of such a supply shock, the current level of inventories would not be enough to absorb the price rise.

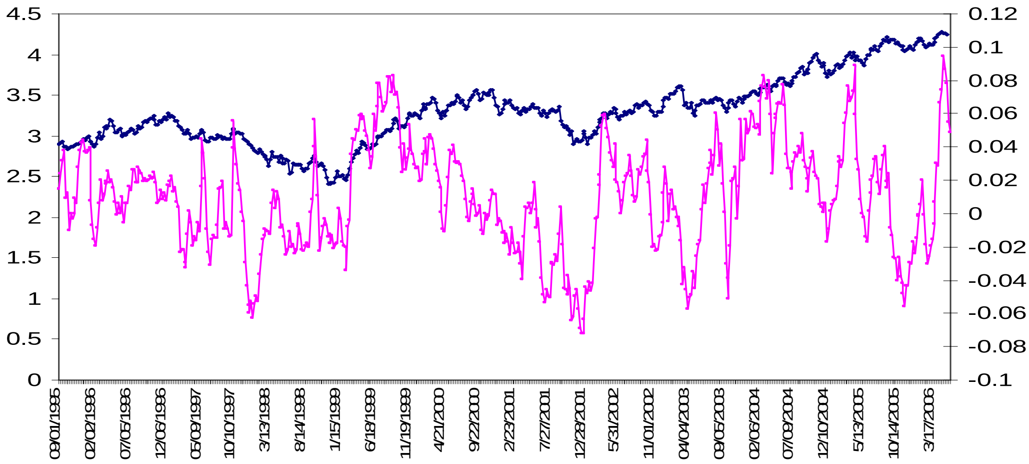
Many observers hold the view that the new players trade on noise and sentiment rather than on fundamentals, with adverse effects on the functioning of oil markets. Black (1986) defines noise traders as agents who sell and buy assets on the basis of irrelevant information rather than on market fundamentals or the arrival of new information. These are usually contrasted with arbitrageurs, rational speculators or 'smart money' that trade on the basis of information and thus tend to push prices towards fundamentals. Although noise traders may be active in financial markets, the traditional view has been that speculators trading on noise can be ignored in models of price formation because they will continuously lose money and will eventually exit the market. This argument was forcefully made by Friedman (1953) who states that "people who argue that speculation is generally destabilizing seldom realize that this is equivalent to saying that speculators lose money since speculation can be destabilizing in general only if speculators on average sell low and buy high" (p. 175).

This traditional view has recently been challenged. Shleifer and Summers (1990), for instance, argue that on average noise traders may be more aggressive than arbitrageurs, either because they are more optimistic or overconfident, and thus are likely to bear more risk. If higher risk is rewarded in the market, then noise traders can earn higher expected returns on average and hence as a group they need not disappear from the market. Kogan *et al*. (2003) find that irrational traders can affect prices even if trading decreases their wealth overtime, implying that the price impact of irrational traders does not rely on their long run survival.

However, even if we assume that noise traders can survive the market, the question is whether changes in demand due to noise trading are big enough to affect prices and destabilize the market. Many have argued that herding behaviour can lead to such a situation. Herding results from an investor's decision to follow the trading strategies of others. If the shifts in demand are correlated with noise traders and do not cancel each other out then noise trading is capable of influencing market prices. Furthermore, the potential for herding behaviour implies that arbitrage is not without risk and hence it is not necessarily the case that arbitrageurs will always be able to arbitrage away the noise trade. In fact, the arbitrageurs may not have the incentive to counter shifts in demand by noise traders and may instead decide to ride the wave in the hope that they can dispose of the assets near the top before the noise traders. In an interesting study, Brunnermeier and Nagel (2004) show that rational traders may have the incentive to trade in the same direction as irrational traders in the short run (i.e. herd themselves) if convergence is expected to be slow.

