

Think Corner Research Note

Factors Impacting Oil Price¹

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Following the persistent increase in the price of oil since 2002 and, in particular, rapid rise between 2007 and mid-2008 and even faster drop in the second half of 2008, the most persistent questions about both current and expected oil prices (as reflected in futures and forwards) revolve around the debate regarding relative dominance of non-fundamental factors, which requires a better understanding of fundamental factors. The deviation from the historical relationship of Brent and WTI benchmarks since late 2010 adds another complication to this analysis.

A review of more than 200 documents (academic research, testimonies, industry publications, government analyses) indicates that there is general agreement that the fundamentals (rapidly increasing demand in emerging economies led by China, sluggish supply, supply disruptions, low spare capacity, discrepancy between products specifications and refinery yields, infrastructure bottlenecks) were responsible for rising prices in the early 2000s and then again in late 2010 and 2011; there is also some support for low interest rates (a result of expansionary monetary policies) and weak U.S. dollar having an impact if only occasionally. Many also offer convincing arguments that there was a speculative bubble at least during the first half of 2008. Although there are competing empirical analyses in the literature, a truly comprehensive test seems to be lacking. We believe this is so because testing the speculative bubble argument robustly would require a comprehensive model incorporating both fundamental and non-fundamental factors at the global scale, for which data availability and quality simply do not exist. The data problem is particularly acute for global oil storage and OTC trading.

*This research note provides a summary and recap of our technical work on oil market dynamics. A separate, forthcoming research note will update our thinking on commodity markets and trading from the original 2009 working paper, *The Future Landscape of Energy Trading*.² Our forthcoming research note will broaden and extend the questions we raised in 2009 pursuant to the work summarized here.*

Problem Statement

Energy is a key input of economic activity and quality of life; consumers value reliable supply of energy sources at affordable and predictable prices. However, most of our energy comes from crude oil (and products refined from it), natural gas and coal. Supply of these fuels always bears a degree of risk and uncertainty that filters into price signals; finding and development (F&D) costs are the first determining factors underlying current and expected prices. Thus, increasing or decreasing risk and uncertainty

¹ In early 2011, the Center for Energy Economics (CEE) team delivered an expert review of factors affecting energy prices for the U.S. Department of Energy's Energy Information Administration (EIA). To prepare this expert report, we reviewed numerous public domain documents and sources (see Works Cited section at the end), visited a number of market participants in the United States and abroad, and derived some internal analytics. We also held a small workshop on October 14, 2010 to test observations, conclusions and recommendations, and gain additional insight from acknowledged experts within the oil and gas market community in Houston and elsewhere. We enlisted formal peer reviewers to ensure quality and objectivity in our work. This article is based on parts of the expert report but it is updated to reflect our review of more recent studies and observations. The views expressed are ours and cannot be attributed to EIA.

² See http://www.beg.utexas.edu/energyecon/thinkcorner/Energy_Trading_Foss.pdf.

associated with supply and the process of reserve replenishment exert substantial impacts on formation of price signals in open markets.³

After decades of use, each fuel is strongly associated with particular end use sectors (e.g., oil products in transportation; coal in power generation and heavy industries; natural gas for feedstock for certain industries, heating and power generation). End-use applications add to variability in price signals by introducing daily and seasonal patterns of use that exacerbate inherent variability in the fuels and technologies themselves. For example, seasonal driving patterns enlarge product and oil price signals; electric power usage, quite variable on a daily and seasonal basis, enlarges price signals for associated, and competing, generation fuels and technologies. Emerging economies' demand for these fuels has been growing very fast, adding new complications to the price discovery process. Alternative energy sources and technologies introduce additional uncertainties such as intermittency of wind and solar, availability of and weather-sensitivity of feedstock for biofuels, and access to materials for batteries.

In sum, markets for our energy sources are characterized by multiple factors that are highly variable and unpredictable over time; interactions among these factors are also hard to decipher and predict. As a result of the array of factors across the energy value chains, from exploration and development through conversion and end use, prices of these fuels have been quite variable and cyclical.

All of these considerations exist for any commodity, whether it is fuel, non-fuel, agricultural, or other. A question is whether commodity prices reflect logical variability associated with availability and cost of supply, demand, and inventories—"fundamentals", which we suggest be re-cast as "intrinsic" value—or whether "non-fundamental" or extrinsic value factors (e.g., speculation or investment by financial players) figure prominently. In this paper, we focus on the price of oil.

As shown in Figure 1, it is clear that the nominal price of oil has risen significantly in the last decade, especially since 2002; the average price since 2002 is \$64 per barrel versus \$20 per barrel between 1986 and 2001.⁴ But it is also clear that for long periods of time price fluctuates around an average price that presumably reflects long-term demand and supply fundamentals (mean reversion). In fact, volatility⁵ has been fairly stable around 40% except for the wild swings of 2007-09 although it, like the mean,⁶ changes over time before reverting back to a long-run average.⁷ During the period of price increase between early 2007 and mid-2008, volatility has been reduced to 31% and during the rapid decline period that followed until late December 2008, it increased to 76%. Since then, volatility settled around 40% again.

³ Note that we do not consider Hotelling's model of optimal extraction as a driver of F&D costs and reserve replenishment. The model's assumptions are not representative of the history of the industry: for example, technology is not fixed; reserves are updated in existing fields; unconventional resources expand the resource base; and joint production of oil and gas changes economics. Evidence in the literature does not support the model; for example see Lin (2009) and Slade and Thille (2009). Nor do we consider OPEC as a consistently successful cartel. For example, Gülen (1996) concludes that, despite increasing output coordination after the quota system started in 1982, OPEC did not act as a cohesive whole and that Saudi Arabia was the swing producer. Smith (2005) rejects traditional cartel model but offers a loosely operating cartel dealing with the cost of forming and enforcing agreements, which is sometimes successful. Smith (2009) contends that OPEC failed in "shutting in" existing production capacity while succeeding in restricting capacity expansion by limiting new upstream investments. Among the 13 studies reviewed in Alhajji and Huettner (2000), only two of them found statistical support for the cartel hypothesis.

⁴ Even in real prices, there is a significant difference: in June 2012 dollars, average price between 1986 and 2001 is \$29 per barrel as compared to \$66 per barrel between 2002 and March 2012 (based on data from the EIA Short Term Outlook, <http://www.eia.gov/forecasts/steo/realprices/>).

