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Fundamentals, Trader Activity and Derivative Pricing

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Abstract

We identify and explain a structural change in the relation between crude oil futures prices across contract maturities. As recently as 2001, near- and long-dated futures were priced as though traded in segmented markets. In 2002, however, the prices of one-year futures started to move more in sync with the price of the nearby contract. Since mid-2004, the prices of both the one-year-out and the two-year-out futures have been cointegrated with the nearby price. We link this transformation to changes in fundamentals, as well as to sea changes in the maturity structure and trader composition of futures market activity. In particular, we utilize a unique dataset of individual trader positions in exchange-traded crude oil options and futures to show that increased market activity by commodity swap dealers, and by hedge funds and other financial traders, has helped link crude oil futures prices at different maturities.

Keywords: Crude Oil Futures, Maturity, Segmentation, Cointegration, Trading Activity, Fundamentals.

JEL codes: G10, G13, N22

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I. Introduction.

Derivative markets have experienced unprecedented levels of activity in the past decade. In the case of commodities, part of this growth stems from financial investors' desire for exposure to commodity prices. We utilize a unique dataset of trader positions in exchange-traded crude oil options and futures, to provide the first formal evidence of a transformation at the world's largest futures market for a physical commodity.[1] In particular we show that, together with changes in the fundamentals of the underlying commodity, increased market activity by commodity swap dealers, and by hedge funds and other financial traders, has had a major impact on linking crude oil futures prices at different maturities.

Under standard no-arbitrage arguments, spot and futures commodity prices are linked by a net cost-of-carry factor that accounts for the time value of money, storage costs, and a possible convenience yield. In theory, futures prices along the term structure should likewise be related through similar cost-of-carry equations. We document that a stable long-run relation has existed since the early 1990s between the prices of futures contracts with less than a year to maturity.[2] The same is not true, however, for longer-maturity contracts. Until 2001, we find that contracts dated one year and beyond were priced as though traded in segmented markets. After 2001, the price of one-year futures began to move in sync with the nearby price and, since mid-2004, both one-year and two-year futures prices have become cointegrated with the nearby price.

This development is economically significant. A critical issue, for many financial or commodity market participants, is whether a long-term relation exists between the prices of some financial instruments even though these prices may diverge in the short run (Kasa, 1992). Such long-run co-movements are precisely the ones that the cointegration analysis identifies (Engle and Granger, 1987; Johansen, 1988). One implication is that long-term hedging strategies should be more effective when they are based on cointegrated futures contracts, i.e., when nearby and backdated contracts are not segmented. Conversely, a lack of market integration across contract maturities could be deleterious to traders who might otherwise rely on its existence for price discovery or hedging purposes.

To ascertain what caused the pricing changes, we compute a rolling measure (the trace statistic) to capture changes over time in the extent to which futures prices are cointegrated. We then identify and test the economic and financial variables that explain the evolution of this trace.

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[1] Total open interest in the New York Mercantile Exchange's (NYMEX) West Texas Intermediate (WTI) crude oil contracts was a notional $322bn at the end of August, 2008.

[2] Quan (1992) documents cointegration between spot and near-term futures (less than three month) in the 1980s.

One candidate explanation is that the fundamentals of crude oil changed, so that either the stochastic process driving the spot price (Bessembinder *et al.*, 1995) or the time-series properties of the net cost-of-carry (Brenner and Kroner, 1995) mutated. Using a time series of real-sector variables, such as the non-Saudi spare crude oil production capacity and different proxies for the strength of world demand for industrial commodities, we identify breaks in late 2003 to early 2004 that help explain the development of futures price cointegration over time. Market fundamentals do play a role in the emergence of cointegration.

Visual inspection and Granger causality tests, however, suggest that changing fundamentals are not the sole cause of greater cointegration. Intuitively, cointegration should result from arbitrage activities that link futures prices at different maturities. In practice, arbitraging may be limited by financial or other market constraints. As noted in Başak and Croitoru (2006), the arrival of new types of traders who face fewer constraints can help alleviate price discrepancies and improve the transfer of risk between market participants. Still, even such less-constrained arbitrageurs may be unwilling to trade illiquid instruments. That is, a "thick" market" is needed for effective arbitrage strategies (e.g., Admati and Pfleiderer, 1988; Roll, Schwartz, and Subrahmanyam, 2007).[3]

To explore whether and how futures trading-related factors contribute to cointegration, we use non-public data from the U.S. Commodity Futures Trading Commission's (CFTC) large trader reporting system that identifies daily individual trader positions at various contract maturities and classifies the traders according to their underlying business. As a result, we are able to analyze the positions of eight types of participants in the WTI crude oil market– four "traditional commercial" categories, including producers, manufacturers, and dealers or merchants; three "non-commercial" categories, including floor brokers and traders, hedge funds, and non-registered participants; and, "commodity swap dealers."[4] The latter's positions reflect over-the-counter swap transactions with commercial entities as well as with commodity index funds and other financial investors.

[3] Interviews with major players in energy derivative markets are consistent with this intuition, and provide a clue as to the sequence of events involved. They suggest that the expectation of stronger fundamentals for industrial commodities (the anticipation of robust economic growth coupled with extraction capacity constraints) stoked investor interest in these assets, which led to an increase in commodity futures market participation by financial institutions and by the intermediaries trading with them. In particular, these interviews suggest that greater crude oil futures trading by commodity swap dealers amid a commodity-index investment boom, together with the growth of swap dealers' positions in medium- and long-term contracts that started in 2003 and strengthened after oil prices became contangoed in 2004, were important factors behind the increased pricing convergence.

[4] Reporting traders account on average for 94% of the total WTI open interest during our sample period. The CFTC provides public data on trader positions in weekly Commitment of Traders (COT) Reports. These reports, however, aggregate large traders into two broad, heterogeneous groups (Commercial *vs*. Noncommercial) and do not break down activity by contract maturity. On January 5, 2007 the CFTC began publishing COT—Supplemental reports that identify Commodity Index Traders specifically, but only for twelve agricultural commodities (not for energy contracts).

Futures and options open interest quintupled between 2000 and 2008. We show that this growth involved a considerable lengthening in the maturity structure, and a sea change in the trader composition, of market activity. More explicitly, we identify three trends in futures trading-related data that speak to the development of cointegration of prices across the futures term structure. One, open interest at maturities greater than one year grew nearly twice as fast as open interest at shorter maturities. Several categories of traders now carry much larger long-dated positions (one year or more) than they held in near-dated contracts (three months or less) in 2000. Two, swap dealers' market share grew markedly during the key years of 2002 and 2003 amid the start of a commodity-index investment boom. Three, "traditional commercial" aggregate market share has halved since 2000 as financial traders greatly expanded calendar-spread trading. Indeed, the market share of financial traders has more than doubled, from less than 20 percent of all open futures and futures-equivalent option positions in 2000 to more than 40 percent in 2008.

Armed with these stylized facts, we use the autoregressive distributed lag modeling approach to cointegration analysis in order to test whether there exists a long-term relation between the strength of price cointegration and the positions of different types of trader. We control for fundamentals that might affect cointegration: spare crude oil production capacity and two proxies of world demand for commodities (an index of non-exchange-traded commodity prices, and the cost of shipping dry freight in bulk). We also control for an exogenous liquidity change (the advent of electronic trading); for the general cost of liquidity (the slope of the term structure of near-term crude oil prices, which captures the cost of maintaining an exposure to crude oil prices by means of a long position in the nearby contract); and, for cross-sectional differences in liquidity (to allow for the fact that most longer-term trading involves contracts maturing in June or December).

In this multivariate setting, we show that fundamentals help to explain the cointegration of futures prices across the term structure – fundamentals matter. Furthermore, we find that the futures market activities of some types of traders (but not others) also help explain cointegration – strong evidence that the composition of trading interests also matters.

Specifically, we show that the strength of the cointegration between the nearby, one-year and two-year crude oil futures price series is linked to the market activities of financial traders, especially in one- and two-year contracts, as well as to the activity of commodity swap dealers in nearby contracts (activity that echoes in large part their commodity index swap business). By contrast, we find little evidence of a positive connection between cointegration and traditional commercial trading or commodity swap dealer activity in one- and two-year contracts (activity likely to result from swap dealers' commodity-index business). Together, our empirical results suggest that increased participation by financial traders, as well as by commodity swap dealers, enhance linkages among various futures prices. In this regard, our results illustrate how greater market activity by some types of traders can enhance market quality in commodity markets.

The remainder of the paper proceeds as follows. Section II summarizes our contribution to the literature. Section III documents changes in the relation between different-maturity crude oil futures. Section IV documents major changes in the maturity structure and the trader composition of the crude oil futures market since 2000. Section V develops testable hypotheses to explain the pricing changes. Section VI analyzes the impact of changes in crude fundamentals and in futures-market characteristics on WTI futures pricing. Section VII concludes.

II. Related Work.

The present paper is related to several strands of the finance and economics literatures. In economics, it is part of a sizeable literature on the role of crude oil fundamentals on macroeconomic aggregates and financial variables.[5] In particular, Kilian and Park (2007) show that the response of U.S. stock returns to an oil price increase depends on whether the increase is the result of a demand or a supply shock in the crude oil space. Rather than assess the impact of commodity fundamentals on price *levels* in securities or derivatives markets, our analysis establishes that fundamentals are relevant in terms of the *linkages* between crude oil futures prices at different maturities.

In finance, our analysis adds to extant work on financial market integration and to a large body of research on the roles of different kinds of traders in financial markets. We also provide the first detailed characterization of hedging and speculative activity in the crude oil futures market, and the first study to document the development of a market for long-dated commodity futures.

We show that, although long-dated crude oil futures were priced as though segmented from near-dated contracts until 2003, these price series are now cointegrated. Our findings complement papers that document greater integration between international equity markets in the last two decades (e.g., Bekaert, Harvey and Lumsdaine, 2002; Carrieri, Errunza and Hogan, 2007). Unlike those papers, which test the equality of the prices of risk across geographic boundaries, our focus is on identifying cointegration across the maturity structure in a single market. In that sense, our paper is also related to studies that document cointegration across the Treasury yield curve (Hall, Anderson and Granger, 1992; Bradley and Lumpkin, 1992) or between spot and near-dated crude

[5] See, e.g., Hamilton (2005), Kilian (2008a), and papers cited therein.

oil futures prices (Quan, 1992). Unlike those papers, we show that the relation between prices across near- and far-dated contract maturities has changed over time, and relate the extent of cointegration to changes in fundamentals as well as in the amount and composition of market activity.

In particular, we show that financial traders who may have little interest *per se* in the underlying commodity can add important dimensions toward integrating the related derivative market and making commodity markets more informationally efficient. Our empirical results are consistent with the notion that greater participation by less-constrained arbitrageurs helps to alleviate price discrepancies, as modeled by Başak and Croitoru (2006). Our results also provide evidence that the growth in swap dealers' futures market participation helps explain the improving price discovery among nearby, one- and two-year futures contracts. To the extent that swap dealers' increased activity in near-term contracts echoes an increase in commodity index investment flows, our findings support other previous empirical evidence that greater uninformed liquidity trading is related to the efficacy of arbitrage activities (Roll *et al*., 2007).

The present paper is also part of a large literature on the role of specific categories of traders in financial markets. Hedge funds, in particular, have drawn a lot of attention in recent years. Much of this scrutiny focuses on the concern that speculators, including hedge funds, may exert a destabilizing effect on financial markets, which could ultimately lead to higher trading costs.[6] In U.S. markets, Brunnermeier and Nagel (2004) find that hedge funds did not exert a correcting force on stock prices during the technology bubble. Haigh, Hranaiova and Overdahl (2007) find that hedge fund activity does not affect price levels in energy futures markets, yet hedge funds are very important to the functioning of the market through the liquidity they provide to other participants. We assess the impact of different groups of traders, including hedge funds, on the linkages between market compartments – rather than on the absolute price levels in a single market.[7] Our results complement this extant research, as we find that hedge fund trading activity is beneficial in that it contributes to bringing in line the prices of commodity futures at different maturities.

Our research yields the first detailed depiction of activity on the world's largest commodity futures market. A number of authors have used the CFTC's publicly-available Commitment of

[6] Chan, Getmansky, Haas and Lo (2006) provide a concise review of the large academic literature on hedge funds. The evidence on whether funds are destabilizing is mixed. For example, Fung and Hsieh (2000) argue that hedge funds had a significant market impact during the European Exchange Rate Mechanism crisis in the early 1990s. By contrast, Choe, Kho and Stulz. (1999), Fung, Hsieh and Tsatsaronis (2000), and Goetzmann, Brown and Park (2000) conclude that hedge funds were not responsible for the Asian crisis in the late 1990s.

[7] Haigh, Hranaiova & Overdahl (2007) also abstract from the questions related to the maturity structure of trader positions that are at the heart of our analysis.

Traders (COT) reports, mostly to shed light on speculative and hedging activity in futures markets.[8] The COT data, however, are highly aggregated: they only differentiate between two broad types of traders ("commercial" vs. "non-commercial"). Our more detailed data allow us to separate the greatly increased activity of some kinds of traders (especially, financial traders and commodity swap dealers) from the lesser growth of futures market activity of other categories of participants (e.g., crude oil producers and manufacturers). These differences matter: to wit, we show that the activities of only some categories of traders help explain changes in market integration.[9]

The public COT data, furthermore, do not break down trader activity at different maturities. Identifying the differential evolutions of the near- and far-ends of the market is a major contribution of the present study. To our knowledge, the only other papers with some formal evidence on the maturity structure of oil (or any commodity) markets precede the development of long-term futures (Neuberger, 1999 and Ederington and Lee, 2002).[10]

Indeed, although crude-oil futures with maturities of up to seven years have been available since 1997, the view that longer-term futures may be too illiquid to be useful for hedging purposes has remained a piece of conventional wisdom. Papers devising short-term hedging strategies for long-term price risk are still predicated on the notion that long-maturity contracts, if at all available, are highly illiquid – see, e.g., Veld-Merkoulova and de Roon (2003). We show that, since 2004, this conventional wisdom no longer applies in that (i) market activity in very-long-dated contracts (>3 years) now routinely exceed typical levels of activity in short-term (<3 months) contracts just a few years ago and (ii) the prices of nearby and further-out contracts have become cointegrated.

III. Changes in the WTI Crude Oil Market: Pricing.

The NYMEX first successfully introduced WTI light sweet crude oil futures in March, 1983. In the following ten years, there was little trading beyond the first few maturity months (Simon and Lautier, 2005). The NYMEX started listing December contracts with maturities up to three, seven

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[8] See, e.g., Hartzmark (1987, 1991), Bessembinder (1992), Leuthold, Garcia and Lu (1994), Chang, Chou and Nelling (2000), de Roon, Nijman and Veld (2000), Wang (2003), Gorton, Hayashi and Rouwenhorst (2007), and Piazzesi and Swanson (2008).

[9] Only a handful of other studies use disaggregated, non-public CFTC data. They are Ederington and Lee (2002), who analyze *heating*-oil NYMEX futures position from June 1993 to March 1997; Chang, Pinegar and Schachter (1997), whose dataset includes six futures markets from 1983 to 1990; and Haigh et al (2007), who analyze possible linkages between hedge fund activity and energy futures market volatility between August 2003 and August 2004.

[10] Many papers, in contrast, analyze the term structure of futures crude oil *prices*. See e.g. Litzenberger and Rabinowitz' (1995) investigation of backwardation; Routledge, Seppi and Spatt's (2000) model and numerical analysis of forward pricing; and Lautier's (2005) study of pricing determinants for short-, medium- and long-dated crude oil futures.

and nine years in 1990, 1997 and 2007, respectively. Since March 2006, all maturity months up to five years (not just June or December contracts) have been listed for trading on the exchange.

A stable long-run relation has existed since the 1980s between crude oil's spot, nearby and three-month futures prices (Quan, 1992). In this Section, we use a recursive cointegration analysis to show that the same is not true for the prices of longer-dated futures.

Our main focus is on one- and two-year-out futures (two years is the outermost maturity for which a long enough continuous time series exists of weekly crude oil futures settlement prices). To provide a context for the extent to which the nearby, one-year and two-year-out futures prices are cointegrated, we also provide cointegration results for the nearby and next two nearby months; and, for the prices of the nearby, six-month, and nine-month futures.

We establish that a stable long-run relation has existed since the early 1990s between the prices of futures contracts with less than a year to maturity.[11] Contracts dated one year and beyond, however, started only more recently to move in sync with the nearby price. It is only since mid-2004 that one-year and two-year futures prices have been cointegrated with the nearby price.