Empirical studies applied to the oil market have mainly focused on the changes in the net long position of non-commercial traders and have noted that these have tended to coincide with changes in the oil price. Figure 4 below plots the net long-term positions of non-commercial traders and the spot price. From this graph, it is possible to make three broad generalizations. First, prices appear to be less volatile than speculative positions. Second, there is no common trend between prices and speculation. In other words, there is no persistent pickup in net long non-commercial positions coinciding with oil prices trending upward. Finally, changes in non-commercial traders' net long positions may coincide with changes in oil prices. But this observation does not establish that speculators necessarily influence oil prices. Evidence that changes in the net long position of non-commercial traders have tended to coincide with changes in the oil price could be the result of change in fundamentals that affect both oil prices and the futures position of speculators. That is why the BIS when commenting on the role of speculators in the oil market has been careful in noting that "it is also possible that shifts in activity in the futures market were driven by changing perceptions of fundamental imbalances in the supply of and demand for oil, including the changing perceptions of commercial traders" (p. 6). In the case of speculators reacting and changing their position on the basis of the arrival of new information, speculation is not necessarily destabilizing. In fact, if speculators have superior information that enable them to respond fast to the arrival of new information, then they may even improve the functioning of the market by speeding the price adjustment process. Consistent with this, Fleming and Ostdiek (1998) find an inverse relationship between an open interest in crude oil futures and spot market volatility. They interpret these findings as evidence that trading improves the depth and liquidity of the underlying market.

Figure 4: Net Long Positions and Oil Prices



Notes: Spot Price in Log Scale (left scale); Net long-term positions in millions of contracts (right scale). Source: IMF, World Economic Outlook, 2006

In a more recent study, Haigh *et al*. (2005) use a unique dataset from the Commodity Futures Trading Commission (CFTC) to examine the role of hedgers and speculators in the crude oil market. The disaggregated data allow the authors to examine the role of hedge funds, considered by many to be responsible for the recent heightened speculative activity. Interestingly, the authors find that these speculators are proving liquidity to hedgers and not the other way around. They also provide evidence that these large speculators have little influence on oil prices. Finally, they find that the evidence of herding is very weak and even if it exists, herding is not destabilizing in the sense that traders do not buy when prices are low and sell when prices are high and hence do not cause the overshooting of oil prices.

4.4 Oil Price Term Structure, Inventories and Oil Prices

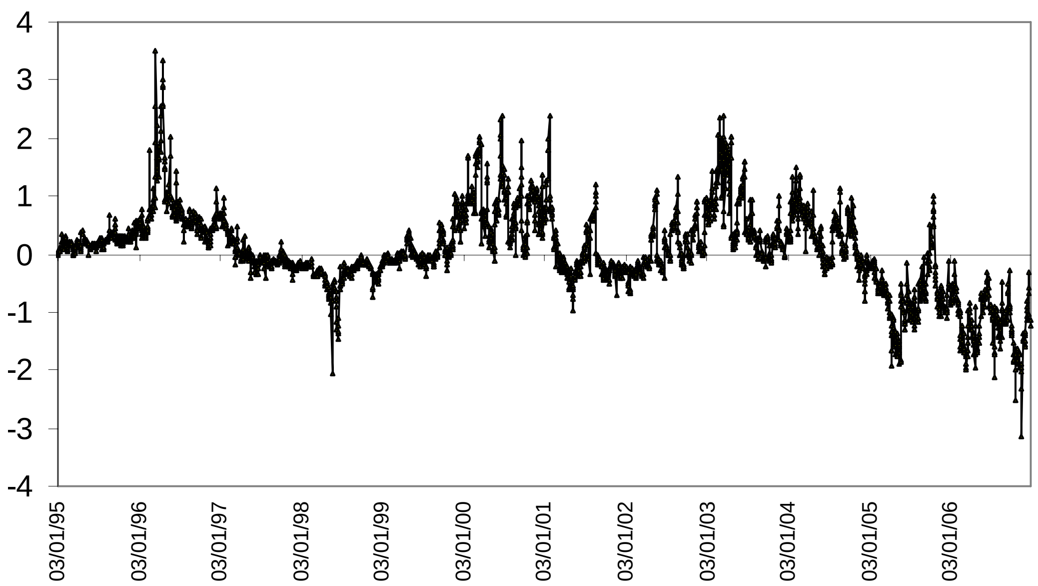
The last three years have witnessed the high build-up of inventories in the US and other OECD countries. By the end of 2006, crude oil inventories in the US stood at 321 million barrels representing 25.2 million barrels over the 5-year average. Total commercial inventories in the US amounted to around 1022 million barrels representing almost 47 million barrels over the five-year average. This rapid rise in inventories raises a number of questions: Why have inventories risen so fast in recent years? What has the impact been on oil prices?