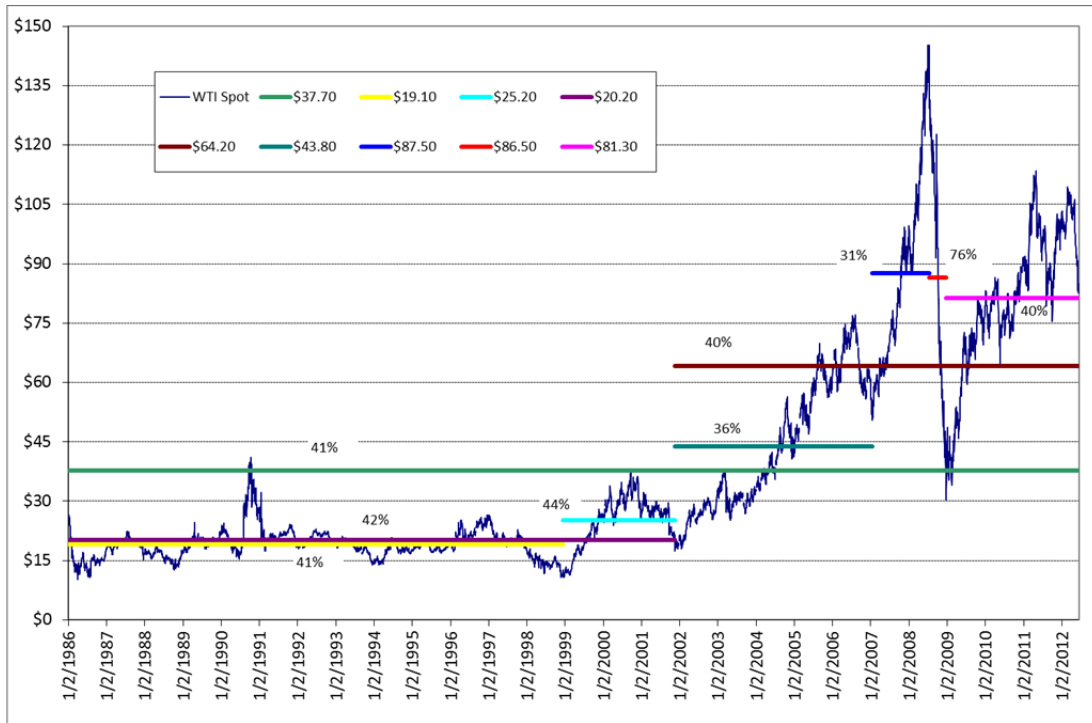
⁵ Standard deviation of natural logarithm of (P_t/P_{t-1}) using daily prices; annualized by dividing with the square root of (1/252). We assume 252 trading days per year.

⁶ If anything, the long-term level of volatility may be more stable than the long-term price level.

⁷ There is ample empirical support in the literature for these assertions; for example, see Sadorsky (2006), Agnolucci (2009) and Kang et al (2009).

Overall, these simple observations seem to suggest that (1) the market is mostly efficient and (2) bubbles are possible.

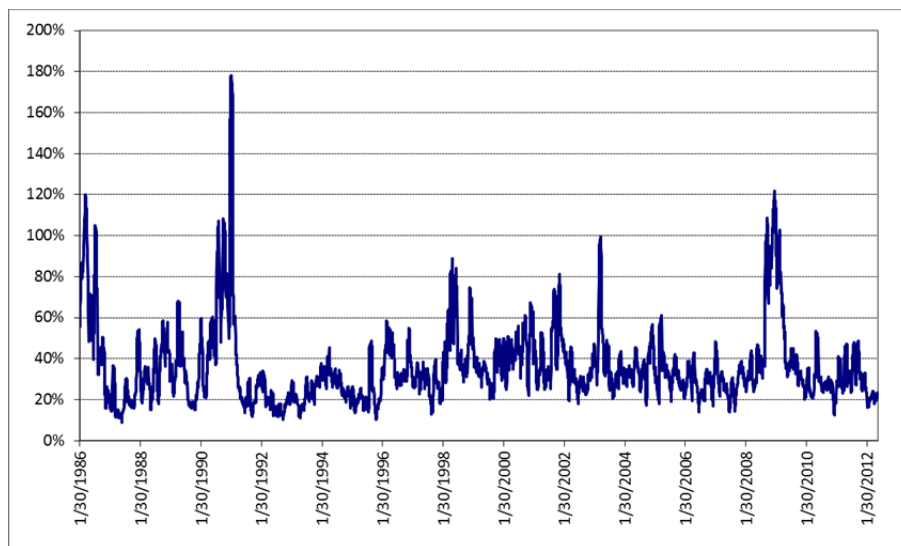
Figure 1. Daily price of WTI spot, averages and volatility for various periods (USEIA/CME)



In the following figures, we show annualized volatility using three different moving average calculations:

1. 10-day (Figure 2);
2. One-month (Figure 3); and
3. One-year (Figure 4).

Figure 2. Annualized daily volatility for oil, 10-day moving average



Volatility rose during 2008-09, especially since mid-2009, but it was as high or even higher in the 1980s and early 1990s when speculative activity by financial players in the futures market was not blamed except for short-lived spikes. There was not as much activity in the futures market in those years neither in terms of volume or variety of participants. In each case, fundamental changes in demand and supply can be easily identified as causes of the large price movements (e.g., Saudi Arabia flooded the market in 1986 to protect its market share and Iraq’s invasion of Kuwait curtailed significant supply until Saudi Arabia and others compensated for the market shortfall). In contrast, there was no similar market shock in 2007-08 although there were many demand and supply developments that tightened the market since the early 2000s.