A. Data

We use NYMEX Tuesday settlement prices from March 1989 to August 2008 for the nearby, next two nearby months, six-month, nine-month, and one-year contracts; and, from September 1995 to August 2008, for the two-year contract. March 1989 (*September 1995*) is the earliest date from which a continuous daily price series can be created for the one-year (*two-year*) futures. This continuity is necessary to create rolling daily positions at different maturities while ensuring that the intervals between these maturities remain constant.

A point of terminology is in order at this stage. Very few WTI crude oil futures traders take delivery. As a result, open interest in the prompt-month WTI futures drops precipitously, as that contract approaches its expiration date and traders who wish to retain their crude oil exposures roll their positions into the next-month contract. At the same time, arbitrage during the last days of a contract's life becomes more difficult because it entails carrying a cash market position – which may "disconnect" the prompt contract's price from other futures prices and make the nearby price more volatile than the farther out months. Because our interest is in the most liquid short-dated contract, we therefore label "nearby contract" the short-dated futures contract with the highest open interest.

[11] In the 1980s, even the prices of six- and nine-month futures were not cointegrated with the nearby price (Quan, 1992).

In practice, this definition means that the "nearby price" typically stands for the price of the prompt-month contract through the seventh or eighth business days of the expiry month, and the price of next-month contract for the remainder of that month.[12]

Figure 1 and Table 1 provide information on the nearby, one-year and two-year price series from July 2000 to August 2008. Two facts emerge. One, the maximum of each price series during the sample period is about seven times larger than the corresponding minimum, reflecting major price increases in the second half of our sample period. Two, the unconditional correlations between the returns on the three series are also much higher in the second half of the sample period.

B. Cointegration Analysis

Economic theory generally deals with equilibrium relationships. Empirical econometric studies attempt to evaluate such relationships by summarizing economic time series using statistical analysis. Applying standard inference procedures in a dynamic time series model, however, requires that the various variables be stationary, since the majority of economic theory is built upon the assumption of stationarity. Therefore, before assessing pricing relations in the crude oil market, it is useful to determine the orders of integration for the variables considered. For this purpose, we perform stationarity tests employing the Augmented Dickey Fuller (ADF) unit root tests.

Table 2 shows that the nearby, one- and two-year futures price series are all nonstationary but become stationary after taking first differences, i.e., they are all $I(1)$ or integrated of order one. Thus, we cannot rely on inferences based on simple OLS regressions involving these variables.[13]

The use of non-stationary variables does not necessarily result in invalid estimators. An important exception arises when two or more I (1) variables are cointegrated (Engle and Granger, 1987); that is, there exists a particular linear combination of these non-stationary variables which is stationary. For example, if Y_t and X_t are both $I(1)$ and there exists a β such that $Z_t=Y_t-\beta X_t$ is $I(0)$, then Y_t and X_t are said to be cointegrated, with β being called the cointegrating parameter.

Johansen (1988) proposes and implements a unified vector autoregressive system approach for testing cointegration. He derives the maximum likelihood estimator of the space of cointegration

[12] Robustness analyses using calendar dates (rather than open interest) to time the roll yield qualitatively similar results.
[13] OLS estimators would have sampling distributions that are very different from those derived under the assumption of stationarity. In particular, if the variables are non-stationary and not cointegrated, then the OLS estimator does not converge in probability as the sample size increases; the t- and F- statistics do not have well defined asymptotic distributions; and, the Durbin-Watson statistic converges to zero. Put differently, OLS regression results might be spurious in that, even if there is no clear relation between the variables, we could still find a statistically significant relationship due to the fact that they share a trend.

vectors and the likelihood ratio test of the hypothesis that it has a given number of dimensions. The procedure involves the following stages:

- Model checking, determination of lag length;
- Determination of cointegration rank based on trace statistics;
- Estimation of the cointegration space.

The first step of the model building involves the choice of lag order. The most common procedure is to estimate a vector autoregression using the undifferenced data, and to then use one of several information criteria to select the number of lag lengths. We use the Schwarz information criterion (SC) to determine the optimal lag. The optimal number of lag is 2 in our case.

After selecting the lag length, the Johansen procedure estimates a vector error correction model (VECM) to determine the number of cointegrating vectors. According to Johansen (1988), a general polynomial distributed lag process, x_t, involving up to k lags, can be written as:

$$x_t = \Pi_1 x_{t-1} + \ldots + \Pi_k x_{t-k} + u_t \tag{1}$$

where x_t is a vector of n variables of interest, Π_i is an $(n \times n)$ matrix of parameters, and u is n-dimensional Gaussian independently distributed random variables with mean zero and variance matrix Λ. This equation can be reformulated into VECM form:

$$\Delta x_t = \Gamma_1 \Delta x_{t-1} + \ldots + \Gamma_{k-1} \Delta x_{t-k+1} + \Theta x_{t-k} + u_t \tag{2}$$

where $\Gamma_i = -\Sigma_{j=i+1}^{k} \Pi_j$, ($i = 1,2,\ldots,k-1$), and $\Theta = \Sigma_{i=1}^{k}(\Pi_i - I)$. This way of specifying the system contains information on both the short- and long-run adjustments to changes in x_t, via the estimates of $\hat{\Gamma}_i$ and $\hat{\Theta}$, respectively. Assuming that x_t is $I(1)$, while r linear combinations of x_t are stationary, we can write

$$\Theta = \alpha\beta', \tag{3}$$

where α is the vector of adjustment coefficients; β is the cointegrating vector; and both are ($n \times r$) matrices. The approach of Johansen (1988) is based on the estimation of system (2) by maximum likelihood, while imposing the restriction in (3) for a given value of r. Johansen demonstrates that β can be estimated by regressing ΔX_t and X_{t-k} on the lagged differences.

The next step in the Johansen approach involves testing the hypothesis about the rank of the long run matrix Θ, or equivalently the number of columns in β. The likelihood ratio test for the determination of the rank r is discussed in Johansen (1992). In general, tests of the hypothesis that $r \leq q$ use the likelihood ratio test statistics:

$$\lambda_{trace}(q) = -T\Sigma_{j=q+1}^{k} log(1-\hat{\lambda}_j) \tag{4}$$

This test is called the trace test. It checks whether the smallest $k-q$ eigenvalues are significantly different from zero.

Most of the existing Monte Carlo studies on the Johansen methodology point out that the dimension of the data series for a given sample size may pose particular problems, because the number of parameters of the underlying VAR models grows very large as the dimension increases. Likewise, difficulties often arise when a given lag length of the system is either over or under parameterized. Reimers (1992) argues that, for small samples, the Johansen procedure over-rejects when the null is true. To correct this bias, Reimers suggests an adjustment in the degrees of freedom in the trace statistic by replacing T by $T-nk$ for small samples. The corresponding degrees-of-freedom-adjusted trace can be written as:

$$\lambda_{trace}^{a}(q) = -(T-nk)\Sigma_{j=q+1}^{k} log(1-\hat{\lambda}_j) \tag{5}$$

In this study, we define Y_t as composed of three elements. They represent the nearby, one-year-out, and two-year-out price series for WTI crude oil futures contracts. Table 3 (discussed in the next sub-section) reports the Johansen trace test for the number of cointegrating relations, i.e., the cointegration rank. The VAR for the Johansen procedure has 2 lags of each variable, thereby allowing for one month of growth rates of the variables. The choice of the cointegration rank is very important in the Johansen methodology because the rest of the analysis is affected by this choice. We use the likelihood ratio test (i.e., the trace test) to determine the cointegration rank. The latter divides the data into *r* relations towards which the process is adjusting and *p-r* relations which are pushing the process. The first set of relations can be interpreted as equilibrium errors, and the second set can be viewed as the common driving factor in the system. If, for example, *r*=0 (no cointegration), then we have "*p* unit roots", i.e., common driving trends in the system.

Panel A in Table 3 presents cointegration rank results for the whole sample period. Panel A should be read from top to bottom. We start by testing the hypothesis that all roots are unit roots

(r=0, p-r=3), which we clearly reject. Next, we test for two unit roots (r=1, p-r=2); this is also rejected by the corrected test statistics at any standard level of significance. However, when we move to the case of one unit root, we cannot reject this null hypothesis using P-value at any given standard level of significance. Therefore, the rank test statistics implies that there is at most one cointegrating relation at standard levels of significance.

We also test the individual elements of β' against zero in the factorization $\alpha\beta' = \Pi$ and investigate the possibility of weak exogeneity of each of the series (testing whether each element of the α vector is equal to zero). The results are presented in the lower portion of Table 3. In particular, Panel B explores the possibility that one of the three series is not in the cointegrating space. While the exclusions of one-year- and two-year-out contracts from the cointegration relation can be accepted at any standard level of significance, the economic importance of these prices requires that they be kept in the analysis. With respect to the short-run adjustment toward the long run relations, α, we also test for weak exogeneity on each market. For each futures maturity, we test for whether or not that futures price responds to perturbations in the cointegrating space. Inspection of Panel C in Table 3 suggests that the nearby contract is weakly exogenous and that the 1 year and 2 year contracts do all the adjusting to the long-run equilibrium.

C. Dynamics of the Relation between Nearby and Long-dated Futures Prices

In order to study the development of the level of cointegration among contracts of differing maturities, we examine the dynamics and extent of relationship (if any) between the three prices using the recursive cointegration method outlined in Hansen and Johansen (1993). This technique has been employed in many studies of convergence across stock markets or interest rates in different countries.[14]

The recursive cointegration technique lets us to test for changes in the level of cointegration among prices during our sample period. It allows us to recover two error-correction-model (ECM) representations. In the “Z-representation,” all the parameters of the ECM (β and α) are re-estimated during the recursions, while under the “R-representation” the short-run parameters (α) are kept fixed to their full sample values and only the long run parameters (β) are re-estimated. We recover the R-representation, since our focus is on changes in the long-run relation between the different price series.

[14] See, e.g., Bremnes, Gjerde and Saettem (1997), Bessler & Yang (2003), and Wang, Yang and Li (2007).

The logic behind the recursive cointegration technique is similar to Johansen's (1988) multivariate cointegration approach. Instead of using all of the observations, we start with an initial sample period from t_0 to t_j (for some choice of j) and calculate the trace statistics for this sub-sample. Then, we increase the sample size by 1 from t_0 to t_{j+1} *(i.e., we* add one more week in each step) and calculate the relevant trace statistics for this sample period. This process continues until we exhaust all the observations. In the final stage, we perform the cointegration analysis for the full sample and calculate the trace statistics. Of course, the trace statistic calculated in the final stage equals the standard static trace statistic calculated with the Johansen (1991) method. The recursive method, however, is far more informative as it allows us to see the *dynamics* of the trace statistic.

Figure 2 presents a time series plot of the normalized trace statistic for each week from 1992 onwards. We use a three-year period for the initialization; hence, since daily price data are available for the 1-year (*2-year*) contract from 1989 (*1995*) onwards, the results start in 1992 (*1998*) for tests involving maturities up to one year (*two years*).

We re-scale all trace statistics in Figure 2 by the 95% quantile of the trace distribution derived for the selected model without exogenous variables or dummies (Johansen and Juselius, 1992). A normalized trace statistic above 1 suggests the rejection of the null hypothesis of no cointegration at the 5% level of significance. In addition, to see whether there exists a cointegrating vector among our variables, the slope of re-scaled trace statistic determines the direction of co-movements between our variables. An upward slope indicates rising co-movement, while a downward slope for the trace statistic reveals declining co-movement between our variables.

The top curve on the graph (dark blue) shows the scaled trace statistic for the "Nearby", "Nearby + 1 month" and "Nearby + 2 months" contracts. For these near-term price series, there is strong evidence of a cointegrating vector throughout the sample period. The next highest curve (drawn in green) shows the scaled trace for the "Nearby", "Nearby + 6 months" and "Nearby + 9 months" contracts. For these three price series, there is statistical evidence of a cointegrating vector from 1992 onward, and of a strengthening of the cointegration after mid-1998.

The third curve starting in 1992 (drawn in red, starting close to 0.3) shows the scaled trace for the "Nearby" and "Nearby + 12 months" (i.e., one-year-out) contracts. These two price series are indubitably cointegrated after July 2003, with the statistical strength of the cointegration increasing greatly after May 2004. Finally, the black curve (starting in 1995) shows the scaled trace statistic for the "Nearby", "Nearby+12 months", and "Nearby+24 months" contracts. Whereas these three contracts were not in long-run cointegration before 2001 (the trace value is well below

1), the trace increased toward 1 (moving toward cointegration) in 2002 and 2003. By mid-2004, the series were cointegrated. They have remained cointegrated ever since.

IV. Changes in the Crude Oil Market: Growth, Trader Composition, and Maturity Structure.

In Section III, we identify significant changes since 2000 in the relation between crude oil futures prices. In this Section, we identify major changes in the makeup of the crude oil futures market. WTI futures and options open interest quintupled between 2000 and 2008. We show that this growth involved a considerable lengthening in the maturity structure, and a sea change in the trader composition, of market activity.

We do so by utilizing non-public CFTC data on open trader positions in exchange-traded commodity futures and options on futures. Section IV.A describes our dataset, and contrasts it to the less-detailed information that is publicly available. Section IV.B summarizes the overall market growth. Section IV.C identifies which types of traders contributed the most to this growth. Section IV.D contrasts activity patterns and growth at short, medium, long and very long maturities.

A. Data Sources

We construct a database of daily position for NYMEX light sweet crude oil (WTI) futures and options-on-futures contracts from the first week of July, 2000 to the last week of August, 2008. The raw position data we utilize and the trader classifications on which we rely originate from the CFTC's Large Trader Reporting System (LTRS).

Specifically, to help it fulfill its mission of detecting and deterring market manipulation, the CFTC's market surveillance staff collects position-level information on the composition of open interest across all futures and options-on-futures contracts for each market. The CFTC also collects information from all large traders about the purposes of their NYMEX positions, and classifies these traders according to their underlying businesses. The position data must be filed daily by traders whose positions meet or exceed the CFTC's reporting threshold. For the WTI oil futures and options market, this threshold was 350 contracts in our sample period. Many smaller positions are also voluntarily reported to the CFTC and are included in the database. As a result, our dataset contains more than 90% of all WTI positions.

The CFTC receives information on individual positions for every trading day. However, here we focus on the Tuesday reports. The weekly frequency matches the frequency at which we sample prices for the analyses in Sections III and VI. Note that the Tuesday data are those which the CFTC summarizes in the weekly Commitment of Traders (COT) Report that it makes available to the public every Friday at 3:30 p.m. Consequently, our findings are directly comparable with those of numerous extant studies that rely on COT data.[15]

1. Public Data: "Commercial" *vs*. "Non-Commercial" Traders

Every Friday, the CFTC publishes a weekly crude oil COT report that contains the overall open-interest figure. This report does not break down open interest figures by contract maturity. It does, however, provide some additional information on different traders' positions by separating the reporting traders between one of two broad categories – "Commercial" and "Non-commercial."[16]

The CFTC classifies all of a trader's reported futures and options positions in a given commodity as "Commercial" if the trader uses futures contracts in that particular commodity for hedging as defined in CFTC regulations. A trading entity generally gets classified as "Commercial" by filing a statement with the CFTC that it is commercially "engaged in business activities hedged by the use of the futures or option markets." In order to ensure that traders are classified accurately and consistently, the CFTC staff may exercise judgment in re-classifying a trader if it has additional information about the trader's use of the markets (CFTC, 2004). "Non-commercials" comprise many types of mostly financial traders, such as hedge funds, mutual funds, floor brokers, etc.

Table 4 illustrates the level of disaggregation contained in publicly-available weekly COT reports of the WTI futures market. For the third week of July from 2000 to 2008, this table shows the open interest in WTI light sweet crude oil futures and futures-equivalent (delta-adjusted) options positions for Commercial (right panel) and Non-commercial (left panel) traders. For each category and each year, long and short positions are reported as fractions of the overall weekly open interest.

Take, for example, the week in 2008 when crude oil prices reached their highest level ever. Panel A shows that, on July 18, 2008, on the short [*long*] side of the 1,344,411 futures open interest, 51.1% [*49.8%*] of all positions were held by commercial traders and 14% [*15.6%*] were held by

[15] A minor difference is that the large trader datasets we use includes *all* positions reported to the CFTC by reporting firms – even those positions of traders small enough that they have no regulatory obligation to do so. In other words, even our aggregate data are a bit more precise than the publicly available data. A second difference is COT frequency, which is less than weekly in studies using pre-2000 data. Starting in 1962, COT data were compiled on an end-of-month basis and published on the 11th or 12th calendar day of the following month. The CFTC switched to mid-month and month-end reports in 1990; to every 2 weeks in 1992; and, to weekly in 2000.