Some have argued that the current build-up of inventories is a sign of oversupply in the crude oil market. When supply exceeds (effective) demand at any point in time, the difference would be added to stock levels. However, this explanation suffers from a major drawback: why would customers want to lift more crude oil than what they would effectively demand? Unless there is an incentive for them to hold inventories, customers are under no obligation to absorb the oversupply from the oil producers. Supply does not create its own demand!

Others have argued that the current build-up is driven by the demand for precautionary inventories in the face of tightness throughout the oil supply chain. For instance, *Petroleum Argus* (19 June 2006) argues that the market is signalling that "just-in-time inventories are no longer appropriate as OPEC has lost the spare capacity that enabled it to act as a buffer, shifting stock risk management down the crude supply chain to refiners". This explanation implies that private oil companies would keep inventories even when it is costly for them to do so. It also implies a fundamental shift in the behaviour of oil companies and refineries towards a new inventory policy. Under pressure to maximize shareholder value, international oil companies have undergone major cost-cutting exercises including cutting inventories to their lowest possible level and shifting to a 'just-in-time inventories' policy. In this new era, oil companies have relied on OPEC's large holdings, consuming countries' strategic petroleum reserves (SPR) and on a developed spot market for immediate deliveries. Thus, the shift back towards a new policy of holding precautionary inventories would imply a structural break in the oil market structure. There is nothing to suggest that this has happened. The shift in inventory policy would also imply a fundamental change in the behaviour of international oil companies. Given that international oil companies are under pressure to maximize shareholder value, the proponents of structural shift in inventory policy must show how holding precautionary inventories would maximize shareholder value even when it is not commercially profitable to hold inventories.

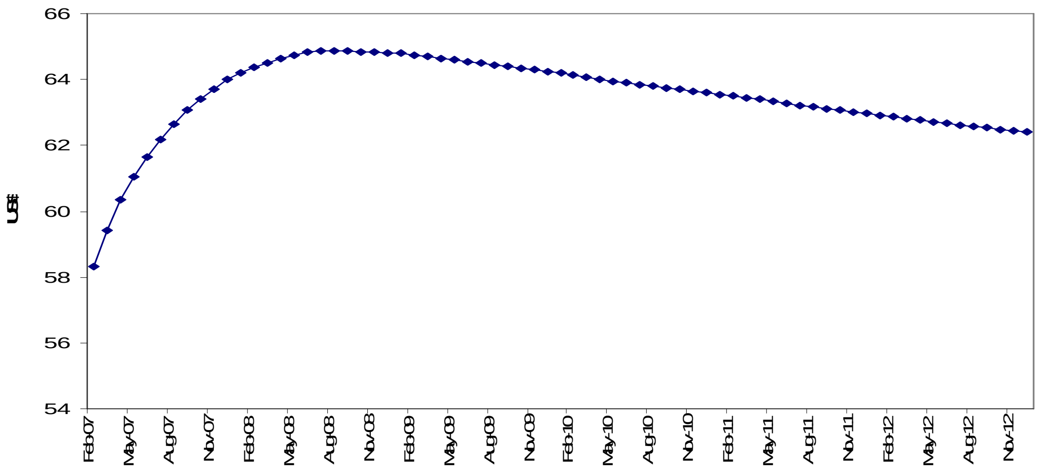
A more plausible explanation is that the recent build-up of inventories is due to the price term structure of WTI or Brent. In an influential article, Litzenberger and Rabinowitz (1995) noted that 80−90% of the time the oil forward curve is in backwardation, i.e. futures prices are often observed to be below the spot prices. However, one striking feature in the current market has been the prolonged contango in the WTI forward curve. Figure 5 below shows that during the last 20 months or so, the nearby (delivery) futures contracts have been trading at a discount to the second month futures contract. Figure 6, which plots the WTI forward price curve, shows a very steep slope with the nearby contract trading at a discount of almost $7 to the August 2008 contract.