Figure 3. Annualized daily volatility for oil, one-month moving average

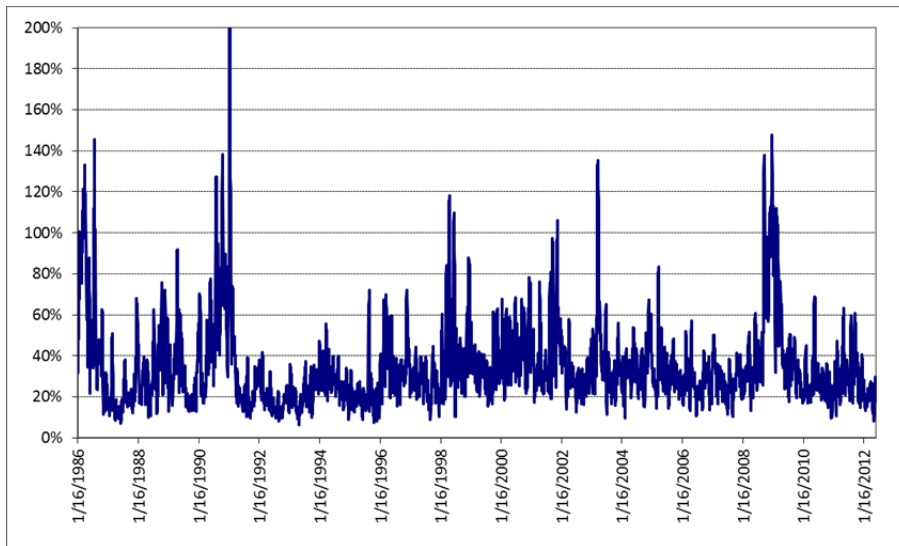
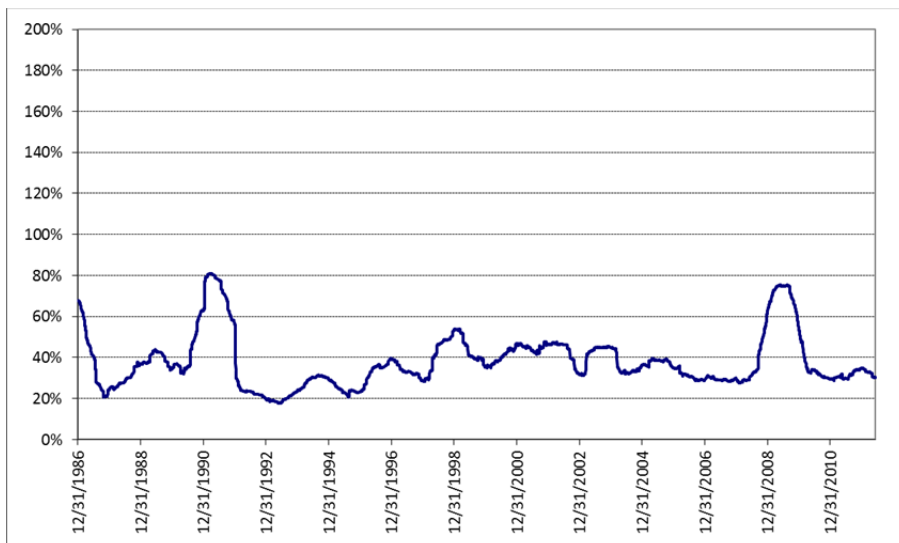


Figure 4. Annualized daily volatility for oil, one-year moving average



Other observations include the following (Table 1 below):

1. Average volatility is the same for all frequencies (approximately 37%).
2. As we reduce frequency (i.e., increase time period for which we calculate volatility), volatility is smoothed.

3. Volatility of volatility (as measured by standard deviation) is higher in higher frequencies (standard deviation is 14% for one-year moving average versus 22% for 10-day moving average).
4. The range of volatility (the difference between max and min) is wider in higher frequencies.

Table 1. Oil price volatility characteristics (January 1986 – June 2012)				
	Average	Stdev	Min	Max
10-day	36%	22%	6%	246%
One-month	37%	20%	8%	182%
One-year	38%	14%	18%	81%

Taken together, these observations are consistent with the view that in the long-run fundamentals govern (i.e., there is mean reversion) but the mean itself may change due to changes in fundamentals; and that financial market participants capture gains in the short-run when there is more volatility, to which they may be contributing with their entry and exit, and change of positions.

Schwartz and Smith (2000) provide the benchmark model of a stochastically changing mean. For a review of this literature and some recent testing of mean reversion, see Bernard et al (2008); the evidence favors reversion to a “continuously evolving mean” consistent with Schwartz and Smith (2000), which underscores the importance of understanding and modeling convenience yield properly (see below for more on storage and convenience yield).

Factors

The world oil market is increasingly complex; there are numerous global factors with the potential to impact the price of oil significantly at any given point in time; these factors and their interactions are dynamic. In Figure 5, we depict a conceptual model of the world oil market, capturing the factors identified in the literature as well as reflecting our own research and international experience.

The empirical literature struggles with this dynamic complexity; researchers using different methodologies, data sets, time periods and/or data frequencies, and focusing on different aspects (or factors) can find support for alternative hypotheses or reach different conclusions even if testing the same hypotheses.⁸ An important constraint is the lack of reliable, publicly available data from (i) increasingly larger portion of the world oil market on both demand (e.g., the pace of demand growth, inventory levels and subsidies in emerging economies led by China) and supply (e.g., access to resources and operations of national oil companies, or NOCs), and (ii) positions of heterogeneous traders in the oil derivatives market, especially related to over-the-counter (OTC) transactions.

As a result, almost all interpretations and arguments offered to explain the extreme price movements in the middle of the 2000s can be considered to have an element of truth – at least some of the time. The ancient parable from India (often used for economists like us) about blind men touching different parts of an elephant and offering conflicting descriptions based on their individual perspectives seems to reflect the state of the oil price research well.