[16] COT reports also provide data on the positions of non-reporting traders, which include speculators, proprietary traders and smaller traders. This category accounts for the difference between total open interest in Table 4 and the aggregate open positions of all reporting (i.e., large) traders in Table 5.

reporting non-commercial traders, with the rest split between 27.5% in spread positions (i.e. calendar spread positions constructed with both long and short futures positions) by reporting non-commercial traders and 8.4% [*7.1%*] in short [*long*] positions held by non-reporting traders.

2. Proprietary Data: The Large Trader Reporting System (LTRS) Data

Whereas the public data only identify "Commercial" vs. "Non-commercial" categories of crude oil traders, the data provided for this study break down these two very broad categories into their respective components, and identify traders' positions at all available contract maturities. That is, each reporting trader is classified into one of twenty-eight possible trader groups in the CFTC's large-trader reporting system (LTRS). Appendix 1 provides lists of the "Commercial" and "Non-commercial" sub-categories, highlighting (in bold) the sub-categories that are the most active in the crude oil market.

The four main commercial sub-categories are (i) "Dealer and Merchant", i.e., wholesalers, exporters and importers, marketers, etc.; (ii) "Manufacturers", i.e., refiners, fabricators, etc; (iii) "Producers", a self-explanatory grouping; (iv) "Commodity Swap Dealers", gathering all reporting swap dealers and arbitrageurs/broker-dealers.[17] These categories typically make up more than 95% of the commercial open interest in our 2000-2008 sample, and close to 99% in the last five years.

Traders in the dealer/merchant, manufacturer and producer sub-categories are often referred to as "traditional" hedgers. By contrast, the swap dealer sub-category (whose activity we shall see has grown significantly since 2000) also includes the positions of non-traditional hedgers, including "entities whose trading predominantly reflects hedging of over-the-counter transactions involving commodity indices—for example, swap dealers holding long futures positions to hedge short OTC commodity index exposure opposite institutional traders such as pension funds" (CFTC, 2006).

The three most active non-commercial sub-categories are (i) "Floor Brokers and Traders"; (ii) "Hedge Funds", which comprise all reporting commodity pool operators, commodity trading advisors, "associated persons" controlling customer accounts as well as other "managed money" traders;[18] (iii) "Non-registered participants" (NRP). The latter category, whose importance we shall see has increased substantially since 2000, mostly comprises financial traders whose positions are large enough to warrant reporting to the CFTC but who are not registered as managed money

[17] The CFTC merged the previously separate financial swap dealers and arbitrageurs/broker-dealer sub-categories with commodity swap dealers partway through our sample period. Haigh, Hranaiova and Overdahl (2007), who identify 27 crude swap dealers from August 2003 – August 2004, find only 1 arbitrageur/broker-dealer and 1 financial swap dealer.
[18] See Appendix 2 for a more detailed discussion of the term "hedge funds" in the context of commodity futures markets.

traders or floor brokers and traders under the Commodity Exchange Act. NRPs also include some smaller non-commercial traders who do not have a reporting obligation but whose positions are nevertheless reported to the CFTC. During the sample period, these three categories made up about 90% of the total non-commercial open interest (including non-reporting traders).

B. Overall Market Growth

Table 4 and Figure 3 use the publicly available COTR information to illustrate the growth in crude-oil futures and option activity on the NYMEX.

Panel A in Table 4 shows that futures open interest more than tripled between July 2000 and July 2007, to more than 1.5 million contracts, but then fell somewhat (to 1.34 million contracts) in July 2008. Panel B shows that growth in option trading was even stronger. Compared to July 2000, the total number of open futures and futures-equivalent-options positions quintupled to almost 3 million contracts in July 2008. The notional equivalent is more than $405 billion (each contract is for 1,000 barrels of oil, or approximately $140,000 at mid-July 2008 prices).

Table 4 highlights a period of moderate futures open-interest growth between July 2000 and July 2003, followed by a period of robust growth through 2007. The blue line in Figure 3 shows a similar pattern for the number of individual crude oil futures traders reporting their positions to the CFTC. This number grew considerably starting in mid-2003, to almost 350 in July 2007 (from about 150 in July 2000). It then leveled off, and fell to below 300 during the Summer of 2008.[19]

C. Trader Composition of Market Activity

Table 4 shows that the composition of the open interest also changed substantially during our sample period. Most notably, the third column in the table points out the increased importance of non-commercial calendar spread positions. The market share of spread traders more than tripled during the sample period, to almost 27% of the futures open interest and over 40% of all open futures and futures-equivalent option positions.

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[19] Our method of computing open interest at the trader level presents the disadvantage of possibly overestimating the importance of spread traders or of trader categories whose "members" are heterogeneous in the direction (long or short) of their futures positions. In turn, this method may underestimate the role of more directional traders (such as crude oil swap dealers, who as a whole are massively long in near-term contracts). Still, this definition of open interest at the trader and sub-category level is the only one that yields the correct total open interest figures when summing up the positions of all traders across a given contract maturity. Furthermore, we ran some robustness checks using the absolute value of traders' net positions (rather than their open interest) and obtained mostly similar regression results.

While Table 4 shows that the overall WTI market growth was due in part to an increase in spread trading, the black line in Figure 3 shows in turn that the growth of spread activity partly reflects an increase in the number of large non-commercial spread traders. Notably, from 2001 through 2003, the number of this kind of futures traders grew proportionally more than the total number of traders did. Precisely, the number of spread traders doubled to almost 50 between May 2001 and January 2004, and then proceeded to triple again (to almost 150 by mid-2007).

The trader-level LTRS data allow us to further break down the market changes by specific trader type and by maturity. For every crude oil futures trader and each contract delivery month, we compute the trader's Tuesday open interest in that contract as the average of that trader's long and short futures positions. We then sum up the individual open interests of all reporting traders in a given category (e.g., all producers, all hedge funds, etc.) for all near-term (< 3 months), medium-term (3 to 12 months), long-term (1 to 3 years), and very-long-term (3+ years) contracts.

Table 5 provides annual averages and growth rates, by maturity, of these open interest figures for nine categories of large traders. To keep Table 5 tractable, we focus on three years: 2000, 2004, and 2008. Figure 4 plots the weekly market shares of seven categories of traders from July 2000 through August 2008. Figure 5 provides further information for seven of the nine trader types. Figure 5a plots the open interest, by maturity, for each of the four most active commercial trader categories: producers, manufacturers, dealers/merchants, and commodity swap dealers. Figure 5b provides similar plots for the three most active non-commercial types: hedge funds, floor brokers/traders, and non-registered market participants. The scale is the same throughout Figure 5, to easily compare the relative magnitudes of the open positions held by different trader categories.

Table 5, and Figures 4 and 5, allow us to make several observations.

(i) Although "traditional commercial" traders now typically hold larger aggregate *net* positions (whether long or short) than in 2000,[20] their aggregate share of the futures open interest has halved since 2000 (from 42% to less than 20%).

(ii) In the same period, the open futures positions held by financial traders (hedge funds and non-registered participants) grew by an order of magnitude – from about 45,000 contracts in the second half of 2000, to more than half a million futures in the first eight months of 2008. As a result, the market share of financial traders has more than doubled, from less than 20% of all open futures and futures-equivalent option positions in 2000 to more than 40% in 2008.

[20] For brevity, we include a single figure on net positions (Figure 8, for swap dealers, which is discussed in Section IV.D). Figures on the net positions of other trader types are available from the authors upon request.

(iii) Swap dealers' market share grew markedly during the key years of 2002 and 2003. Overall, though, commodity swap dealers' market *share* has been relatively stable, mostly fluctuating around 35% of the open interest. In a fast-growing market, of course, this fact implies that swap dealers' activity increased substantially in absolute terms. Part of this considerable growth reflects the direct and indirect influx of commodity index money in futures markets (CFTC, 2008).

D. Market Growth at Different Contract Maturities

Figure 6, which uses the LTRS data, complements Table 5 and Figure 5 by providing annual open interest averages for all reporting (i.e., large) traders by contract maturity. Table 5 and Figures 5 and 6 reveal a sea change in the maturity structure of the crude oil futures market.

(iv) While the market as a whole has grown, growth has been stronger at the back end of the maturity curve. For futures only as well as for futures and options combined, Table 5 shows that the open interest in longer-dated contracts (one year or more) was greater, in the first eight months of 2008, than the open interest in contracts with less than a year to maturity used to be in 2000.

(v) Table 5 links this transformation to the fact that several categories of traders now carry larger (commercial dealers) or much larger (commodity swap dealers, hedge funds, non-registered participants) open positions in long-dated contracts (one year or more) than they used to hold in near-term contracts (three months or less) in 2000.

(vi) Among traditional commercial traders categories, crude oil producers have been almost absent from the long-term market. Manufacturers, in contrast, had a strong presence until 2005, and crude oil dealers and merchants retain a strong presence to this day.[21]

(vii) Much, but not all, of the growth of net positions in long-dated contracts took place after 2003. Figure 5a shows that swap dealers' open positions in such contracts started to grow in mid-2003. In contrast, Figure 5b shows that the open positions of other major players in these contracts did not start to rise substantially until 2004 (hedge funds) or 2005 (non-registered participants).

(viii) The evidence that swap dealers were first to move into longer-dated contracts is in line with our interviews of some of the most senior participants in the U.S. energy futures markets. As indicated also by these interviews, the growth of swap dealers' backdated positions accelerated in

[21] Small traders (those with individual positions small enough that they do not report their positions to the CFTC large-trader database) account for approximately 12% of net positions in near-term contracts, but make up only 3-4% of net positions in long-term contracts.

the second half of 2004 – at the time when the WTI futures market contangoed, after a long period of backwardation (see Figure 7).[22]

(ix) Among all trader categories, commodity swap dealers' positions in short- *vs*. long-dated contracts exhibit the most striking differences. Of particular interest is Figure 8 which shows that swap dealers' positions in near-dated contracts (< 3 months) are net long (likely reflecting a greater propensity of commodity investment flows to be directed to short-term contracts), whereas their further-out positions are mostly spread positions and are often net short. Put differently, Figure 8 suggests that commodity swap dealers' short-term and long-term positions reflect different trading motives. Figure 5a provides further evidence in support of this conjecture. In April 2007, swap dealers' open positions in shorter-term futures dropped by about 40%; they have remained relatively level ever since. Since mid-2007, in contrast, swap dealers have taken large and growing positions in long-term contracts (1 to 3 years).

In the next two Sections, we investigate whether this considerable market growth – or the fundamentals behind this growth – helped strengthen linkages between different-maturity futures.

V. Explaining the Emergence of Price Cointegration: Variables and Testable Hypotheses.

Using the trace statistic from a recursive cointegration analysis to measure changes over time in the extent to which the nearby, one-year and two-year futures prices are cointegrated, Section III identifies the emergence of a stable long-term relation between these three price series. In this Section, we develop testable hypotheses regarding possible explanations for this change in pricing structure. We consider real-sector variables (V.A) and metrics of market activity (V.B).

A. Real Variables

In theory, the prices of crude oil for spot *vs*. future delivery should be related by a cost-of-carry factor accounting for the time value of money, storage costs and possibly a convenience yield. Prices further along the futures maturity curve should be related to one another through similar cost-of-carry equations. One possible explanation for the pricing changes we document in Section III, is that the crude oil fundamentals evolved – affecting the time-series properties of the spot price for crude oil (Bessembinder *et al.*, 1995) or of the net cost-of-carry for long-dated oil futures contracts

[22] When the term structure of futures prices is in contango (upward sloping), contracts expiring further out in time cost more. Hence, rolling a nearby position into the next-nearest-dated contracts is costly (see, e.g., Erb and Harvey, 2006).

(Brenner and Kroner, 1995). To assess whether changes in fundamentals led to price cointegration, we consider two real-sector variables relevant to the pricing of crude oil: (1) the strength of world demand for industrial commodities; (2) capacity constraints affecting crude oil production.

1. Commodity-Demand Shock

In a recent article, Kilian (2008b) proposes a novel measure of global real economic activity predicated on the intuition that "increases in freight rates may be used as indicators of (…) demand shifts in global industrial commodity markets." Specifically, Kilian constructs a global index of single-voyage freight rates for bulk dry cargoes including grain, oilseeds, coal, iron ore, fertilizer and scrap metal. This index, which accounts for the existence of "different fixed effects for different routes, commodities and ship sizes," can be computed as far back as January 1968. It is deflated with the U.S. consumer price index (CPI), and linearly detrended to remove the impact of the "secular decrease in the cost of shipping dry cargo over the last forty years." A change in the time series properties of freight-rates is apparent starting in the spring of 2003, after which shipping costs rise substantially (Kilian, 2008b: Figure 1). The 2003-2008 period stands in sharp contrast to the previous two decades (which did not witness periods of sustained freight rate increase).

Similarly, Korniotis (2008) finds that exchange-traded as well as non-traded commodities experienced statistically significantly higher quarterly growth rates from 2004 to 2008 than from 1998 to 2003. He shows that "this structural change in the growth rate levels is both economically and statistically significant." The structural break finding is robust, in that it extends to agricultural products and in that there is no statistically significant price-appreciation gap between exchange-traded and non-traded commodities.

For our empirical analysis, we build on these observations and construct a weekly inflation-adjusted spot price series for an equally weighted basket of non-exchange-traded commodities.[23] By focusing on non-exchange-traded commodities, we ensure that the fluctuations of the basket's price do not stem from changes in the activities of financial institutions in commodity futures markets. Given a desire for an index that is diversified across commodity types, but also facing limitations in the availability of spot price data, our basket comprises seven commodities: rice, coal,

[23] The Kilian index exists at a monthly frequency. This is one reason why we focus on the inflation-adjusted price of a basket of commodities to identify demand shock common to all commodities, as that price series can be constructed at the same weekly frequency as the trace statistic. We obtain qualitatively similar results with the nominal price series, as well as with weekly cubic interpolations of the Kilian shipping cost index series.

manganese, rhodium, cadmium, cobalt and tungsten.[24]

Figure 9 plots our index from January 1997 to August 2008. In line with the monthly Kilian (2008b) freight-rate index and both Korniotis (2008) quarterly commodity price indices (traded and non-traded), this graph supports the notion that, starting in 2003 and more strongly after 2004, a demand shock pushed upward the prices of most commodities. A large change in the growth rate of the index is visible, with sustained growth and few price decreases from 2003 to August 2008.

In order to link these structural breaks to cointegration, recall that Bessembinder *et al.* (1995) document how distant oil prices used to be not very responsive to changes in near prices. Assuming efficiency, they attributed this finding to mean-reversion in spot prices. In this vein, one possible reason why distant-delivery prices became cointegrated with near-delivery prices is that, amid a structural break in commodity prices, spot crude oil prices no longer are mean-reverting but now are closer to following a random walk. These observations lead to our first testable hypothesis:[25]

Hypothesis 1: Higher commodity prices are associated with greater price cointegration across the maturity structure.

2. Crude Oil Fundamentals

In addition to a demand shock common to all commodities, we explore whether a change in the stochastic processes driving crude oil's price or its cost-of-carry could have originated from a shock specific to the crude oil market. Indeed, recent research indicates that, between 2003 and 2008, the confluence of robust economic growth worldwide and of capacity constraints in crude oil extraction was responsible for a considerable increase in oil prices (Hamilton, 2008).[26]

Using data from the Energy Information Administration (US Department of Energy), we plot in Figure 10 the spot price of WTI crude oil *vs.* the total spare crude oil production capacity outside of Saudi Arabia. We focus on the non-Saudi spare production capacity, because the clearest

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[24] Although futures exist on rough rice and Appalachian coal, the CFTC's Commitments of Traders Reports show that the open interest and number of traders in these contracts are small (both in absolute terms and compared to other major commodities). Our basket adds coal to the basket of non-exchange-traded agricultural and industrial commodities constructed by Korniotis (2008). To abstract from absolute price-level differences across commodities, we construct the index by compounding an equally-weighted average of individual commodity returns, and deflating the resulting series. Spot price data are from Bloomberg; deflators, from the US Bureau of Labor Statistics.

[25] Testing this hypothesis directly would require a very long time series of quality spot price data. Routledge, Spatt and Seppi (2000), however, note that spot data in 1992-1996 are not available.

[26] See also U.S. Interagency Task Force on Commodity Markets, 2008. *Interim Report on Crude Oil*. Washington D.C.

evidence of a major change in oil market fundamentals is evident in this variable (as opposed to world oil consumption, Saudi surplus oil production capacity, OECD stocks of crude oil, etc.). Figure 10 highlights a major change in the physical crude oil market. From January 1995 to February 2004, when spare capacity was relatively plentiful, prices fluctuated around $29. From March 2004 to August 2008, in contrast, non-Saudi spare capacity was close to zero and spot oil prices ranged between $27 and $142. Our second testable hypothesis is thus:

Hypothesis 2: Lower non-Saudi oil spare production capacity is associated with increased price cointegration across crude oil futures maturities.