Figure 5: First Month Futures Contract–Second Month Futures for WTI



Source: EIA Website

Figure 6: WTI Forward Price Curve (as of January 3, 2007)



Source: Nymex Website

Given this oil price term structure, it is no surprise that commercial inventories have been rising fast. If the price of oil for future delivery is trading at a large premium over the price of oil for immediate delivery, this would cover the costs of carrying inventories prompting market participants with storage facilities to accumulate inventories, stock up their tanks and lock a profit by selling contracts in the futures market. Finding a buyer to take the other side of the bet is not a problem in the current environment where there are expectations of tighter crude oil market conditions in the future and where geopolitical uncertainties and a thin spare capacity have made financial bets on potential supply shocks extremely attractive.

As Figure 5 shows, the last time the crude oil market entered into prolonged contango (which lasted more than 12 months) was in 1998. What is interesting to note is that contrary to the current contango which, until recently, has been associated with an upward trend in oil prices, the 1998 contango was associated with a declining trend in oil prices. The 1998 episode is an interesting one because it shows how the market can fall in reinforcing contango. Contango will encourage those with physical facilities to accumulate inventories. If rising inventories are interpreted by market participants as an increase in crude oil supply relative to demand, the price of oil for immediate delivery would go down. This would increase the difference between the oil price for future delivery and prompt price, increasing the size of the contango. This in turn will induce traders with physical capacity to augment their stock further, which will cause further decline in prompt prices and widen the contango. This reinforcing contango can continue for a period of time, causing sharp falls in prompt crude oil prices. In such a situation, contango is associated with falling oil prices and large accumulation of inventories.

This time round the situation is quite different: until very recently, the contango and the associated rise in inventories were occurring together with an upward trend in oil prices. The conventional wisdom is that building up inventories would depress oil prices. In a recent conference paper, Morse (2006) argued that this conventional wisdom may no longer be valid. High levels of inventories are no longer seen as a necessary sign of oversupply and hence do not exert downward pressure on prices.[14] It is argued that the main reason behind this transformation is that in the absence of spare capacity, the market's perception of what constitutes a high level of inventories has changed. With the decline of OPEC's spare capacity, the current levels of stock (although high by historical standards) do not imply that markets are oversupplied.

A more plausible explanation is that the relationship between inventories and oil prices has not changed. Higher than expected levels of inventories still cause oil prices for prompt delivery to decline. However, there are other factors that are pushing prompt prices in the opposite direction, shadowing the impact of inventories on oil prices. In other words, the decline in oil price caused by rising inventories is continuously being dominated by other factors causing oil prices to rise. Until the impact of other factors is isolated, it is not possible to conclude whether the relationship between inventories and oil prices has changed.