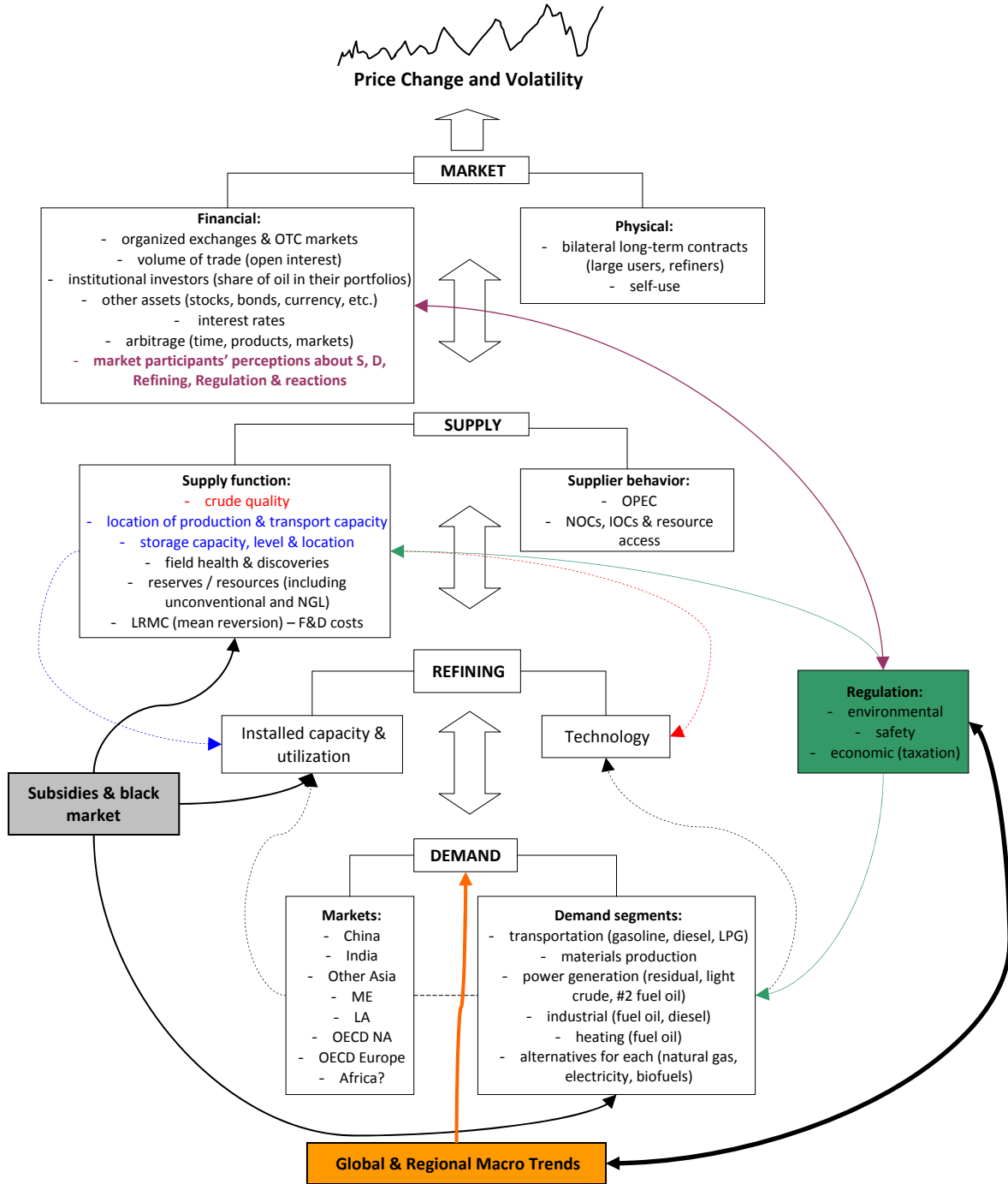
It is not easy to decipher timeframes over which different factors and relationships matter more. The problem of different factors having different impacts at different periods in a cycle or across cycles is recognized by other researchers. This reality compounds problems in empirical analysis and forecasting and underlines the importance of understanding the fundamentals via the views of a wide range of market participants and experts even if their individual views are based on anecdotal data – similar to

⁸ For example, the structural breaks such as the 1973-74 oil embargo and the start of crude oil futures trading at NYMEX in 1983 (and many more) need to be considered. In today’s high volume trading in derivatives markets, frequency of data is also important: low frequency data (e.g., monthly) may not be appropriate to test short-term trading behavior, which can benefit from high frequency data (e.g., daily or intraday).

putting together pieces of a puzzle (sometimes it helps to step back and look at the big picture rather than getting lost in the details).

Figure 5. Conceptual Model of World Oil Market

Price impacts market players, especially financial investors (high ST elasticity); demand; supplier decisions regarding E&P investment; downstream (pipelines & refinery) investment and operations (all with low ST elasticity). The gap in elasticities enhances ST volatility. Both LT and ST price change and volatility occur. The cycle repeats itself continuously.



We summarized the factors that seem to be most commonly discussed and tested along with a ranking of their significance based on our literature review and expert opinions we collated (Table 2). There seems to be a consensus in that demand growth, especially in emerging economies and especially in the early part of the 2000s, was the key driver of the rising prices although its significance waned while that of speculative investment in commodities started to increase and peaked in 2007 and the first half of 2008. Weakening of OPEC spare capacity and declining non-OPEC production tightened the demand-supply balance further. Such tightening is ideal for speculative trades to thrive. It is important to note, though, that there are several other factors that have likely played a role at some point, including expansionary monetary policy, weakening of the US dollar, refinery specifications and environmental regulations on fuels, changes in SPR among others. If nothing else, the news and perceptions about these factors contributed to the formation of trading strategies, which seems to have been excessively bullish until mid-2008. Dependence on news and perceptions rather actual data on fundamentals to exercise relatively short-term trades underlines the complexity of the global oil market as depicted in Figure 5 above.

Table 2 – Factors impacting the price of oil and their significance in different time periods*				
Factors	2002-04	2005-06	2007-08H1	2008H2-
Rapid demand growth in emerging economies led by China (unanimous up to 2005 and after 2008; but some pointed out that global demand growth, including that of China, leveled off and even declined from 2007H2 to 2008H1).	✓✓✓✓	✓✓✓	✓✓/x	✓
Financial investment (see Appendix 1 for a detailed summary of this literature).	✓/x	✓✓/x	✓✓✓/x	✓✓/x
Distillate stockpiling by China before Beijing Olympics and due to Sichuan earthquake in May 2008 (industry press and financial analysts) – no direct empirical testing probably due to lack of data but Amenc et al (2008) offer some relevant data.			✓✓	
New low-sulfur regulations in EU and US, mismatch between available crude quality and refinery technology (Verleger, 2009b, Amenc et al, 2008) – related to distillate stockpiling in China.			✓✓	+
Adding light sweet crude oil into SPR (Verleger, 2009a, 2009b).			✓	
OPEC spare capacity declining (counter by Yanagisawa, 2008: OPEC spare capacity declined because they supplied more oil in response to increasing demand in 04-05) – curiously some studies include Saudi spare capacity and others do not in their empirical analyses.		✓	✓	✓/x
Non-OPEC production capacity declining (unanimous) – Hamilton (2009b) does not find supply scarcity to be a driver in the 2000s but confirms that costs have been rising and production has been declining for a variety of reasons.		✓✓	✓	✓
Perfect storm of geopolitical events by Smith (2009): Venezuela stopping supplies to ExxonMobil in February 2008, pipeline bombings in Iraq in March 2008, labor strikes in Nigeria and Scotland in April 2008, militant attacks on facilities in Nigeria in April through June, and reports of declining Mexican exports. Verleger mentions that lost production of light sweet Nigerian crude could not be readily compensated by heavy sour crude from Saudi Arabia.			✓	
Expansionist monetary policy leading to low interest rates (Akram, 2009; Krichene, 2006, 2008; Anzuini et al, 2012; Diwan, 2008))	✓	✓	✓✓	✓
Weak US dollar (Akram, 2009; Krichene, 2006, 2008; IMF, 2008; He et al, 2010; Breitenfellner and Cuaresma, 2008; Diwan, 2008)	✓	✓	✓✓	✓
* Significance rankings are admittedly subjective but they reflect our judgment, which is based on the number of times a factor was cited by independent researchers or experts; how convincing the arguments were; and whether they were challenged or not (and if challenged, how convincingly). ✓ implies support for this factor in the literature; x implies rejection (with strong counter-arguments and/or empirical evidence) of this factor.				