B. Trader Composition of the Crude oil Futures and Option Market

Price discovery and risk transfer are critical functions of futures markets. Garbade and Silber (1983) show theoretically that risk transfer and price discovery are interrelated, and that the ability of a market to simultaneously perform these functions depends on the strength of the linkage between the derivative markets and the markets underlying those derivatives. These authors show that trading provides the linkage between cash and futures prices and leads to a closer correlation between prices, a more efficient transmission of information, and improved hedging opportunities.

Our second set of hypotheses recognizes the fact that market linkages are unlikely to take hold without participants keen to exploit apparent pricing aberrations. That is, price discovery should improve in a market as it becomes less thinly traded. Between near- and long-dated futures prices, some of the necessary trading activity could consist of cross-maturity arbitrage (or spread) trades or, alternatively, of speculative directional trades (i.e., trades that involve either long or short positions but not both). In either case, it should matter what kinds of traders try to take advantage of perceived price discrepancies across the maturity structures. If too many market participants are perceived as possibly acting on the basis on superior information, then would-be arbitrageurs may elect not to trade against them. If so, then a change in market conditions that begets an "exogenous" increase in non-discretionary liquidity trading (or the arrival of a new kind of liquidity trader) could provide the "thick market" needed for arbitraging and other discretionary trading (Admati and Pfleiderer, 1988) and act as a catalyst for changes in pricing relations.

Commodity index investors exhibit the very profile of uninformed traders. To the extent that a large fraction of the commodity index money is reflected in the nearby crude oil futures positions of commodity swap dealers – see Sections IV.C (iii) and IV.D (ix) – we surmise that:

Hypothesis 3: The cointegration between short-term and long-term futures crude oil futures prices is positively related to the magnitude of commodity swap dealer positions in nearby futures (but not necessarily in longer-term contracts).

Once liquidity trading has grown sufficiently, of course, it becomes easier for speculators and financial arbitrageurs to enter the market, as they face less risk that the counterparties to their trades would be better informed. Hence, one would expect that an increase in the market share of traders who are eager to exploit apparent pricing discrepancies, yet may not be trading on the basis of private information, should enhance price cointegration across contract maturities. The kinds of financially-motivated traders least likely to have private information in commodity markets are hedge funds and other financial traders. Further, to the extent that these two types of traders face fewer financial constraints than more traditional trader categories, their arrival should help alleviate price discrepancies and improve the transfer of risk between market participants (as in Başak and Croitoru, 2006). These observations yield our fourth testable hypothesis:

Hypothesis 4: Greater market participation by hedge funds and non-registered participants (especially in long-dated contracts) leads to increased cointegration between short-term and long-term futures crude oil futures prices.

Lastly, our interviews of market participants suggest that, whereas traders wishing to gain exposure to crude oil initially took long positions in nearby futures contracts, changes in the term structure of futures prices later made this strategy less attractive. Precisely, it became costly to roll forward long positions in the nearby futures after the crude oil market became “contangoed,” i.e., after the term structure of crude oil futures prices became upward-sloping in mid-2004 (see Figure 7). Intuitively, traders who previously had been rolling nearby positions started to have incentives to move further along the futures maturity curve. These observations beget our final hypothesis:

Hypothesis 5: Greater price cointegration between near- and long-dated futures is positively associated with the slope of the near term structure of crude oil futures prices.

VI. Explaining the Pricing Changes: Empirical Analysis.

In this Section, we test our five hypotheses by looking for statistical evidence of a long-term relation between the strength of cointegration across contract maturities, and crude oil fundamentals as well as the futures positions of different traders at some or all maturities. Section VI.A describes our methodology. Section VI.B describes our explanatory variables. Sections VI.C and VI.D, respectively, summarize and discuss our findings.

A. Methodology

Before estimating the effect of trader participation on the strength of cointegration between nearby and further out contract prices, we first check the order of integration of each variable using Augmented Dickey Fuller Tests. Table 6 presents the unit root tests for the variables entering in our estimation equation. Most of the position variables are I(0), but the trace statistics and the real variables are I(1). Since some of the variables are nonstationary, we use a cointegration analysis to test whether there is a *long term* relation between the position data and trace statistics.

The Engle and Granger (1987) and Johansen (1988, 1991) cointegration techniques require that all the variables in the estimation equation be integrated of the same order. Here, some of the variables are I(0) while others are I(1). Pesaran and Shin (1999) show that the autoregressive distributed lag (ARDL) model can be used to test the existence of a long-run relationship between underlying variables and to provide consistent, unbiased estimator of long-run parameters in the presence of I(0) and I(1) variables in the estimation. The ARDL estimation procedure reduces the bias in the long run parameter "β" in finite samples, and ensures that it has a normal distribution irrespective of whether the underlying regressors are I(0) or I(1).

We start with the problem of estimation and hypothesis testing in the context of the following ARDL(p,q) model:

$$y_t = \delta w_t + \sum_{i=1}^{p} \gamma_i y_{t-i} + \sum_{i=0}^{q} \alpha_i x_{t-i} + \varepsilon_t \tag{6}$$

where y is a $t \times 1$ vector of dependent variable, x is a $t \times k$ vector of regressors, *and* w stands for a $t \times s$ vector of deterministic variables such as an intercept, seasonal dummies, time trends, or exogenous variables with fixed lags.[27] In vector notation, Equation (6) is:

$$\gamma(L)y_t = \delta w_t + \alpha(L)x_t + \varepsilon_t$$

where $\gamma(L)$ is the polynomial lag operator $1 - \gamma_1 L - \gamma_2 L^2 - ...\gamma_p L^p$; $\alpha(L)$ is the polynomial lag operator $\alpha_0 + \alpha_1 L + \alpha_2 L^2 + +... + \alpha_q L^q$, and L represents the usual lag operator ($L^r x_t = x_{t-r}$). The estimate of the long run parameters can then be obtained by first estimating the parameters of the ARDL model by OLS and then solving the estimated version of (6) for the cointegrating relationship $y_t = \psi w_t + \theta x_t + v_t$ by

$$\hat{\theta} = \frac{\hat{\alpha}_0 + \hat{\alpha}_1 + ... + \hat{\alpha}_q}{1 - \hat{\gamma}_1 - \hat{\gamma}_2 ... \hat{\gamma}_p}$$

$$\hat{\psi} = \frac{\hat{\delta}}{1 - \hat{\gamma}_1 - \hat{\gamma}_2 ... \hat{\gamma}_p}$$

where $\hat{\theta}$ gives us the long-run response of y to a unit change in x and, similarly, $\hat{\psi}$ represents the long run response of y to a unit change in the deterministic exogenous variable .

In practice, we obtain the standard errors of the long run coefficients using "Bewley regressions." Bewley's (1979) approach involves the estimation of the following regression

$$y_t = \psi w_t + \theta x_t + \sum_{i=0}^{p-1} \eta_i \Delta y_{t-i} + \sum_{i=0}^{q-1} \kappa_i \Delta x_{t-i} + \xi_t$$

by the instrumental variable method, using $(w_t, x_t, \Delta x_t, \Delta x_{t-1}, \Delta x_{t-q+1}, y_{t-1}, ...y_{t-p})$ as instruments. Pesaran and Shin (1999) show that the instrumental variable estimators of ψ and θ obtained using the Bewley (1979) method are numerically identical to the OLS estimators of ψ and θ based on the ARDL model (the latter alone, of course, provides an ECM representation when the variables under study are cointegrated).

When estimating the long-run relationship, one of the most important issues is the choice of the order of the distributed lag function on y_t and the explanatory variables x_t. We carry out the two-step ARDL estimation approach proposed by Pesaran and Shin (1999). First, the lag orders of *p* and *q* must be selected using some information criterion. Based on Monte Carlo experiments, Pesaran and Shin (1999) argue that the Schwarz criterion performs better than other criteria. This

[27] The error term is assumed to be serially uncorrelated.

criterion suggests optimal lag lengths p=1 and q=1 in our case. Second, we estimate the long run coefficients and their standard errors using the ARDL(1,1) specification.

B. Variables

We use the trace statistic for the nearby, 1-year and 2-year prices (see Figure 2) as the dependent variable. As explanatory variables, we use proxies of the crude oil market fundamentals, data on the open positions of specific kinds of trader, and controls for overall market activity and exogenous liquidity shocks.

In line with *Hypotheses 1* and *2*, we use two variables for market fundamentals: a weekly index of non-exchange-traded commodity prices (LPI), and non-Saudi spare crude oil production capacity. Because the spare capacity data are available only monthly, we use cubic interpolations to generate a weekly time series (SPARE) from the end-of-month EIA estimates.

To match the way we compute the trace statistic, we focus on the open interest of each trader type (all manufacturers, all producers, etc.) in three contracts: nearby, one-year-out, and two-year-out futures. In this manner, our regressions capture changes over time in specific levels of participation that could be tied to the concurrent increase in the trace statistic.[28]

We use two specifications. In one set of regressions (denoted "Model 1" in Tables 7-9), we use market shares for each trader type – that is, we scale the open positions of each trader category in the relevant contract(s) by the open interest of all traders in all three contracts (nearby, one- and two-years). Once we control for the overall open interest (as discussed in the next sub-section), this first specification allows us to assess whether the composition of that open interest matters. In the second set of regressions (denoted "Model 2" in Tables 7-9), our trader participation variables measure the absolute figure of the relevant open interest.

We include the slope of the term structure of near-term crude oil prices (SLOPE), which measures the cost of maintaining an exposure to crude oil prices by means of a long position in the nearby WTI futures. As discussed in *Hypothesis 5*, this variable captures incentives of long-only traders (e.g., commodity index traders) to move positions further along the maturity structure.

We use either of two explanatory variables to capture the overall trading activity: the total open interest across all traders and all contract maturities (TOI), and the Tuesday trading volume in

[28] Several studies employing recursive cointegration techniques (e.g. Haigh, 2000) attempt to explain changes in the level of cointegration over time, by informally relating (often abrupt) changes in trace values using information to actual (usually one-time) events.

the nearby, one-year and two-year-out futures (FVOL). The first variable captures the overall market growth. The second variable captures the reality that trading volume in the relevant contracts may not be a constant proportion of the open interest in these contracts. In practice, we find that TOI and FVOL are cointegrated, so we use only one of these two variables at a time. We obtain qualitatively similar results with TOI or FVOL; hence, we report results for TOI only.

NYMEX crude oil trading volume grew massively (relative to open interest) after the start of electronic trading in September 2006. We use a dummy variable (ETRADE) to capture this fact: we set it equal to 1 starting with the first Tuesday of September 2006, and 0 prior to that date.

Lastly, a substantial portion of the long-dated crude oil market activity involves contracts maturing in June or December. We use two liquidity dummies to capture this fact, which we set equal to 1 when the nearby, one-year-out and two-year-out contracts mature in June (JUN) or December (DEC) and to 0 otherwise.

C. Results

Tables 7, 8 and 9 present our ARDL regression results. We use positions for each category of trader independently in Table 7, and jointly in Tables 8 and 9. In Tables 7 and 8, the real-sector variable is the non-traded industrial commodity price index (LPI); in Table 9, the proxy for crude oil fundamentals is the non-Saudi spare capacity (SPARE). In all three tables, we run two models: in the first model, the explanatory variable is the market *share* of a trader category; in the second model, we use instead the number of open contracts itself.

In Tables 8 and 9, we report the results for one- and two-year open interests combined, with nearby open interest as a separate variable. We report three specifications in Table 7:

Panel A: nearby, one- and two- year open interests combined;
Panel B: one- and two-year open interests combined, nearby open interest separate;
Panel C: three separate variables for the nearby, one- and two-year open interests.

The industrial-commodity price index variable (LPI) is often significant (with the expected positive sign) in Table 8, which supports the first testable hypothesis delineated in Section V.A. Together with the slope of the term structure of crude oil prices, the spare crude oil production capacity variable (SPARE) is also highly statistically significant (with the expected negative sign) in all the regressions of Table 9, which supports our second hypothesis. In short, changes in market fundamentals help explain the greater co-integration.

In both Tables 8 and 9, the coefficient on SLOPE (the slope of the nearby term structure of crude oil prices) is positive and almost always statistically significant. Notably, SLOPE is highly significant in all the regressions that use SPARE as the proxy for fundamentals. If we interpret an upward-sloping term structure of crude oil futures prices as an indication of a forthcoming supply tightening, then this finding suggests that, in a crude oil market where it takes years to develop new production capacity, a dearth of spare capacity brings prices in line at near and long horizons.

The coefficient on SLOPE is positive, i.e., contango in the near-term is associated with higher cointegration across short- and long-dated contracts. This fact suggests, as *Hypothesis 5* conjectures, that the transmission mechanism from changes in fundamentals to price cointegration across the term structure involves market activity by traders rolling short-term futures positions.

Consistent with the interpretation that trader activity matters, we find that overall market activity (TOI) help explain the trace statistic – and, critically, that, after controlling for changes in the overall open interest, the composition of that open interest matters in the manners outlined in *Hypotheses 3 and 4*.

Specifically, our regressions show that the strength of the cointegration between the nearby, one-year and two-year crude oil futures price series is linked to the market activities of financial traders, especially in one- and two-year contracts (Tables 7.1 and 7.2, Panels B and C; Table 8, Panel A.2), as well as to the activity of commodity swap dealers in nearby contracts – activity that reflects in large part their commodity index swap business (Table 7.1, Panel A; Table 8, Panel B.2; Table 9, Panel B.2). By contrast, we find little evidence of a positive connection between the strengthening of cointegration and the activities of traditional commercial traders or the activity of swap dealers in one-year and two-year contracts (which is, arguably, less likely to result from swap dealers' commodity-index business).

D. Discussion and Possible Caveats

Our analysis indicates that changes in fundamentals, coupled with changes in the market activities of three specific categories of traders, help explain the strengthening of linkages between nearby and far-out crude oil futures prices. In this regard, our results illustrate how increased participation by some types of traders can enhance price linkages in commodity markets.

One might worry that relation need not imply causation. A battery of univariate Granger causality tests, however, confirm that the direction of causality runs from fundamentals and market activity to cointegration, and not the reverse. With this potential concern laid to rest, we now round out this Section by discussing our proxies for fundamentals, and the relation between traders' end-of-day positions and their futures market activity.

To test *Hypothesis 1*, we use a weekly index of non-exchange-traded commodity prices (the LPI variable). Our results are robust to using another proxy of the world demand for commodities. Specifically, when replacing LPI by SHIP (i.e., by weekly interpolations of the monthly Kilian (2008b) shipping cost index), we find that the SHIP variable is usually statistically significant in the same regressions as LPI, and that the same combinations of other explanatory variables typically remain significant (with the same signs).

One possible worry stems from the observation that both the LPI and SHIP variables partly reflect the price of crude oil, since the latter is a key component of the production and transportation costs of commodities. To wit, at typical 2005 (*mid-2008*) charter rates, the bunker fuel used to propel ships accounted for approximately one third (*one half*) of dry-cargo shipping costs. More formally, a co-integration analysis of SHIP and LPI shows that these two variables are cointegrated with the inflation-adjusted price of crude oil in the last ten years.

Visual inspections of the SHIP and crude oil price series, however, suggest that the shipping cost increases predated, by more than six months, the start of a sustained increase in crude oil prices. Furthermore, the prices of oil and the *non-oil* components of SHIP and LPI should move broadly in sync, if all three are driven by a demand shock common to all commodity markets.

Lastly, to alleviate any residual concern about regressing the trace statistic (which measures linkages between various crude oil *prices*) on two non-oil *price* measures that are cointegrated with the *price* of crude oil, we note two things. First, the third variable we use to capture fundamentals, SPARE, is a quantity measure – yet it is also cointegrated with the crude oil price series. Second, the statistical significance of fundamentals is even stronger when we replace the combination of LPI and SLOPE or of SHIP and SLOPE in our regressions with SLOPE and SPARE. Put differently, our analysis of the link between fundamentals and cointegration is not subject to the concern of regressing "prices on prices."

Our regressions show that the "market activities" of specific groups of traders contributed to the 2003-2004 emergence of price cointegration across the maturity curve in the crude oil futures market. This result entails several possible caveats.

First, all traders grouped in a given LTR category may not share similar motives for trading. In the "commodity swap dealers" category, for example, not all traders partake in the commodity index (CIT) business – and far from all of the activity of those dealers that are involved in the CIT business is related to index trading (CFTC, 2008). The "non-registered participants" and "hedge funds" categories likely are also heterogeneous. The CFTC data made available for this study do not allow us to improve much on the LTR classification. If anything, however, within-category heterogeneity should bias against finding a statistically significant relations between the activities of specific trader categories and the strength of cointegration. It is thus all the more relevant that we do find such relations; that they are statistically significant for the predicted categories; and, that the regression coefficients have the expected sign.