4.5 Have There Been Structural Changes in the Oil Market?

Are the above drivers cyclical or structural in nature? By using the informal approach, it is not possible to provide a quantitative assessment of changes in the oil market such as changes in price and income elasticity or the inventory–price relationship (Stevens, 2005). That being said, the informal approach adopted here allows us to provide a qualitative assessment of whether the market has witnessed structural

[14] Morse (2006) argues that "key truisms of the old market are that prices fall in a contango and that stock builds will undermine any price rise". However, in a structurally tight market, these "truisms may not be valid". Morse, E. The Global Oil Market Outlook: Ten Lessons About the Petroleum Sector. Presentation given at the 2006 Summer Fuels Outlook Conference Washington, D.C., April 11, 2006.

changes with a lasting impact on oil price behaviour or whether the recent strength in the oil prices has been mainly caused by temporary drivers. In what follows, we focus on two aspects: spare capacity and the greater reliance on the futures market for price discovery.

The most obvious change has been the gradual decline of spare capacity to very low levels, especially when compared to mid 1980s and early 1990s. As discussed above, low spare capacity implies that in case of shocks, prices will bear the bulk of the adjustment. This raises an important question: will the spare capacity in the upstream oil be re-established to its previous high levels? To answer this question, it is important to stress that the spare capacity that has provided a large cushion against oil market shocks has not been the outcome of a rational investment decision. Instead, it has emerged as a result of specific market developments in the mid 1980s and early 1990s which left OPEC member countries with a large spare capacity. Most observers suggest that these market conditions cannot be repeated and hence increased spare capacity would not materialize unless new investments are made. This, however, raises the question: who should bear the costs of investment in spare capacity? The international oil companies are not willing to bear these costs since investment in spare capacity does not conform to the principle of shareholder value maximization as it implies the company is holding idle assets. On the other hand, most national oil companies, due to many financial and political constraints, may not be able to invest in new capacity, probably with the exception of Saudi Arabia whose declared policy is to maintain a spare capacity of 2–3 mbd, which is quite low representing only around 2% of global production. The obstacles facing investment in the oil sector and the failure to address the complicated issue of who should bear the costs of investment in spare capacity simply mean that the required investment is not likely to materialize. It seems that the 'international oil order' where non-OPEC supplies much of the incremental global oil demand and OPEC provides the capacity cushion has been shaken in recent years, with potential implications on oil markets.

A less obvious transformation has been the shift from the spot to the futures market for price determination (see Fattouh, 2006). This has increased the role of financial investors and traders in oil price movements. This development may have lasting effects on short-term movements in oil prices and volatility, but not on the long run behaviour of oil prices. Any long-term trends in oil prices will be dictated by market fundamentals rather than by the sentiment of investors.

The shift to the futures market may also affect the market through its impact on OPEC behaviour. An important consequence of the recent shift to the futures market for oil price determination is the wide range of factors that OPEC needs to consider in making its output decisions, such as the level of inventories, the forward curve's shape, the size of speculative positions in the futures market and the bearish or bullish sentiments of traders. This greatly complicates the decision-making process for the simple reason that OPEC has only one policy tool at its disposal (implementing production cut) with which it would like to achieve a wide range of objectives.[15] This may have undesired consequences on oil price fluctuations, inducing volatility and causing sharp rises or falls in oil prices in some instances.

5. Conclusions

In this paper, we have discussed three main approaches for analysing oil prices: the exhaustible resources, the supply–demand framework and the informal approach. Each of these approaches suggests a certain set of drivers of oil prices. However, we have emphasized that all of the above approaches suffer from major limitations, especially when used to make predictions. This is not to say that current frameworks for analysing oil prices should be avoided. They usually provide useful insights on the functioning of the world oil market and how it might evolve in the future. However, attempts to draw accurate predictions about oil market conditions based on these models will certainly result in errors. Various players in the oil market such as international organizations, oil companies and governments should keep this in mind when making their investment decisions or policy recommendations. Pushing hard for strategies based on the projections of these models defeat their purpose, and may result in misguided, even dangerous, policies.

[15] See Fattouh (2007b) for a discussion on OPEC's dilemma in the current market situation.

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