Despite data limitations and methodological issues in individual empirical studies, the totality of the literature we reviewed tested against published expert opinions and our own advisors' reviews led us to several overarching observations.

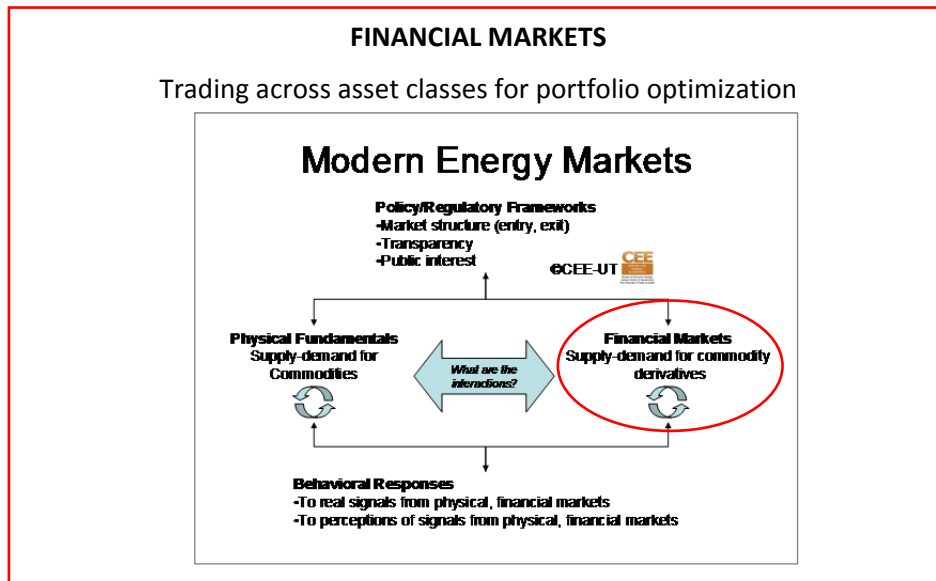
- There is a distinct need to clearly differentiate among various time horizons ranging from day-to-day fluctuations to several weeks or months and to several years.
 - Market fundamentals govern long-term prices for the most part; in other words, mean reversion eventually occurs. However, the “mean” changes along with changes in fundamentals; hence, it is important and probably most valuable to focus on resource availability and cost of development and delivery, as well as longer term demand dynamics rather than short-term volatility. Once structural breaks are taken into consideration, the “mean reversion” hypothesis finds significant support in the empirical literature.
 - Fundamentals are becoming more global and are not always well understood, partially due to lack of good and timely data, especially on consumption, storage, subsidies & black market activity, investment and spare capacity from emerging markets and NOCs and their governments.⁹
 - Short-term trading is governed by a large variety of market participants' financial goals within a portfolio approach and perceptions about market fundamentals. But, definitions of “short run” and especially “long run” are variable. Short run views are dominated by perceptions on industry news,¹⁰ seasonality and weather events. Longer run horizons are highly diverse with respect to timing as both demand and supply projects have long but varying lead times. As oil and gas projects become ever larger, more complex and expensive, distinct conflicts between short and long run views and positions will only become exacerbated.
- One needs to distinguish between physical and financial markets.
 - Relatively new players (institutional investors such as hedge funds and index funds) have brought large sums of money into oil derivatives trading since the early 2000s, treating oil as another asset class in their portfolios. The most significant investment by these players coincided with the period of most striking increase in the oil price in late 2007 and the first half of 2008. Many industry watchers and numerous empirical studies concluded that these investments amplified the oil price increase beyond a level justified by tightening demand and supply fundamentals. Some of the reviewed literature also stipulated a wave of financial bubbles that moved from market to market since the late 1990s, with the commodity bubble of 2007-08 following the real estate bubble. Other researchers did not find evidence supporting such an impact. The empirical literature has not reached a consensus on this debate. In our view, a consensus is unlikely due to data limitations and methodological differences; but, the

⁹ The IEA is increasingly drawing attention to data problems from China on the demand side and from producing countries (often dominated by NOCs) on the supply side. The JODI (www.jodidata.org), pioneered by IEA, OPEC, OLADE, APEC, EUROSTAT and UNSD, now covers more than 90 countries and may be a starting point for closing data gaps on refinery input and output, and stocks. The IEA's Oil Market Report provides useful data and is probably based on a more detailed global database. There are also proprietary sources on valuable information such as tanker data.

¹⁰ OPEC announcements are particularly relevant. Horan et al (2004) find that implied volatility of oil options rises as a meeting on production decisions approaches and drops over five days following the meeting. Demirer and Kutan (2010) find that production cut announcements have an impact on spot and futures markets while no such relationship is detected for announcements of production increases.

- weight of the arguments favors the bubble thesis (see Appendix 1 for our reasoning in reaching this conclusion).¹¹
- It is important to note that these large investments in oil derivatives by non-traditional participants is often distinguished from traditional speculation, which is necessary for an efficient market; and that they are not seen as manipulation. To be clear, there are many instances of manipulation attempts in this market as indicated by numerous investigations by CFTC and DOJ but these efforts are not thought to alter long-term prices driven by fundamentals or even cause bubbles (e.g., see Wray, 2008 and Pirrong, 2010).
 - The level of activity in over the counter (OTC) markets is, by all accounts, significant but not transparent. With new U.S. Commodities Futures Trading Commission (CFTC) data, exchange based positions are better understood but still CFTC seems to have more granular data on different players used by CFTC affiliated researchers (most papers by Büyükşahin and others); access to these data will help other researchers improve their analysis. Whether and how increased transparency is fostered in OTC markets hinges on how CFTC and peer regulators in other countries implement the myriad new laws and regulations impacting financial systems. The quest for more transparency on OTC data is also supported by IOSCO (2009). Even some proponents of the “no bubble” thesis favor closing down of the so-called “Enron”, “London” and “swaps” loopholes (e.g., Verleger, 2009b).¹²

Figure 6. Modern Energy Markets



¹¹ As shown in Figure 6, we proposed in 2009 that physical-financial interactions were more complex with portfolio effects.