A second possible caveat to our results is that we measure traders' activities by their end-of-day open positions – as opposed to volume of trading. We use position data not because the CFTC databases links a trader's main-line-of-business information to his end-of-day position data but not to his within-day trade and quote activity. Rather, we do so because the cointegration techniques used in Section III assess co-movements between prices over long periods of time – and, similarly, a trader's end-of-day position in a given contract summarizes the extent of his trading in that contract over a long period (namely, the entire life of the contract). Still, to the extent that a trader's futures positions on the NYMEX may reflect over-the-counter (OTC) transactions cleared on NYMEX's ClearPort facility, it is nevertheless important to confirm that our measure of market activity moves in long-term sync with the related trading activity on the Nymex. Consistent the intuition that the same underlying factor drives futures open interest and trading volume in the sample period, Johansen cointegration analyses show that the volume and open interest series are indeed cointegrated overall, as well as for the nearby, one-year and two-year series.

VII. Conclusions.

We document that, in the wake of strong growth in the market for exchange-traded crude oil derivatives, the prices of one-year and two-year futures became cointegrated with the price of the near-month futures in 2004. Using data on crude oil fundamentals and a unique dataset of trader-level futures-market position data, we investigate two questions. One, can changes in fundamentals help explain the strengthening cointegration among nearby and distant futures contracts in crude oil? Two, which categories of traders (if any) are associated with the emergence of cointegration?

We find that fundamentals contributed to this pricing development. We also find that an increase in commodity swap dealer positions in the nearby contract, as well as increases in the market activity of other traders (in particular, hedge funds' and other financial traders' activities in long-dated contracts) helps further explain the cointegration of prices in this markets.

The changes we document have potentially significant implications for those interested in the effectiveness of hedges constructed with crude oil futures and for those interested in the quality of information contained in futures prices across the term structure.

As the market for crude oil futures further develops, with greater participation at horizons beyond two years, one might anticipate similar linkages emerging at the longer end of the futures spectrum. At the same time, amid a recent fall in demand for crude oil (and a concomitant increase in spare production capacity) and an unprecedented credit crisis (which might affect the ease with which financial traders can carry out commodity arbitrage strategies), a natural question is whether the links between short, medium and long-term prices could become weaker. Time will tell. This question, therefore, we leave for further research.

References

Admati, Anat R. and Paul Pfleiderer, 1988. "A Theory of Intraday Patterns: Volume and Price Volatility," *Review of Financial Studies*, 1 (1), pp. 3-40.

Başak, Süleyman and Benjamin Croitoru, 2006. "On the Role of Arbitrageurs in Rational Markets," *Journal of Financial Economics*, 81 (1), pp. 143-73.

Bekaert, Geert, Campbell R. Harvey and Robin L. Lumsdaine, 2002. "Dating the integration of world equity markets." *Journal of Financial Economics*, 65, pp. 203–247.

Bessembinder, Hendrik, Jay F. Coughenour, Paul J. Seguin, and Margaret Monroe Smoller, 1995. "Mean Reversion in Equilibrium Asset Prices: Evidence from the Futures Term Structure." *Journal of Finance*, 50 (1), pp. 361-75.

Bessler, David and Jian Yang, 2003. "The Structure of Interdependence in International Stock Markets," *Journal of International Money and Finance*, 22 (2), pp. 261-87.

Bewley, R.A., 1979. "The Direct Estimation of the Equilibrium Response in a Linear Dynamic Model." *Economic Letters* 3 (4) , pp. 357–361.

Bradley, Michael G. and Stephen A. Lumpkin, 1992. "The Treasury Yield Curve as a Cointegrated System," *Journal of Financial and Quantitative Analysis*, 27 (3), pp. 449-63.

Bremnes, Helge, Østein Gjerde and Frode Saettem, 1997. "A Multivariate Cointegration Analysis of Interest Rates in the Eurocurrency Market." *Journal of International Money and Finance*, 16, pp. 767–78.

Brenner, Robin J. and Kenneth F. Kroner, 1995. "Arbitrage, Cointegration, and Testing the Unbiasedness Hypothesis in Financial Markets." *Journal of Financial and Quantitative Analysis*, 30 (1), pp. 23-42.

CFTC, 2004. *Backgrounder: The Commitments of Traders Report.* Washington, DC: U.S. Commodity Futures Trading Commission, July. Available online at: http://www.cftc.gov/opa/backgrounder/opacot596.htm

CFTC, 2006. *Notice Regarding Supplemental Commitments of Traders Report.* Washington, DC: U.S. Commodity Futures Trading Commission, December 5. Available online at: www.cftc.gov/files/cftc/cftcnoticeonsupplementalcotreport.pdf

CFTC, 2008. *Staff Report on Swap Dealers and Index Traders*, September. Available online at: http://www.cftc.gov/newsroom/generalpressreleases/2008/pr5542-08.html

Carrieri, Francesca, Errunza, Vihang, and Ken Hogan, 2007. "Characterizing world market integration through time." *Journal of Financial and Quantitative Analysis*, 42(4), pp. 915-40.

Chan, Nicholas, Mila Getmansky, Shane M. Haas, and Andrew W. Lo, 2006. "Systemic Risk and Hedge Funds," in Mark Carey and René Stulz (eds.), *Risks of Financial Institutions*, Chicago, IL: University of Chicago Press, pp. 35-330.

Chang, Eric, Ray Y. Chou, and Edward F. Nelling, 2000. "Market Volatility and the Demand for Hedging in Stock Index Futures," *Journal of Futures Markets*, 20 (2), pp. 105-25.

Chang, Eric C., J. Michael Pinegar and Barry Schachter, 1997. "Interday Variations in Volume, Variance and Participation of Large Speculators Source," *Journal of Banking and Finance*, 21 (6), pp. 797-810.

Choe, Hyuk, Bong-Chan Kho and René M. Stulz, 1999. "Do Foreign Investors Destabilize Stock Markets? The Korean Experience in 1997," *Journal of Financial Economics*, 54 (2), pp. 227-64.

de Roon, Frans A., Theo E. Nijman, and Chris Veld, 2000. "Hedging Pressure Effects in Futures Markets," *Journal of Finance*, 55 (3), pp. 1437-56.

Ederington, Louis H. and Jae Ha Lee, 2002. "Who Trades Futures and How: Evidence from the Heating Oil Futures Market," *Journal of Business*, 75 (2), pp. 353-73.

Engle, Robert F. and Clive W. J. Granger, 1987. "Co-integration and Error Correction: Representation, Estimation, and Testing." *Econometrica*, 55 (2), pp. 251-76.

Erb, Claude B. and Campbell R. Harvey, 2006. "The Strategic and Tactical Value of Commodity Futures," *Financial Analysts Journal*, 62 (2), pp. 69-97.

Evans, Martin D.D. and Richard K. Lyons, 2005. "Do Currency Markets Absorb News Quickly?" *Journal of International Money and Finance*, 24 (2), pp. 197-217.

Fung, William and David A. Hsieh., 2000. "Measuring the Market Impact of Hedge Funds," *Journal of Empirical Finance,* 7 (1), pp.1-36.

Fung, William, David A. Hsieh, and Konstantinos Tsatsaronis, 2000. "Do Hedge Funds Disrupt Emerging Markets?" In Litan, R.E. and Santomero, A.M., editors, *Brookings-Wharton Papers on Financial Services*, pp. 377-421.

Garbade, Kenneth D. and William L. Silber, 1983. "Price Movements and Price Discovery in Futures and Cash Markets." *The Review of Economics and Statistics*, 65, pp. 289–97.

Goetzmann, William .N., Stephen J. Brown, and James M. Park, 2000. "Hedge Funds and the Asian Currency Crisis of 1997," *Journal of Portfolio Management*, 26(4), pp. 95-101.

Gorton, Gary B., Fumio Hayashi and K. Geert Rouwenhorst, 2007. "The Fundamentals of Commodity Futures Returns," NBER Working Paper No. 13249, July.

Haigh, Michael S., 2000. "Cointegration, Unbiased Expectations and Forecasting in the BIFFEX Freight Futures Market," *The Journal of Futures Markets*, 20(6), pp. 545-71.

Haigh, Michael S., Jana Hranaiova, and James A. Overdahl, 2007. "Price Volatility, Liquidity Provision, and the Role of Hedge Funds in Energy Futures Markets," *Journal of Alternative Investments*, Spring.

Hall, Anthony D., Heather M. Anderson, and Clive W. J. Granger, 1992. "A Cointegration Analysis of Treasury Bill Yields, *Review of Economics and Statistics*, 74 (1), pp. 116-26.

Hamilton, James D., 2005. "Oil and the Macroeconomy." The New Palgrave Dictionary of Economics, Second Edition. Steven N. Durlauf and Lawrence E. Blume, Eds.. Palgrave Macmillan, 2008.

Hamilton James D., 2008. "Understanding Crude Oil Prices." Energy Policy and Economics Working Paper No. 23, University of California Energy Institute, June. Revised, November.

Hansen, Henrik and Søren Johansen, 1993. "Recursive Estimation in Co-integrated VAR Models," Discussion Paper, Institute of Mathematical Statistics, University of Copenhagen.

Hansen, Henrik and Søren Johansen, 1999. "Some Tests for Parameter Constancy in Co-integrated VAR Models," *Econometrics Journal*, 2 (2), pp. 306-33.

Hartzmark, Michael L., 1987. "Returns to Individual Traders of Futures: Aggregate Results," *Journal of Political Economy*, 95 (6), pp. 1292-306.

Hartzmark, Michael L., 1991. "Luck versus Forecast Ability: Determinants of Trader Performance in Futures Markets," *Journal of Business*, 64 (1), pp. 49-74.

Johansen, Søren, 1988. "Statistical Analysis of Cointegration Vectors," *Journal of Economic Dynamics and Control*, 12 (2/3), 231-254.

Johansen, Søren, 1991. "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models," *Econometrica*, 59 (6), pp. 1551-80.

Johansen, Søren and Katarina Juselius, 1990. "Maximum Likelihood Estimation and Inference on Cointegration – with Applications to the Demand for Money," *Oxford Bulletin of Economics and Statistics*, 52 (2), pp. 169-210.

Kasa, Kenneth, 1992. “Common stochastic trends in international stock markets.” *Journal of Monetary Economics*, 29 (1), pp. 95-124.

Kilian, Lutz, 2008a. “The Economic Effects of Energy Price Shocks.” *Journal of Economic Literature*, forthcoming.

Kilian, Lutz. 2008b. “Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market.” *American Economic Review*, forthcoming

Kilian, Lutz and Cheolbeom Park, 2007. “The Impact of Oil Price Shocks on the U.S. Stock Market.” CEPR Working Paper 6166, March. Revised, June 2008.

Korniotis, George. 2008. “Commodity Markets with and without Futures Markets.” Mimeo, Division of Research and Statistics, Board of Governors of the Federal Reserve System, September.

Lautier, Delphine, 2005. “Segmentation in the Crude Oil Futures Term Structure,” *Finance India*, 19 (4), pp. 1303-20.

Leuthold, Raymond M., Philip Garcia, and Richard Lu, 1994. “The Returns and Forecasting Ability of Large Traders in the Frozen Pork Bellies Futures Market,” *Journal of Business*, 67 (3), pp. 459-73.

Litzenberger, Robert H. and Nir Rabinowitz, 1995. “Backwardation in Oil Futures Markets: Theory and Empirical Evidence,” *Journal of Finance*, 50 (5), pp. 1517-45.

Neuberger, Anthony, 1999. “Hedging Long-Term Exposures with Multiple Short-Term Futures Contracts.” *Review of Financial Studies*, 12(3), pp. 429-59.

Pesaran, M. Hashem and Yongcheol Shin, 1999. “An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis.” In S. Strom, ed., *Econometrics and Economic Theory in the Twentieth Century*. New York, NY: Cambridge University Press.

Piazzesi, Monika and Eric Swanson, 2008. “Futures Prices as Risk-adjusted Forecasts of Monetary Policy,” *Journal of Monetary Economics*, 55 (4), pp. 677-691.

Pilipović, Dragana, 1998. *Energy Risk*. New York: McGraw Hill, xiv+248 pages.

Quan, Jing, 1992. “Two-Step Testing Procedure for Price Discovery Role of Futures Prices.” *Journal of Futures Markets*, 12 (2), pp. 139-49.

Roll, Richard, Eduardo Schwartz, and Avindhar Subrahmanyam, 2007. “Liquidity and the Law of One Price: The Case of the Futures/Cash Basis,” *Journal of Finance*, 62 (5), pp. 2201-34.

Routledge, Brian R., Duane J. Seppi and Chester S. Spatt, 2000. “Equilibrium Forward Curves for Commodities,” *Journal of Finance*, 55 (3), pp. 1297-338.

Simon, Yves and Delphine Lautier, 2005. *Marchés Dérivés des Matières Premières*. Paris: Economica.

Veld-Merkoulova, Yulia and Frans A. de Roon, 2003. “Hedging Long-Term Commodity Risk.” *Journal of Futures Markets*, 23 (2), pp. 109-34.

Wang, Changyun, 2003. "The Behavior and Performance of Major Types of Futures Traders," *Journal of Futures Markets*, 23 (1), pp. 1-31.

Wang, Zijun, Jian Yang, and Qi Li, 2007. “Interest rate linkages in the Eurocurrency market”, *Journal of International Money and Finance*, 26 (1), pp. 86-103.

Appendix 1: Large trader categories

Panel A: Commercial Traders

CFTC Code	*CFTC Name*	*Present in WTI futures & options markets*
18	Co-Operative	
AD	**Dealer/Merchant**	**Y**
AM	**Manufacturer**	**Y**
AO	Agricultural/Natural Resources – Other	Y (*very small*)
AP	**Producer**	**Y**
AS	**Commodity Swaps/Derivatives Dealer**	**Y**
FA	Arbitrageur or Broker/Dealer	Y *(merged into AS)*
FB	Non U.S. Commercial Bank	
FC	U.S. Commercial Bank	
FD	Endowment or Trust	
FE	Mutual Fund	
FF	Pension Fund	
FG	Insurance Company	
FH	Hedge Fund	
FM	Mortgage Originator	
FO	Financial – Other	
FP	Managed Account or Pool	
FS	Financial Swaps/Derivatives Dealer	Y *(merged into AS)*
FT	Corporate Treasurer	
LF	Livestock Feeder	
LO	Livestock – Other	
LS	Livestock Slaughterer	

Panel B: Non-commercial Traders

CFTC Code	*CFTC Name*	*Present in WTI futures & options markets*
HF	**Hedge Fund**	**Y**
FBT	**Floor Broker /Trader**	**Y**
FCM	Futures Commission Merchant	Y *(very small)*
IB	Introducing Broker	Y *(very small)*
NRP	**Non-Registered Participant**	**Y**

Notes: Appendix 1 lists the trader sub-categories in the CFTC's large-trader reporting system (LTRS). Bolded entries are those on which most of our analysis focuses. When the CFTC publishes its weekly Commitment of Traders Report, these various sub-categories are aggregated in two broad groups: "Commercials" (Panel A), who have declared an underlying hedging purpose, and "Non-commercials" (Panel B), who have not. In **Panel A**, "Dealer/Merchant" (AD) includes wholesalers, exporter/importers, crude oil marketers, shippers, etc. "Manufacturer" (AM) includes refiners, fabricators, etc. "Agricultural / Natural Resources – Other" (AO) may include, for example, end users. "Commodity Swaps/Derivatives Dealer" (AS) aggregates all reporting "Swaps/Derivatives Dealers" (FS) and "Arbitrageurs or Broker Dealers" (FA), two categories that were merged in the CFTC's internal reporting system part-way through our 2000-2008 sample period. In **Panel B**, "Hedge Funds" (HF) aggregate all reporting Commodity Pool Operators (CPO), Commodity Trading Advisors (CTAs), "Associated Persons" (APs) controlling customer accounts, as well as other "Managed Money" (MM) traders. Note that hedge funds involved in financial contracts that are shown to be hedging would be included in the Commercial category FH. "Floor Broker / Trader" (FBT) aggregates all reporting floor brokers and floor traders. "Non-registered participants" (NRP) are non-commercial traders not registered under the Commodity Exchange Act (CEA). This category, which has grown significantly since 2000, mostly comprises financial traders with positions large enough to warrant reporting to the CFTC, it also includes smaller traders who do not have such a reporting obligation but whose positions are nevertheless reported.

Appendix 2: Defining Hedge Funds.

