



Explaining crude oil prices using fundamental measures[☆]

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ABSTRACT

Oil is the world's most important commodity, and improving the understanding of drivers of its price is a longstanding research objective. This article analyses real oil prices during 1984–2007 using a monthly dataset of fundamental and market parameters that cover financial markets, global economic growth, demand and supply of oil, and geopolitical measures. The innovation is to incorporate proxies for speculative and terrorist activity and dummies for major industry events, and quantify price impacts of each. New findings are positive links between oil prices and speculative activity, bond yields, an interaction term incorporating OPEC market share and OECD import dependence, and the number of US troops and frequency of terrorist attacks in the Middle East. Shocks also prove significant with a \$6–18 per barrel impact on price for several months.

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1. Introduction

Crude oil is perhaps the world's most important commodity. It constitutes ten percent of international trade, and four percent of global GDP (IMF, 2008). In mid 2009, seven of the world's 20 largest firms by market capitalization were oil companies (*Forbes*, 8 April 2009). Crude's price has been the subject of intense academic analysis, which – not surprisingly – is pro-cyclical, so high prices of recent years have brought a resurgence. Recent work has markedly improved oil price models, largely through expanding the range of explanatory factors and better integrating them. This paper builds on recent work, and adds a specific focus on popular explanations for the strong rise in oil prices in the last decade.

Anecdotal evidence is that a broad range of factors have recently been economically significant in the oil market, and the first one I consider is speculation. In a typical comment on the role of speculators, an article in *Forbes* magazine [23 September 2008] suggested they had lifted oil's previous price of about \$100 per barrel by more than \$40. A second set of factors relate to the link between oil prices and security risks in oil producing regions, especially the Middle East. Thus retired Federal Reserve Chairman Greenspan (2007) wrote "... everyone knows: the Iraq War is largely about oil". Finally it is not just occasional wars that have shocked oil prices, but numerous unexpected events covering economic, military, and political factors.

This paper investigates the influence on global oil prices of futures market speculation, threats to security in the Middle East, and shocks from unexpected, short-lived events. These factors are widely seen as important to oil prices, with considerable supporting anecdotal evidence, but empirical testing to date has been fragmented and their impact is uncertain.

I examine the economic significance of these factors to oil prices by introducing three measures that have not been previously used in oil price models. The first new variable proxies for speculative activity, and is the ratio of turnover in the oil futures market to physical sales of oil. The second variable measures threats to security in the Middle East, which is where oil production facilities are most concentrated, and is proxied by terrorist attacks and US troop deployments in the region. The third explanatory variable explicitly incorporates major shocks to the oil market, and uses dummies to identify the periods covered by a list of 'major events' affecting oil prices prepared by the US Energy Information Administration (EIA).

In addition to the new variables, my model incorporates fundamental measures from prior oil market analyses, and examines their impacts over 25 years using mostly monthly data.

This approach is a direct extension of recent trends in analysis of oil prices using fundamental measures. These typically assume prices reflect supply–demand equilibrium: shocks are caused by exogenous shortfalls in supply, whose initiators lie in markets, inventory, or supplier behavior, or when demand rises faster than expected. Thus core explanatory variables incorporated in published models of global oil prices include oil production (OPEC and non-OPEC), inventories, demand (GDP, and proxies such as transport price indexes), oil futures prices, and a number of wars and other events affecting the oil market.

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A now common approach to oil price analysis is the co-integrating framework of Engle and Granger (1987), which Hammoudeh et al. (2008) applied to oil prices. Other papers emphasize the importance of fundamental factors on oil prices. Déés (2007) use quarterly data to model oil prices in terms of oil inventories and demand, and OPEC behavior in terms of production, production capacity, and producer quotas. Ewing and Thompson (2007) examine links between oil prices and macro-economic variables and found that oil prices are procyclical, lagging industrial production, and leading consumer prices. Sari et al. (2011) examine price links or information transmission between oil futures and other markets, and find that oil prices are led by other commodity prices and global risk as proxied by the VIX Index. Kaufmann et al. (2008) find that refining plays a role in prices, with lower refinery utilization leading to a preference for higher quality crude oil and a rise in average crude prices. Other important recent contributions come from Chevillon and Riffart (2009), Merino and Ortiz (2008), and Zhang et al. (2009).