¹² **Enron loophole:** The extent to which energy commodity derivatives are traded over the counter rather than in exchanges and the lack of transparency associated with OTC trades. **London loophole:** the volume of trade in international exchanges that are not subject to same regulations as exchanges in the United States. **Swaps loophole:** the prevalence of swaps or index trading in energy commodity derivatives. A U.S. Government Accountability Office report in October 2007 observed that CFMA 2000 created an environment for financial players to enter into the commodities markets in a large way via exempt commercial (primarily electronic trading facilities) and OTC markets and hence bypassing speculative limits in exchange-based trading (Enron loophole). GAO (2007) also noted that it became more difficult for CFTC to regulate fraud and manipulation in these markets partially due to limits on CFTC authority and partially due to lack of transparency of trading data in these markets. Jickling and Cunningham (2008), in a Congressional Research Service Report for Congress, summarize proposed legislative responses to close the three loopholes.

- Related to above, it is argued that there has been too much dependence on quantitative models to explain market movements and outcomes. Market conditions (uncertainties) change and, therefore, quant models must change, but many researchers probably have not made adjustments, or don't know how to.¹³
- Herding is real; to the extent equity and commodity markets can be complementary at times, herding will be contagious (some studies even show that herding can be larger in commodities than in equities – e.g., Boyd et al, 2010).
- Improving data reporting and collection will help resolve some of the uncertainties but limits to quantitative modeling and over-reliance on models during times of significant change will remain as challenges.

A Simplified Framework

We believe a simplified approach that is firmly based on industry fundamentals and that can make the best use of available data would be useful in keeping track of oil price dynamics. To begin with, we assert that the oil prices (and commodity prices in general) are driven by differences in intrinsic (supply-demand fundamentals) and extrinsic (everything else) factors (Table 3).

Table 3 – Price = intrinsic + extrinsic (+/-)		
Intrinsic		Extrinsic
Supply (F&D cost for the marginal barrel as the proxy indicator of price)		Financial – portfolio relationships (gold, exchange rates, etc.) – players in the market and their positions
Demand = consumption + inventory		Environmental regulations on products, refinery technology and crude quality
Consumption	Inventory	Macroeconomic factors (inflation, interest rates – monetary policy)
Rapid growth markets	Non-OECD data, oil at sea	Geopolitics (strikes, unrest, etc.)
Subsidies	ST price elasticity of D	

Although the framework may be “simplified” data challenges remain immense. We have identified a number of gaps in data and analysis across all of these conditions.

- **Intrinsic versus extrinsic value** – traded value of oil and other commodities is sometimes substantially different from what might be expected based on physical fundamentals. Economic theory suggests that the cost of finding incremental supplies to meet demand (consisting of consumption plus inventory as depicted in Table 3) should be the market clearing price. Any discrepancy between this cost and the traded price of oil can be attributed to extrinsic factors.¹⁴ To a large extent, uncertainty about intrinsic value drives other factors, such as market participant behavior and money flows. As such, F&D costs need to be better understood at the global level.¹⁵ Although F&D cost information may have limitation even in the United States, our

¹³ Lo and Mueller (2010) and Derman (2010) are particularly insightful in this regard.

¹⁴ For example, during the 31st International Conference of the International Association for Energy Economics in June 2008 (near the height of the price spike), Fereidun Fesharaki and Kenichi Matsui associated 25-40% of the price of the day with financial trading activities, i.e., above the level justified by the fundamentals. Other analysts made similar remarks throughout the price increase period. Diwan (2008) demonstrated the increase in F&D costs between 2002 and 2007 and the difference between the increased F&D cost and the price of oil as determined in the futures market. More recently, Sankey et al (2012) estimates US marginal cost of supply at \$80 per barrel.

¹⁵ Note that consumption and inventory developments are also uncertain but if we believe that the oil market clears physically (i.e., every single barrel demanded for whatever purpose is supplied at any given day), understanding the details of the demand side is secondary to having a good grasp of cost of marginal barrel supplied.

analysis indicates that it provides a good starting point. FRS data should be improved with supplemental data, wider coverage of companies and regions. Another approach is to develop an upstream cost index; major inputs for an upstream project are fairly well-known, steel prices, fees charged by service companies, shipping fees for offshore projects, and so on.

- **Surplus production and delivery capacity** is a form of storage. Relative change in surplus capacity, as compared to change in demand and perceived values and returns from competing investment opportunities, drives perceptions of extrinsic value. Numerous complications arise, including global oil industry organization (the role of the Organization of Petroleum Exporting Countries, OPEC), the role and performance of NOCs and government subsidy policies that inflate demand for petroleum products. NOC behavior and strategies and governments' subsidy policies need to be studied in detail. The need for better quality data on surplus capacity in producing countries, consumption and inventories from emerging economies, and "oil at sea" is paramount. *Without these data, empirical testing of fundamentals and the speculation-storage linkage will remain handicapped.*
- **Refining structure is key.** Refining links demand with crude oil supply and is impacted by any number of variables, including demand side policies (subsidies, environmental regulation and crude quality). The impact of various fuel specifications, biofuels, refinery subsidies, global distribution of refineries, their technologies and access to various quality crudes require a deeper understanding. In the absence of such improvements in data, testing the impact of mismatch between fuel specifications and refining structure will be very difficult, especially at the global level.
- **Oil represents a store of value** relative to other asset classes available to investors, regardless of the role of oil as a source of essential "energy" value. Low or negative correlation between commodities and stocks and bonds render oil (and other commodities) a risk diversification tool in financial portfolios.¹⁶ However, a couple of recent studies raised questions about the validity of this low correlation during highly volatile times and when commodities become a large part of the investment portfolios.¹⁷ The role of oil in various market participants' portfolios, and their actions in OTC markets versus in exchange trading, has been changing and the pattern of these changes needs to be analyzed. Comparison with other commodities that may have longer histories as part of financial portfolios could also be informative as to future progression of oil as an asset class.
- **Money flows and volatility** associated with those flows do play a role in the oil market. Uncertainty about intrinsic and extrinsic values creates price volatility. Price volatility creates profit opportunities and thus volatility attracts capital. Capital will only flow where returns are perceived to be highest given risk appetite. There is some evidence in the literature on speculative bubbles moving from market to market. As oil is now commonly seen to be another asset, it is now necessary for policy makers and regulators to comprehend the value of information provided by money flows in the financial system and its meaning for a growing set of interrelated asset classes.

¹⁶ For example, see Swedroe and Kizer (2008), Cifarelli and Paladino (2010), Gorton and Rouwenhorst (2006), Chong and Miffre (2010), Galvani and Plourde (2010), and Büyükhahin, Haigh and Robe (2008).