"Hedge fund" activity in energy derivatives markets has been the subject of intense scrutiny in recent years by academic researchers, market participants, policy makers, and the media. Yet, there is no accepted definition of a "hedge fund" in futures markets, and there is nothing in the statutes governing futures trading that defines a hedge fund. Furthermore, there is nothing that requires hedge funds to be categorized in the CFTC's Large Traders Reporting System (LTRS).

Still, many hedge fund complexes are either advised or operated by CFTC-registered commodity pool operators (CPOs) or Commodity Trading Advisors (CTAs) and associated persons (APs) who may also control customer accounts. Through its LTRS, the CFTC therefore obtains positions of the operators and advisors to hedge funds, even though it is not a requirement that these entities provide the CFTC with the name of the hedge fund (or another trader) that they are representing.[29]

It is clear that many of the large CTAs, CPOs, and APs are considered to be hedge funds and hedge fund operators. Consequently, we conform to the academic literature and common financial parlance by referring to these three types of institutions collectively as "hedge funds." In addition, for the purposes of this paper, market surveillance staff at the CFTC identified other participants who were not registered in any of these three categories but were known to be managing money – these are also included in the hedge fund category (see bottom of Appendix 1).

[29] A commodity pool is defined as an investment trust, syndicate or a similar form of enterprise engaged in trading pooled funds in futures and options on futures contracts. A commodity pool is similar to a mutual fund company, except that it invests pooled money in the futures and options markets. Like its securities counterparts, a commodity pool operator (CPO) might invest in financial markets or commodity markets. Unlike mutual funds, however, commodity pools may be either long or short derivative contracts. A CPO's principal objective is to provide smaller investors the opportunity to invest in futures and options markets with greater diversification with professional trade management. The CPO solicits funds from others for investing in futures and options on futures. The commodity-trading advisor (CTA) manages the accounts and is the equivalent of an advisor in the securities world.

Table 1: Descriptive Statistics and Correlation Analysis on Weekly Crude Oil (WTI) Futures Prices, 2000-2008

Panel A: Tuesday settlement prices

	July 2000 to August 2008			July 2000 to June 2004			July 2004 to August 2008		
	Nearby	**1-year**	**2-year**	**Nearby**	**1-year**	**2-year**	**Nearby**	**1-year**	**2-year**
Maximum	140.97	141.74	139.47	42.33	36.91	34.17	140.97	141.74	139.47
Minimum	18.46	19.98	20.33	18.46	19.98	20.33	39.54	35.43	33.31

Panel B: Sample moments, Tuesday to Tuesday returns

	July 2000 to August 2008			July 2000 to June 2004			July 2004 to August 2008		
	Nearby	**1-year**	**2-year**	**Nearby**	**1-year**	**2-year**	**Nearby**	**1-year**	**2-year**
Mean	0.30%	0.36%	0.39%	0.05%	0.13%	0.17%	0.54%	0.58%	0.60%
Median	0.85%	0.63%	0.43%	0.87%	0.40%	0.28%	0.83%	0.89%	0.61%
Maximum	10.61%	8.34%	9.01%	9.48%	6.51%	5.78%	10.61%	8.34%	9.01%
Minimum	-25.30%	-13.16%	-10.29%	-25.30%	-13.16%	-10.29%	-16.97%	-11.94%	-9.50%
Std deviation	4.68%	3.09%	2.76%	5.13%	2.69%	2.16%	4.22%	3.43%	3.22%

Panel C: Simple Correlations, Tuesday to Tuesday Returns

	July 2000 to August 2008			July 2000 to June 2004			July 2004 to August 2008		
	Nearby	**1-year**	**2-year**	**Nearby**	**1-year**	**2-year**	**Nearby**	**1-year**	**2-year**
Nearby	1			1			1		
1-year	0.85	1		0.84	1		0.89	1	
2-year	0.70	0.96	1	0.65	0.92	1	0.80	0.98	1

Notes: Table 1 provides summary information computed from the Tuesday settlement price series for the near-month, 1-year out (nearby + 12 months) and 2-year out (nearby + 24 months) WTI sweet crude oil futures contracts between July 3, 2000 and August 28, 2008. We use Tuesday settlement prices for all figures. If Tuesday prices are not available (i.e., if markets are closed on a given Tuesday), then we use the next Wednesday price instead or, in the very few instances when the market is also closed that Wednesday, the previous Monday settlement price.

Table 2: Augmented Dickey-Fuller (ADF) tests for Futures Prices

Price Series	**K**	**H_O: $I(1)$ vs. H_1: $I(0)$**	**H_O: $I(2)$ vs. H_1: $I(1)$**
Nearby	3	-1.7317	-17.3825
1-yr contract	3	-0.2294	-9.5076
2-yr contract	1	-1.0262	-28.5536

Notes: The critical values are from Fuller (1976): –3.12 (10%), –3.41* (5%) and –3.96 (1%). Hence, based on these results, all three price series are I(1). The optimal lag length *K* is based on the Akaike Information Criterion (AIC).

Table 3. Cointegration Analysis of Prices

Panel A: Trace tests on order of cointegration[a]

λ_{trace} *test statistic*	H_O:	*critical value(p-value)*
50.93	r = 0	34.10 (0.000)
22.91	r ≤ 1	19.87(0.020)
4.72	r ≤ 2	8.47 (0.323)

Panel B: Tests for exclusion from the cointegrating vector[b]

	H_O:	$\chi^2_{(1)}$ *value(p value)*
Nearby	$\beta_N = 0$	3.115 (0.078)
1 yr contract	$\beta_1 = 0$	0.969 (0.325)
2 yr contract	$\beta_2 = 0$	0.468 (0.494)

Panel C: Tests for weak exogeneity[c]

	H_O:	$\chi^2_{(1)}$ *value (p value)*
Nearby	$\alpha_N = 0$	0.198 (0.656)
1 yr contract	$\alpha_1 = 0$	6.63 (0.01)
2 yr contract	$\alpha_2 = 0$	6.08 (0.01)

Notes: [a] Tests are on eigenvalues with the Π matrix. The λ_{trace} statistic is $-N(\sum_{i=r+1}^{2}\ln(1-\lambda_i))$, where λ_i are ordered (largest to smallest) eigenvalues on Π.

[b]Tests are based on the following: $T = N(ln(1\text{-}\lambda_R) - ln(1\text{-}\lambda_U))$, where λ_R is the eigenvalue calculated with the restriction and λ_U the eigenvalue calculated without the restriction. Based upon these results, the exclusions of 1 year out and 2 year out contracts are accepted at 10 percent level of significance. However, given the economic significance of these contracts, we keep them in our cointegration relation.

[c]Weak exogeneity tests suggest that the nearby contract price is a weakly exogenous variable that influences the long-run path of other variables in the system – in this case, the other two prices – but is not influenced by these other variables.

Table 4: Crude Oil Futures and Options: Open Interest Snapshots, 2000 –2008

Panel A: Crude Oil Futures, Third Week of July

	Non-Commercial (%)			Commercial (%)		Open Interest
	long	short	spread	long	short	
2000	10.2	6.0	6.0	74.4	76.9	456,717
2001	3.6	13.7	9.1	80.5	65.8	453,943
2002	13.1	5.9	18.1	56.4	66.7	486,180
2003	19.8	12.7	8.4	62.7	67.5	536,017
2004	16.1	10.9	8.4	67.3	71.5	696,850
2005	13.2	10.9	16.7	62.1	63.6	822,636
2006	17.7	12.4	21.1	54.9	60.1	1,086,762
2007	16.1	8.9	20.3	58.5	65.3	1,549,425
2008	15.6	14.0	27.5	49.8	51.1	1,344,411

Panel B: Crude Oil Futures and Futures-equivalent Options, Third Week of July

	Non -Commercial (%)			Commercial (%)		Open Interest
	long	short	spread	**long**	**short**	
2000	7.8	2.9	11.0	73.4	75.9	607,156
2001	3.1	8.0	13.7	77.3	69.0	608,391
2002	7.6	1.5	24.3	59.3	67.2	773,550
2003	14.0	5.0	18.6	60.4	67.6	779,513
2004	11.8	4.6	19.6	62.1	68.5	1,026,123
2005	9.4	5.1	26.5	58.5	62.2	1,303,209
2006	12.1	6.3	30.9	52.5	58.3	1,706,416
2007	10.9	4.5	26.7	58.8	64.9	2,453,667
2008	8.0	5.1	42.7	45.6	48.4	2,974,130

Notes: **Table 4** provides a snapshot of open interest changes since 2000. Open interest data for futures and futures-equivalent (delta-adjusted) option positions are from the weekly Commitment of Traders Reports from July 2000 through July 2008. For each year, the snapshot is for the third week of July (e.g. July 17, 2007). We report open interest figures for futures only and for total positions (i.e., the sum of futures and *futures-equivalent* options positions) of commercial and non-commercial traders. When the CFTC publishes its weekly Commitment of Traders Report, reporting traders are categorized into two broad groups: "Commercials" (right panel), who have declared an underlying hedging purpose, and "Non-commercials" (left panel), who have not. For each category, the long and short positions are reported as fractions of the overall open interest. In Table 4B, for example, on the short [*long*] side of the 773,500 open interest on Tuesday, July 16, July 2002, 67.2% [*59.3%*] of all positions were held by commercial traders and 1.5% [*7.6%*] were held by reporting non-commercial traders, with the rest split between 24.3% in spread positions (i.e., calendar spread positions constructed with long and short futures positions) held by reporting non-commercial traders and 7% [*8.8%*] in outright short [*long*] positions held by non-reporting traders.

Table 5: Open Interest by Maturity and Trader Category – Annual Averages

	Futures Only						Futures & Futures-equivalent Options					
Panel A: 2000	**0-3 months**	**3-12 months**	**1-3 years**	**3+ years**	**Total**		**0-3 months**	**3-12 months**	**1-3 years**	**3+ years**	**Total**	
Manufacturers	30,361	13,185	7,858	2,479	53,883		37,601	16,720	7,985	2,479	64,784	
Other Commercials	3,292	1,664	120	-	5,076		3,540	1,810	120	-	5,471	
Producers	11,131	6,733	2,413	899	21,176		15,575	9,947	2,494	899	28,915	
Dealers/Merchants	49,401	37,665	20,068	5,173	112,307		58,100	42,351	20,691	5,173	126,316	
Commodity Swap Dealers	41,155	42,206	40,682	9,090	133,132		68,684	77,563	53,300	9,091	208,637	
Unclassified Commercials	11,715	4,642	1,688	72	18,117		16,267	6,018	1,997	72	24,354	
Non-Registered	9,590	3,602	654	736	14,581		21,891	10,418	728	736	33,774	
Floor Brokers/Traders	6,320	12,250	6,432	443	25,445		22,695	23,083	7,819	443	54,039	
Hedge Funds	16,542	7,228	6,340	595	30,705		18,072	8,244	7,077	595	33,988	
Total	**179,505**	**129,175**	**86,256**	**19,487**	***414,423***		**262,425**	**196,155**	**102,210**	**19,488**	***580,278***	
Commercial	147,053	106,096	72,830	17,713	343,692		199,767	154,409	86,588	17,713	458,477	
Non-Commercial	32,452	23,080	13,426	1,774	70,731		62,658	41,745	15,623	1,775	121,800	
NonComm + Swap Dealers	73,606	65,286	54,107	10,864	203,863		131,342	119,308	68,923	10,865	330,438	
Panel B: 2004	**0-3 months**	**3-12 months**	**1-3 years**	**3+ years**	**Total**	Diff vs.2000	**0-3 months**	**3-12 months**	**1-3 years**	**3+ years**	**Total**	Diff vs.2000
Manufacturers	27,266	9,533	10,932	1,273	49,004	-9%	34,543	11,756	11,074	1,273	58,646	-9%
Other Commercials	2,031	328	-	1	2,360	-54%	2,935	909	36	1	3,882	-29%
Producers	11,119	2,897	486	1	14,503	-32%	12,463	3,190	501	1	16,155	-44%
Dealers/Merchants	78,364	55,359	25,046	13,683	172,452	54%	99,832	75,068	29,837	13,879	218,615	73%
Commodity Swap Dealers	64,812	78,102	55,763	23,352	222,029	67%	108,535	145,303	75,881	24,810	354,529	70%
Unclassified Commercials	120	539	2	-	661	-96%	126	583	3	-	713	-97%
Non-Registered	20,931	9,060	4,956	3,241	38,188	162%	41,808	25,532	6,879	3,241	77,460	129%
Floor Brokers/Traders	16,130	20,600	8,999	2,460	48,190	89%	58,512	52,444	9,731	2,460	123,146	128%
Hedge Funds	59,220	18,052	7,752	3,525	88,550	188%	74,950	29,117	10,857	3,538	118,463	249%
Total	**279,995**	**194,469**	**113,935**	**47,536**	***635,936***	53%	**433,704**	**343,904**	**144,798**	**49,202**	***971,609***	67%
Diff vs.2000	56%	51%	32%	144%	53%		65%	75%	42%	152%	67%	
Commercial	183,713	146,757	92,228	38,310	461,008	34%	258,434	236,811	117,332	39,963	652,539	42%
Non-Commercial	96,282	47,713	21,707	9,226	174,928	147%	175,270	107,093	27,467	9,240	319,069	162%
NonComm + Swap Dealers	161,094	125,814	77,470	32,578	396,957	95%	283,805	252,397	103,348	34,049	673,598	104%
Panel C: 2008	**0-3 months**	**3-12 months**	**1-3 years**	**3+ years**	**Total**	Diff vs.2000	**0-3 months**	**3-12 months**	**1-3 years**	**3+ years**	**Total**	Diff vs.2000
Manufacturers	21,990	8,265	4,978	189	35,423	-34%	26,874	10,069	5,355	189	42,487	-34%
Other Commercials	861	373	170	-	1,404	-72%	1,000	387	170	-	1,556	-72%
Producers	13,233	2,490	386	-	16,109	-24%	15,196	3,261	523	-	18,980	-34%
Dealers/Merchants	86,349	63,208	43,399	9,844	202,800	81%	147,277	118,306	62,819	14,635	343,037	172%
Commodity Swap Dealers	126,363	135,701	128,288	49,876	440,227	231%	217,358	343,346	292,534	94,713	947,952	354%
Unclassified Commercials	-	-	-	-	-	-100%	-	-	-	-	-	-100%
Non-Registered	74,951	41,741	23,072	8,116	147,880	914%	191,023	179,688	52,800	11,414	434,925	1188%
Floor Brokers/Traders	23,018	24,402	2,393	1,103	50,916	100%	139,676	147,703	10,736	1,103	299,218	454%
Hedge Funds	125,066	145,722	76,899	24,692	372,378	1113%	181,590	252,291	137,939	38,314	610,134	1695%
Total	**471,830**	**421,903**	**279,585**	**93,820**	***1,267,137***	206%	**919,992**	**1,055,052**	**562,877**	**160,369**	***2,698,289***	365%
Diff vs.2000	163%	227%	224%	381%	206%		251%	438%	451%	723%	365%	
All Commercials	248,795	210,037	177,221	59,909	695,963	102%	407,704	475,369	361,401	109,538	1,354,012	195%
All Non-Commercials	223,034	211,865	102,364	33,911	571,174	708%	512,288	579,682	201,476	50,831	1,344,278	1004%
NonComm + Swap Dealers	349,397	347,566	230,652	83,786	1,011,401	396%	729,646	923,029	494,010	145,545	2,292,230	594%

Notes: **Table 5** shows open interest in crude oil futures and options. After averaging the long and short positions of every large trader in any given contract, we add these estimates of open interest appropriately (e.g., for all commercial traders, or for all positions less than 3 months, etc.). We then compute annual averages for each trader category and maturity bucket in 2000 (July-Dec.), 2004 (Jan.-Dec.), and 2008 (Jan.-Aug.). Table 5 is comparable to Figures 5-6.