Several recent papers have examined the importance of speculation in oil prices. Kaufmann and Ullman (2009) find that price innovations occur first in spot markets and that there are only weak links from futures markets to spot markets. They conclude that prices respond to fundamentals and are exacerbated by speculation. This is confirmed by Kaufmann (2011) who identifies supply disruptions as the major contributor to the late 2000s oil price spike. Cifarelli and Paladino (2010) also examine links between spot and futures oil prices and find that serial correlation of oil returns rises with price volatility and that futures markets lead price changes. They conclude this speculation-driven model better fits oil prices than one using fundamentals. Sornette et al. (2009) found that oil prices in 2006–8 exhibited bubble-like dynamics, fueled by market uncertainty that is symptomatic of speculation.

The motivation of this paper is to extend this literature in three ways. The first is to more conclusively determine the role of speculators, and quantify their price impact. The second extension is to explicitly model the impact of threats to security, which has previously been sparsely covered. The third extension is to quantify the price impact of one-time major events, and hence better understand recent shocks such as fears that the market has reached Peak Oil.

The results extend previous analyses of oil price dynamics by incorporating popular explanations within a theoretically grounded explanation of what factors determine oil's price over the short and long term, and evaluate their economic importance using standard analytical techniques. The innovation is to incorporate a variety of parameters that are popularly associated with oil prices but have not yet appeared in formal analyses, especially expansion of the volume of sales on the oil futures market relative to the physical market, and military and terrorist activities in the Middle East. Analysis uses monthly data for the last quarter century to examine four intuitively important influences on oil's price: supply factors, particularly concentration of supplies and inventories; demand factors, particularly global macro-economic variables; financial measures, particularly bond yields and oil futures volumes; and political factors, including threats to, and disruptions of, oil markets.

My analysis makes three principal contributions to the literature on oil prices. First it provides an updated understanding of the international oil market by analysis of data from a wide variety of sources using standard econometric techniques. The second is to confirm anecdotal evidence of the significance to oil prices of speculators, and of terrorist attacks and military activity in the Middle East. The third contribution is to explain longitudinal oil prices in conventional terms that are consistent with generally recognized economic intuitions, rather than accept that the oil market has somehow been transformed, and moved prices to a higher path (perhaps a 'super cycle' in commodity prices).

At this stage a brief summary of my results may be useful. The most economically significant impact on oil price is OPEC's market share, so that a one standard deviation increase reduces oil prices by \$12 per barrel. Other important influences that have significant, positive influences on oil's price are – in decreasing order of economic importance – corporate bond yields, the size of the oil futures market relative to physical demand, global GDP, an interaction term incorporating OPEC market share and OECD dependence on imported oil, which reflects OPEC's ability to leverage its market dominance when major consumers increase dependence on imports, the number of US troops deployed in the Middle East, and the frequency of fatal terrorist attacks in the Middle East. Most of these independent variables remain significant and of similar magnitude when tested against subsamples from the first and second halves of the period. Major events proved important, too, and nine events caused perturbations in oil prices, generally by about \$(2007) 6–18 per barrel and lasting between two and 18 months.

Looking ahead, the next section describes the international crude oil market and develops hypotheses about influences on oil prices. Section 3 outlines the analytical methodology and data used. Results are reported in Section 4, and I close with a discussion and conclusions in Section 5.

2. Components of the crude oil price model

The oil price model analyzed here has five groups of independent determinants – namely supply factors, demand factors, financial measures, political factors, and major events – whose significance and attributes are described in this section.

2.1. Oil supply

Crude oil is a naturally occurring substance whose supply has several economically important characteristics. Apart from a limit to its ultimate availability, oil is not distributed evenly around the world in homogenous deposits, but is concentrated in the Middle East, which contains 57 percent of global reserves and contributed 30 percent of 2009 global production (BP, 2010). So, although it may be optimum to preferentially exploit the most accessible and lowest cost resources, these are not necessarily discovered first and monopolists do not immediately produce all cheap oil. Finally, oil's discovery and extraction are complex, capital-intensive processes with long lead times and uncertain outcomes. These factors impose frictions that induce lumpy development of new capacity, which can establish a supply overhang that impedes market clearing and promote boom–bust cycles that are familiar in commodity prices.

A dominant feature of the supply side of the oil market is its concentration within the producer cartel OPEC that was formed in 1960 and whose principal members are Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela. OPEC members dominate global oil production with almost half the total, and make the organization an obvious object for study of monopoly pricing power (e.g. Hansen and Lindholt, 2008). Such studies largely assume that OPEC has a superior understanding of the dynamics of the market and the ability to restrict supplies, so that – at least in some periods – it can manipulate crude prices. Many studies suggest that major producers in OPEC swing production to maintain constant revenues, which leads to a negative relationship between oil prices and OPEC production (Kaufman et al., 2004).

Although variables relating to oil supply would ideally describe available quantities and the costs of discovery and production, such data are not reliably obtainable. The only long-term measure of oil costs is produced by the Energy Information

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