¹⁷ For example, see Silvennoinen and Thorp (2010) and Tang and Xiong (2011).

Appendix 1 - Summary of literature on the role of financial investment

<p>Commonly accepted: demand and supply fundamentals were extremely powerful throughout the 2000s, reaching historical levels in 2003-04; and were the main reasons for rising price. Low price elasticity of demand and price subsidies in China, India and other emerging economies curtailed demand response; supply expansion was too slow.</p>	
<p>Commonly accepted: speculation has increased: significant sums of money (relative to the size of the oil derivatives market) were invested in the oil derivatives market (along with other energy and non-energy commodities) in the mid-2000s, supplied by hedge funds, index funds and other non-commercial players.</p>	
<p>Question at hand: did the financial inflows (from large portfolio investors relatively new to the oil market and with different investment goals and horizons than most commercial players) have an impact on the price of oil (in other words, did they cause a bubble) in 2007-08? (Note that this question is different than “did large investors cornered / manipulated the market?” – there is scant evidence in the literature to support the manipulation hypothesis).</p>	
Independent empirical studies that conclude no impact	Independent empirical studies that conclude impact
<p>Interagency Commodity Task Force on Commodity Markets (July 2008) – empirical results are somewhat mixed. Granger causality may not be the right tool. Senate asked for an investigation, promised follow-up study not produced.</p>	<p>Möbert (2009) for Deutsche Bank Research- weekly & monthly data, possibly more appropriate to capture impact of sustained investment by financial participants than daily data; treats long and short positions explicitly and explores dispersion between them over time; most other studies directly focus on net long position.</p>
<p>IMF (2008) - Inclusive look at various commodities. Inventory test is handicapped since data on "commodity inventories are poor and lack global coverage." One regression uses CFTC's non-commercial positions, which is now commonly accepted as too aggregate to be useful. It is also difficult to identify how much of the trading activity undertaken by commercial players is actually speculative. These trader classifications need to be revisited.</p>	<p>Sornette et al (2009) – unique methodology based on statistical physics and complexity theory with predictive qualities. A novel approach that can benefit from peer review in the future.</p>
<p>Büyüksahin and Harris (2010)* - daily position & price data not available to other researchers. Granger causality with daily data has been criticized by many as inaccurate test of the question at hand and is difficult to interpret.</p>	<p>Gilbert (2010a) - Since data on Commodity Trading Advisors and Commodity Pool Operators are not available, trend-following behavior in the price series itself is tested estimating recursively a first-order Augmented Dickey-Fuller (ADF) regression, an approach developed by Phillips, Wu & Yu (2009); and Granger causality approach is used to test whether the "Corazzolla Index" (quantum index of net positions taken by index providers) explain commodity price movements. Some new tests with technical limitations as acknowledged by the author (pp. 5-6, 12-13).</p>
<p>Brunetti et al (2010) – daily position & price data, various tests. Granger causality with daily data has been criticized by many as inaccurate test of the question at hand and is difficult to interpret.</p>	<p>Phillips and Yu (2010) - statistically significant bubble characteristics in all seven series (three financial assets, two commodities including oil, one bond rate and one exchange rate). Recursive first-order Augmented Dickey-Fuller (ADF) regression approach developed by Phillips, Wu & Yu (2009). A novel approach that can benefit from peer review in the future.</p>
<p>Till (2009) – Working's T using CFTC's disaggregated data (caveats: no OTC data; speculation was judged not excessive based on threshold for agricultural commodities – is it appropriate for energy?)</p>	<p>Gilbert (2010b) – a rigorous and more comprehensive analysis of commodity markets. In addition to Granger causality, it uses the methodology from Phillips and Yu (2010). Granger causality with daily data is subject to same criticism but could perform better with lower frequency data.</p>
<p>Irwin & Sanders (2010) - Granger causality, Fama-MacBeth and long-horizon regression tests. CFTC's quarterly Index Investment Data for December 31, 2007 - March 31, 2010 and daily positions held by the U.S. Oil and Natural Gas Funds for July 5, 2006 - March 31, 2010.</p>	<p>Robles et al (2009) - The use of monthly data and different lags appears more appropriate for testing potential impact of sustained speculative activity. Causality was tested for 49 different 30-month periods, which also adds to accuracy of testing. Finally the use six different indicators for speculative activity adds robustness.</p>
<p>OECD (2010) – produced by Irwin & Sanders. Granger causality and Working's T. Results are weak for the two energy commodities “because of considerable</p>	<p>Baffes and Haniotis (2010) - Excellent review of pro and con arguments regarding role of index funds. Useful to look at the relationship of commodity prices across various</p>

<p>uncertainty about the degree to which the available data actually reflect index trader positions in these markets.” The null of no Granger causality can be rejected for crude oil at 10% and the sign is positive (Table 5); that is, index investments increased the oil price volatility.</p>	<p>groups. Econometric analysis and data are not discussed in detail. Role of speculation, although discussed in great detail and logically, was not directly tested.</p>
<p>Stoll & Whaley (2010) – exception to their general conclusion: “A separate analysis for crude oil futures—the commodity futures with the single largest notional value in the indexes (but not rolled in the same way within the indexes)—shows a positive and significant return differential.” Note, however, that this doesn’t necessarily imply an increase in the level of oil price.</p>	<p>Caballero et al. (2008) develop a general equilibrium model to analyze money flow among global financial assets and commodities.</p>
<p>Boyd et al (2010) – herding by hedge funds can be stabilizing volatility (30 futures markets); not a test of the impact on the price level. This conclusion is supportive of Haigh et al (2007) who reject “the hypothesis that hedge fund trading causes price volatility in energy futures markets.”</p>	<p>Cifarelli and Paladino (2010) employ a multifactor ICAPM model to investigate the relationship among oil prices, stock prices and the exchange rate. Although they cannot claim their results as absolute proof of speculation’s impact on oil prices, they conclude that “large daily upward and downward shifts in oil prices do not fit a fundamental-driven market.”</p>
<p>Plante & Yücel (2011a, 2011b) – the authors conclude that fundamentals such as world GDP growth and decreasing OPEC excess capacity were the main drivers and, focusing on the spot-futures-storage relationship, that “the data are in line with what the theory predicts we should see when market tightness and a reasonably well-functioning futures market exist.”</p>	<p>Kaufmann (2011) - A comprehensive analysis, employing multiple methodologies, exploring new data sets, and providing substantiated critique of previous literature.</p>
	<p>Kaufmann and Ullman (2009) – Impact of fundamentals exacerbated by speculators. Using weekly data and two different model specifications to test for causality increases the robustness of the results. Looking at 10 different crudes and spot-futures relations is rare in the literature but valuable given the integrated nature of the global market.</p>
	<p>Einloth (2009) concludes that speculation did not play a role in the movement of oil up to \$100/bbl however speculative storage have played a role in the run up to \$140/bbl. This is a fresh look at "storage" to gauge whether speculation played a role; convenience yield calculated using futures prices (consistent with theory) bypasses some of the problems associated with gathering actual storage data. Still, there are some caveats. For example, one cannot differentiate between speculative and non-speculative builds even for the available US data.</p>
	<p>Frankel & Rose (2010) find evidence of speculative bubble in the form of bandwagon effect, trading based on extrapolation of recent trends where increasing prices feed expectations of further increases. This effect is in addition to fundamentals such as demand growth.</p>
	<p>Went et al (2009), using a non-parametric duration dependence test, find evidence of speculative bubble in 11 of 28 commodities they tested, including WTI.</p>
<p>Testimonies</p>	<p>Testimonies</p>
<p>Verleger (2009b) – no direct testing of the question at hand but a strong alternative: mismatch between changing product demand (emissions regulations) and the refining sector. CFTC representatives including one by the Acting Chairman Lukken (2008) and NYMEX CEO, Newsome (2008)</p>	<p>Cooper (2008), Gheit (2008), Greenberger (2008a, 2008b), Guilford (2008), Masters (2008a, 2008b), Ramm (2008), Petzel (2009), Steenland (2008)</p>