Table 6: Augmented Dickey-Fuller (ADF) tests for the Regression Variables

Panel A: ADF for the Trace Statistic

	Level	First Difference
Trace	-0.70	-9.43***

Panel B: ADF for the Fundamentals

	Level	First Difference
Kilian (2008b) Shipping Index	-0.94	-5.82***
Crude Oil Spare Capacity	-0.73	-11.23***
Industrial Commodity Price Index	-0.42	-3.94***

Panel C: ADF for the Shares of Open Interest by Trader Category

	Nearby		1-year		2-year	
	Level	First Difference	Level	First Difference	Level	First Difference
Dealer/Merchants	-4.14***	-12.04***	-2.71*	-3.39**	-1.83	-2.36
Manufacturers	-3.61***	-15.79***	-2.62*	-2.11	-0.46	0.30
Producers	-2.31	-7.16***	0.66	-1.50	0.54	-0.01
Other Ag/Nat Resource	0.44	-2.25	-2.49	-1.61	-4.25***	-2.24
Commodity Swap Dealers	-8.74***	-11.99***	-6.29***	-6.76***	-3.47***	-3.30**
Floor Brokers/Traders	-3.94***	-9.15***	-2.73*	-3.59***	-3.44***	-2.32
Hedge Funds	-5.68***	-18.63***	-4.01***	-8.46***	-3.47***	-3.62***
Non-reporting	2.13	-9.63***	-2.35	-1.90	-3.16**	-4.15***
All Commercials	-8.32***	-26.73***	-4.61***	-6.29***	-2.70*	-2.70*
All Non-Commercial	-3.62***	-20.48***	-4.60***	-8.03***	-4.46***	-5.58***
Non-Commercials + Swap Dealers	-5.20***	-20.10***	-6.17***	-8.95***	-4.47***	-4.75***
All Traditional Commercials	-3.69***	-23.71***	-2.39	-3.45***	-1.30	-1.63

Notes: Stars (*, **, ***) indicate the rejection of non-stationarity at standard levels of statistical significance (10%, 5% and 1%, respectively). Critical values are from McKinnon (1991). Panels A and B show, respectively, that the independent variable (the trace statistic of the co-integration analysis of nearby, one-year-out and two-year-out futures prices) and the explanatory variables that capture market fundamentals are I(0). Panel C shows that the market shares of most trader categories are I(1).

Table 7.1: Explaining the Trace Statistic by the *Proportion* of Open Interest held by each Trader Category, 2000-2008

Panel A: Single Variable for Positions at all 3 Contract Maturities

	Constant	Slope	E-Trading	LPI	Nearby + 1-year + 2-year	TOI
Dealer/Merchants	-0.4525	2.9192*	-0.5683***	0.2962	-0.8589	8.21E-07**
Manufacturers	-1.1528*	2.2954*	-0.5179***	0.5160**	-2.3584**	4.46E-07
Producers	-1.1777	2.3729	-0.5803***	0.4275	-0.5730	7.74E-07*
Other Ag/Nat Resource	-1.2090	2.4020	-0.5844***	0.4239	1.1824	8.01E-07**
Swap Dealers	-1.1451	2.5498	-0.5721***	0.3956*	0.3684	8.00E-07**
Floor Brokers/Traders	-1.1503	2.3782	-0.5865***	0.4115	-0.1882	8.13E-07**
Hedge Funds	-1.2740	2.5833	-0.5500***	0.4424*	0.5901	6.54E-07
Non-Reporting	-0.5824	2.9445**	-0.5099***	0.2561*	3.7882***	5.79E-07*

Panel B: Separate Variables for Positions in Nearby *vs.* Long-dated Contracts

	Constant	Slope	E-Trading	LPI	Nearby	1+2 years	TOI
Dealer/Merchants	-0.3631	3.7606**	-0.4747***	0.2813	-0.7152	-5.3157**	7.69E-07**
Manufacturers	-1.1802*	2.2586*	-0.5185***	0.5225**	-2.3023**	-2.9017	4.40E-07
Producers	-1.2096	2.6689*	-0.4939***	0.4563*	0.4662	-34.6561**	6.08E-07*
Other Ag/Nat Resource	-1.2032	2.3887	-0.5856***	0.4217	1.0782	7.6436	8.06E-07**
Swap Dealers	-1.0788	2.1463	-0.5865***	0.3670	0.6842	-2.1063	8.58E-07***
Floor Brokers/Traders	-1.1382	2.5090	-0.5862***	0.4116	-0.0040	-2.2947	8.01E-07**
Hedge Funds	-1.2754	2.6296	-0.5624***	0.4472*	0.4646	1.2734	6.56E-07
Non-Reporting	-0.8676	2.5943**	-0.5291***	0.3339*	3.5149**	10.9184*	5.22E-07

Panel C: Separate Variables for Positions at Each Contract Maturity

	Constant	Slope	E-Trading	LPI	Nearby	1-year	2-year	TOI
Dealer/Merchants	-0.3658	3.7397**	-0.4733***	0.2820	-0.7059	-5.6044**	-3.6696	7.66E-07**
Manufacturers	-1.1626*	1.8789	-0.5484***	0.5125**	-2.4461**	2.1487	-12.7779	4.90E-07
Producers	-1.2084	2.7003*	-0.4927***	0.4557*	0.5095	-33.9794*	-41.3668	6.07E-07
Other Ag/Nat Resource	-1.1744	2.5036	-0.5761***	0.4165	1.1409	-1.0078	15.1016	7.96E-07**
Swap Dealers	-1.3615	2.9263	-0.6348***	0.4417	0.5332	0.3420	-11.7527*	8.44E-07**
Floor Brokers/Traders	-1.1806	2.6616	-0.5955***	0.4177	-0.0001	1.6124	-12.5929	8.13E-07**
Hedge Funds	-1.2374	2.6149	-0.5635***	0.4367	0.4215	0.9278	2.9630	6.76E-07
Non-Reporting	-0.8591	2.5925**	-0.5303***	0.3298*	3.6776***	13.2414**	-2.3388	5.15E-07

Notes: July 2000-August 2008. Bewley (1979) regressions control for the overall open interest across all contract maturities (TOI) and NYMEX e-trading after September 2006. We use an industrial commodity price index variable (LPI) as a proxy for fundamentals. We do not report coefficients for variables that are almost never statistically significantly different from 0 (dummies for June and December liquidity effects). Position data are scaled by the open interest, across all trader types, in nearby, 1- and 2-year contracts. Statistical significance at the 10%, 5% or 1% level is denoted by *, **, or ***.

Table 7.2: Explaining the Trace Statistic by the *Number* of Open Contracts held by each Trader Category, 2000-2008

Panel A: Single Variable for Positions at all 3 Contract Maturities

	Constant	Slope	E-Trading	LPI	Nearby + 1-year + 2-year	TOI
Dealer/Merchants	-1.4698	1.8412	-0.5689***	0.4849*	1.38E-06	6.48E-07
Manufacturers	-1.1634	2.3120	-0.6043***	0.4298*	-2.20E-06	8.10E-07**
Producers	-1.0456	2.6102	-0.5626***	0.3620	9.29E-06	7.97E-07**
Other Ag/Nat Resource	-1.1850	2.4257	-0.5801***	0.4210	6.09E-07	7.91E-07**
Swap Dealers	-0.9711	2.3883	-0.5783***	0.3601	1.67E-06	6.61E-07*
Floor Brokers/Traders	-1.3339	2.2614	-0.5601***	0.4599*	4.76E-06	6.68E-07*
Hedge Funds	-1.2322	2.8063*	-0.5835***	0.4570*	1.55E-06	4.93E-07
Non-Reporting	-0.5621	2.8801**	-0.6154***	0.2870	5.86E-06**	4.86E-07

Panel B: Separate Variables for Positions in Nearby *vs.* Long-dated Contracts

	Constant	Slope	E-Trading	LPI	Nearby	1+2 years	TOI
Dealer/Merchants	-1.4557	1.9409	-0.5443***	0.4770*	1.69E-06	-1.51E-07	6.41E-07
Manufacturers	-1.1348	2.4134	-0.6012***	0.4233*	-2.31E-06	-2.48E-06	8.13E-07**
Producers	-0.9483	3.1042**	-0.4816***	0.3556	1.08E-05	-7.92E-05	6.80E-07*
Other Ag/Nat Resource	-1.1669	2.3541	-0.5740***	0.4179	-1.73E-06	2.71E-05	7.89E-07**
Swap Dealers	-0.9346	2.3013	-0.5816***	0.3461	1.84E-06	7.83E-07	6.83E-07**
Floor Brokers/Traders	-1.3329	2.4858	-0.5639***	0.4614*	6.03E-06	-6.02E-07	6.51E-07
Hedge Funds	-1.2261	2.8177*	-0.5813***	0.4554*	1.63E-06	1.37E-06	4.86E-07
Non-Reporting	-0.6721	2.7522**	-0.6242***	0.3166	5.61E-06**	1.15E-05	4.71E-07

Panel C: Separate Variables for Positions at Each Contract Maturity

	Constant	Slope	E-Trading	LPI	Nearby	1-year	2-year	TOI
Dealer/Merchants	-1.4241	1.9714	-0.5336***	0.4711*	1.69E-06	-2.39E-06	6.68E-06	6.34E-07
Manufacturers	-1.1297	1.9623	-0.6619***	0.4046	-2.34E-06	2.64E-05	-4.92E-05	9.19E-07**
Producers	-1.0147	2.7147*	-0.4910***	0.3773	9.46E-06	-1.09E-04*	3.29E-05	6.68E-07*
Other Ag/Nat Resource	-1.1448	2.4988	-0.5669***	0.4130	-1.22E-06	3.87E-05	1.15E-05	7.84E-07**
Swap Dealers	-0.9619	2.3778	-0.5814***	0.3545	1.78E-06	1.53E-06	-2.81E-07	6.75E-07**
Floor Brokers/Traders	-1.3741	2.5927	-0.5628***	0.4709*	5.72E-06	1.02E-05	-1.70E-05	6.43E-07
Hedge Funds	-1.1587	2.8170*	-0.5797***	0.4350*	1.53E-06	5.47E-07	5.65E-06	5.24E-07
Non-Reporting	-0.6798	2.6173*	-0.6355***	0.3180	6.06E-06**	1.45E-05	-1.62E-06	4.50E-07

Notes: July 2000-August 2008. All Bewley (1979) regressions control for the overall open interest across all contract maturities (TOI) and the existence of side-by-side pit and electronic trading (1 after September 2006, 0 before). In this table, we use a non-exchange-traded industrial commodity price index variable (LPI) as a proxy for fundamentals. We do not report regression coefficients for variables that are almost never statistically significantly different from 0 (dummies for June and December liquidity effects). Statistical significance at the 10%, 5% or 1% level is denoted by *, **, or ***.

Table 8: Explaining the Trace Statistic with Position Data from Swap Dealers and Multiple Non-Commercial Categories

Panel A.1: Commodity Swap Dealers and all Non-Commercial Traders Combined

	Constant	Slope	E-Trading	LPI	TOI	Nearby	1+2 years	December	June
All Non-Commercials + Swap Dealers (1. Market Share)	-1.2403*	2.7710**	-0.4992***	0.3703**	5.40E-07	0.9091*	0.6665	0.0276	-0.0591
All Non-Commercials + Swap Dealers (2. Positions)	-0.9391	2.6527*	-0.5752***	0.3699*	4.31E-07	1.18E-06*	3.72E-07	-0.0351	-0.0778

Panel A.2: Breakdown by Sub-Category

		Model 1 (Market Shares)	Model 2 (Positions)
	Constant	-0.6154	-0.5447
	Slope	2.9229**	3.0677*
	Electronic Trading	-0.5333***	-0.6418***
	LPI (Commodity Prices)	0.2529	0.2809
	TOI (Total Open Interest)	5.38E-07	5.03E-07
	December	0.0993	0.0068
	June	0.0552	-0.0353
Commodity Swap Dealers	Nearby	0.8269	1.15
	(1-year + 2-year)	**-2.5287***	-5.20
Floor Brokers & Traders	Nearby	-1.1535	0.87
	(1-year + 2-year)	0.0112	2.28
Hedge Funds	Nearby	0.1757	-0.80
	(1-year + 2-year)	**2.2005***	1.57
Non-Reporting Traders	Nearby	**3.2921****	**5.76****
	(1-year + 2-year)	**9.1948***	**25.40***

Notes: Sample period: July 2000 - August 2008. All Bewley (1979) regressions control for the overall open interest across every single contract maturity (TOI); dummies for June and December liquidity effects and the existence of side-by-side pit and electronic trading (1 after September 2006, 0 before). In this table, we use a non-exchange-traded industrial commodity price index variable (LPI) as a proxy for fundamentals. Statistical significance at the 10%, 5% or 1% level is denoted by *, **, or ***.

Table 8 (continued): Explaining the Trace Statistic with Position Data from Multiple Commercial Categories

Panel B.1: All Commercial Traders Combined (including Swap Dealers)

	Constant	Slope	E-Trading	LPI	TOI	Nearby	1+2 years	December	June
All Commercials (1. Market Share)	-0.4329	3.1487**	-0.4728***	0.4380**	4.70E-07	-0.9203**	-2.2878**	0.2527*	0.0378
All Commercials (2. Positions)	-1.2190	2.1046	-0.5586***	0.4047*	6.62E-07*	9.38E-07	1.84E-07	0.0080	-0.0596

Panel B.2: Breakdown by Sub-Category

		Model 1 (Market Shares)	Model 2 (Positions)
	Constant	-1.1217**	-0.7111
	Slope	2.3176**	2.7528**
	Electronic Trading	-0.4561***	-0.5155***
	LPI (Commodity Prices)	0.4609**	0.3213
	TOI (Total Open Interest)	4.37E-07	5.81E-07*
	December	0.2118*	0.1241
	June	0.0104	-0.0673
Manufacturers	Nearby	**-1.8737****	-4.23
	(1-year + 2-year)	-1.1802	-0.03
Other Natural Resource	Nearby	-0.5001	-4.41
	(1-year + 2-year)	18.5449**	39.20*
Producers	Nearby	0.8301	6.94
	(1-year + 2-year)	**-27.9645****	**-68.90***
Commodity Swap Dealers	Nearby	**0.8607****	**1.90***
	(1-year + 2-year)	-0.7703	0.79

Notes: Sample period: July 2000 - August 2008. All Bewley (1979) regressions control for the overall open interest across every single contract maturity (TOI); dummies for June and December liquidity effects and the existence of side-by-side pit and electronic trading (1 after September 2006, 0 before). In this table, we use a non-exchange-traded industrial commodity price index variable (LPI) as a proxy for fundamentals. Statistical significance at the 10%, 5% or 1% level is denoted by *, **, or ***.

Table 9: Explaining the Trace Statistic with Position Data from Swap Dealers and Multiple Non-Commercial Categories

Panel A.1: Commodity Swap Dealers and all Non-Commercial Traders Combined

	Constant	Slope	E-Trading	Spare	TOI	Nearby	1+2 years	December	June
Dealers (1. Market Share)	0.2110	4.0452**	-0.4788***	-0.0372*	9.40 E-07***	0.7579	0.1958	0.0253	0.0028
wap Dealers (2. Positions)	0.4977***	4.2057**	-0.5232***	-0.0419**	6.53 E-07**	1.43 E-06**	3.15 E-07	-0.0784	-0.0360

Panel A.2: Breakdown by Sub-Category

		Model 1 (Market Shares)			Model 2 (Positions)		
		Coefficient		p value	Coefficient		p value
Constant		**0.3944**	**	0.0117	**0.5433**	***	0.0003
Spare Capacity		**(0.0434)**	**	0.0260	**(0.0465)**	**	0.0134
Slope		**3.4561**	***	0.0037	**3.9456**	***	0.0069
TOI (Total Open Interest)		**7.81 E-07**	***	0.0076	**6.95 E-07**	**	0.0131
Electronic Trading		**(0.5281)**	***	0.0000	**(0.6465)**	***	0.0000
December		0.1302		0.3488	0.0163		0.9088
June		0.1423		0.1773	0.0264		0.7822
Floor Brokers & Traders	Nearby	(2.0397)		0.1665	-7.09 E-07		0.8713
	(1-year + 2-year)	0.7341		0.8823	1.26 E-06		0.9107
Hedge Funds	Nearby	0.0168		0.9768	-9.12 E-07		0.5030
	(1-year + 2-year)	**2.6162**	*	0.0735	2.53 E-06		0.3391
Non-Reporting Traders	Nearby	**3.6755**	**	0.0476	**7.44 E-06**	**	0.0348
	(1-year + 2-year)	8.2870		0.1371	2.41 E-05		0.1402
Commodity Swap Dealers	Nearby	0.7819		0.2177	1.22 E-06		0.2801
	(1-year + 2-year)	**(3.6009)**	**	0.0422	-6.22 E-06		0.1768

Notes: Sample period: July 2000 - August 2008. All Bewley (1979) regressions control for the overall open interest across every single contract maturity (TOI); dummies for June and December liquidity effects and the existence of side-by-side pit and electronic trading (1 after September 2006, 0 before). In this table, we use non-Saudi spare crude oil production capacity (SPARE) as a proxy for fundamentals. Statistical significance at the 10%, 5% or 1% level is denoted by *, **, or ***.