Theoretical underpinnings	Theoretical underpinnings
<p>Storage did not increase – this is based on the conventional relationship between futures and cash prices: unless demand and supply are perfectly inelastic (see next row), a futures-cash price gap should lead to inventory build-up (Hamilton, 2009a; Kilian and Murphy, 2010; IEA, 2008; IMF, 2008; Interagency Commodity Task Force on Commodity Markets, 2008 among others). But this relationship, or at least its testing based on available storage data, is challenged strongly in the literature (see cell across) and contradicted even by data from IEA, Verleger and others. One particular difficulty is differentiating movements in futures prices from other factors that can impact inventory levels; another is the direction of causality among these variables.</p>	<p>See Einloth (2009) few rows above. Pirrong (2008) – “Those searching for evidence of speculative excess need look elsewhere than the price-inventory relation.” Parsons (2009) – “The oil price spike of 2003-2008 certainly looks like a bubble...The argument that the lack of above-ground storage proves the oil price was not a bubble has no merit, and is based on an old mindset about oil prices. The price movements of 2003-2008 would not have driven an accumulation of above-ground storage, whether the price movements were caused by changing fundamentals or by the foolish beliefs that drive a bubble...The beliefs driving a bubble can gain traction without there being any identifiable individuals behind it.” Focal point theory put forward by Fattouh (2010a) support this view (in fact, there is a rich literature on herding that supports the view that bubbles can form without manipulation). Singleton (2010) concurs with these analyses while asserting that “rational management of crude oil inventories can enhance volatility in oil prices when aggregate demand has a persistent growth component.” Eckaus (2008) claim that inventory capacity was low and those with spare capacity (i.e., OPEC producers) were not willing to supply oil for storage. Khan (2009) mostly concurs with these views also adding that “...data on oil inventories are notoriously poor...do not include oil tankers, commonly referred to as “oil at sea”...” IEA (2009) concludes that global crude inventories started increasing in the second quarter of 2008. More importantly, the IEA acknowledges lack of non-OECD storage data; given that non-OECD markets represent about 50% of global consumption (and growing), the lack of data is a serious handicap, which the IEA attempts to bypass via estimating a ‘miscellaneous to balance’ component. Furthermore, the IEA (2009) states that “...high level of stockbuilds do not necessarily result from speculation per se.” (p. 99). Instead a slowing demand could create a mismatch with existing levels of production and refinery runs. Kaufmann (2011) examines the US private inventories (refiners, tank farms, pipelines, leases and Alaskan oil in transit) based on the EIA data and finds an increasing trend starting in early 2004. This result qualifies Hamilton (2009a), who observes significantly reduced stocks held by refiners in the United States in late 2007 and early 2008, and other studies using refinery inventory data only. Saporta et al (2009) raise another possibility: large consumers such as industrial facilities may decide to use up their inventories rather than purchasing new supplies if they believe price increases to be speculative and hence temporary.</p>
<p>Short-term price elasticity is not zero - Kilian and Murphy (2010) challenge the conventional wisdom on near zero short-run price elasticity of demand based on a novel structural econometric model, which explicitly takes into consideration inventory levels and changes. But (1) OECD inventory data not representative of global picture, (2) dry cargo shipping rate is related to bunker fuel, (3) refiner’s acquisition cost include cost of tanker transportation. Kaufman (2011) provides a detailed critique.</p>	<p>Hamilton (2009b) - if the short-run price elasticity of fuel demand is zero, speculation may lead to rising oil price without any increase in oil inventories. Hamilton (2009a and 2009b), Smith (2009) and others provide price elasticity estimates that are very close to zero. Pierru and Babusiaux (2010) develop a dynamic model where price elasticity of demand is an increasing function of the time horizon considered, which allows for oil demand adjusting to price changes slowly but continuously: speculation can push oil prices above the level justified by market fundamentals without a significant increase in inventories at least for several months.</p>

Demand and supply fundamentals in 2007-08	Eckaus (2008), Khan (2009) and Baffes and Haniotis (2010) provide evidence that demand growth has slowed down by 2007, demand was lower and production capacity was higher in early 2008 than late 2007 and OPEC spare capacity was higher in 2008.
For every long there must be a short (players and their strategies do not matter)	Institutional investors exclusively long, exclusively OTC (Spector, 2005, 2007); portfolio investment (Erb & Harvey, 2006; Gorton & Rouwenhorst, 2006; Chong & Miffre, 2010; Büyüksahin, Haigh & Robe, 2008; Cifarelli & Paladino, 2010)
Most of this research uses daily data.	Daily data may not be appropriate to evaluate impact of financial inflows over weeks or months (Singleton, 2010; Gilbert, 2010a; Möbert, 2009)
* Büyüksahin authored many other papers in collaboration with other researchers from or affiliated with CFTC. These studies provide insights into trading by different players in the energy futures markets that is useful in making interpretations about relationship across different maturity futures prices and those between commodity and equity markets; but do not directly address the impact of speculation or investment on the price level. Also, since the data used in these studies are not publicly available, other researchers cannot conduct similar studies or use the data to test various hypotheses.	

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