Table 9 (continued): Explaining the Trace Statistic with Position Data from Multiple Commercial Categories

Panel B.1: All Commercial Traders Combined (including Swap Dealers)

	Constant	Slope	E-Trading	Spare	TOI	Nearby	1+2 years	December	June
All Commercials (1. Market Share)	1.1500***	5.0167***	-0.3927***	-0.0580**	8.41 E-07***	-0.6959	-3.0308**	0.0767*	0.1575
All Commercials (2. Positions)	0.3076**	3.6903*	-0.4899***	-0.047*	9.50 E-07***	1.27E-06	-1.68E-07	-0.0031	0.0037

Panel B.2: Breakdown by Sub-Category

		Model 1 (Market Shares)			Model 2 (Positions)		
		Coefficient		p value	Coefficient		p value
	Constant	**1.2188**	***	0.0008	**0.5134**	***	0.0055
	Spare Capacity	**(0.0348)**	**	0.0212	**(0.0381)**	**	0.0422
	Slope	**4.9582**	***	0.0001	**4.2750**	***	0.0060
	TOI (Total Open Interest)	**7.04 E-07**	***	0.0004	**8.17 E-07**	***	0.0004
	Electronic Trading	**(0.3683)**	***	0.0005	**(0.4727)**	***	0.0003
	December	**0.2855**	**	0.0253	0.1091		0.5299
	June	0.1021		0.2018	(0.0186)		0.8269
Manufacturers	Nearby	**(1.9859)**	*	0.0560	-3.17 E-06		0.3653
	(1-year + 2-year)	2.4473		0.3285	8.03 E-08		0.9900
Producers	Nearby	1.1362		0.4592	8.85 E-06		0.1563
	(1-year + 2-year)	**(22.5346)**	**	0.0455	**-7.59 E-05**	*	0.1041
Commercial Dealers	Nearby	**(1.4558)**	***	0.0097	-5.76 E-07		0.6550
	(1-year + 2-year)	**(3.7662)**	*	0.0786	7.31 E-08		0.9857
Commodity Swap Dealers	Nearby	0.2253		0.6172	**2.24 E-06**	*	0.0841
	(1-year + 2-year)	(1.6968)		0.2249	7.74 E-07		0.7899

Notes: Sample period: July 2000 - August 2008. All Bewley (1979) regressions control for the overall open interest across every single contract maturity (TOI); dummies for June and December liquidity effects and the existence of side-by-side pit and electronic trading (1 after September 2006, 0 before). In this table, we use non-Saudi spare crude oil production capacity (SPARE) as a proxy for fundamentals. Statistical significance at the 10%, 5% or 1% level is denoted by *, **, or ***.

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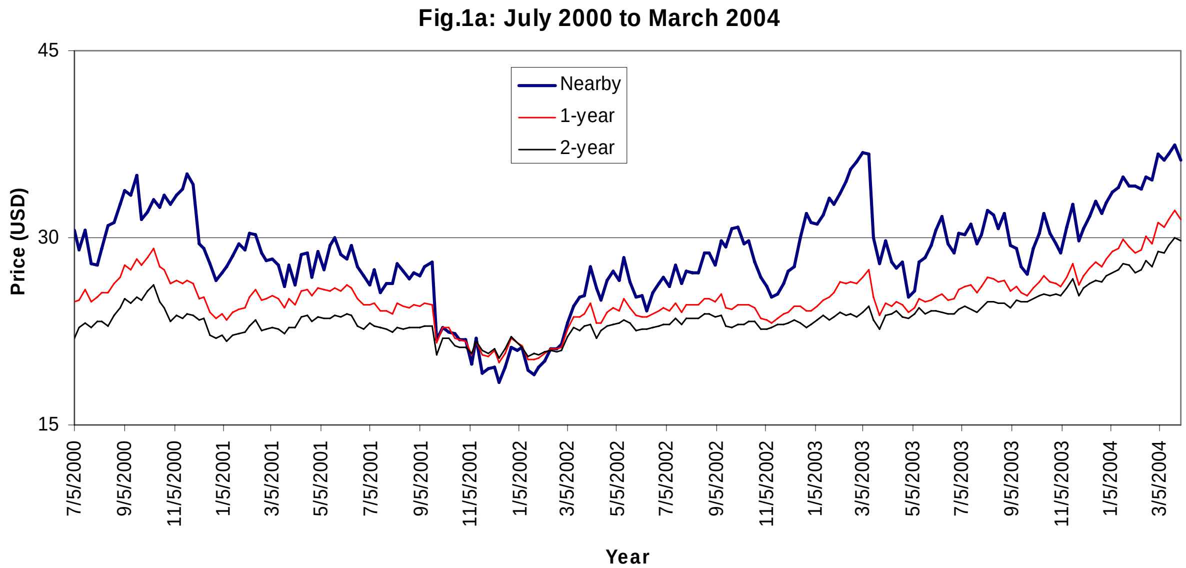
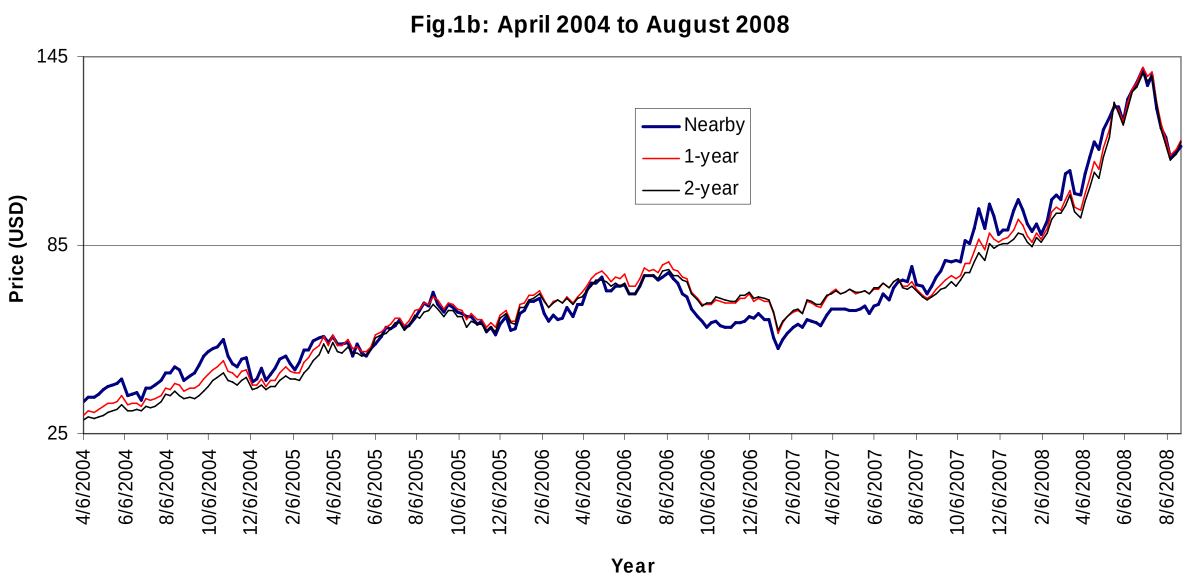
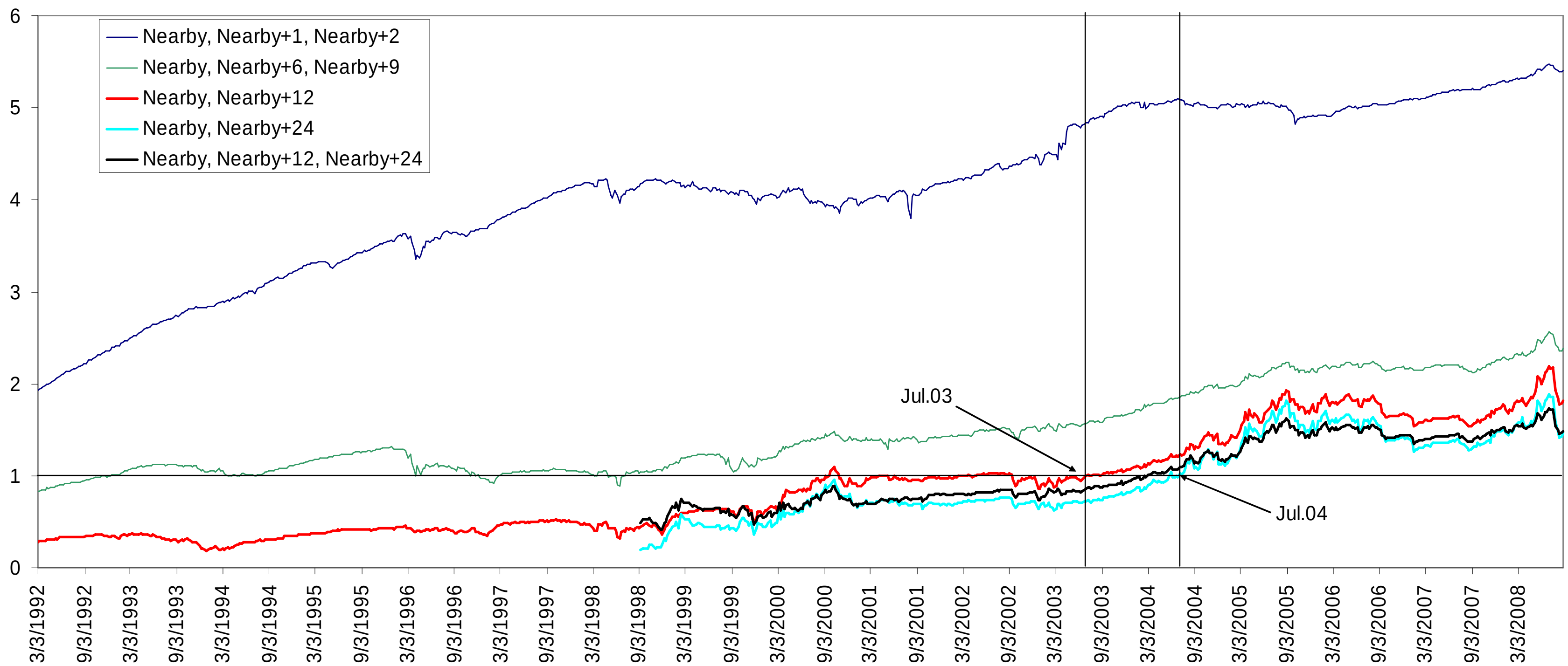
Figure 1: Nearby and Backdated WTI Crude Oil Futures Prices, 2000-2008





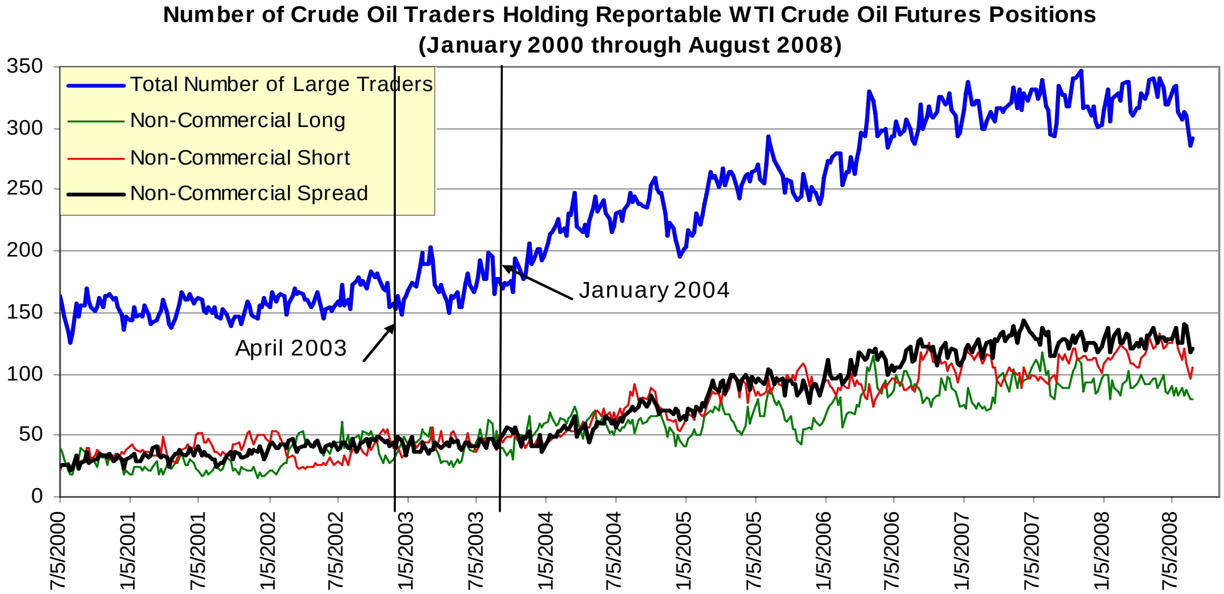
Notes: **Figure 1** shows the WTI futures prices for nearby (blue line), one-year out (pink line) and two-year out (yellow line) deliveries. A change in the pattern of the three time series is evident. Starting in the Fall of 2003, the three price series have an upward trend and move more closely together.

<u>**Figure 2. Recursively Calculated Trace Test Statistics Scaled by the 5% Critical value for Various Contracts.**</u>



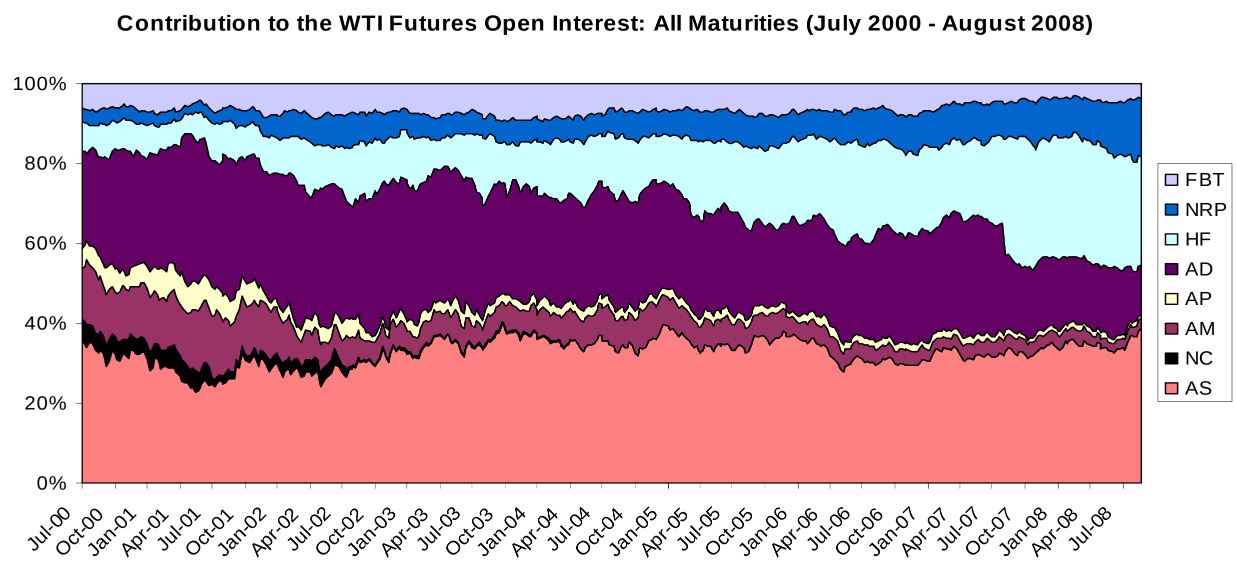
<u>**Notes**</u>: Figure 2 shows R-1 form of five recursively-calculated Trace Test statistics, scaled by the 5% critical value, for different sets of crude oil futures from March 1992 to August 2008. The solid horizontal line represents the 5% critical value (=1). The **dark blue curve**, starting close to 2 in 1992, shows the scaled trace for the "Nearby", "Nearby + 1 month" and "Nearby + 2 months" contracts. For these near-term prices, there is strong evidence of a cointegrating vector throughout the sample period. The **green curve**, starting just under 1, shows the scaled trace for the "Nearby", "Nearby + 6 months" and "Nearby + 9 months" contracts. For these three series, there is evidence of a cointegrating vector from 1993 onward. The **red curve**, starting close to 0.3, shows the scaled trace for the "Nearby" and "Nearby + 12 months" (i.e., 1-year) contracts. These two price series were not cointegrated until July 2003, with the statistical strength of the cointegration increasing greatly after May 2004. Finally, the **black curve** (starting in 1998) shows the scaled trace statistic for the "Nearby", "Nearby+12 months", and "Nearby+24 months" (i.e., 1-year) contracts. These three price series were not cointegrated until Spring 2004. Finally, the **light blue curve** shows the scaled trace statistic for the "Nearby", and "Nearby+24 months" (i.e., 2-year) contracts. These three price series were not cointegrated until June 2004. A three-year period was used for the initialization; hence, because daily price data are available for the 1-year (*2-year*) contract only from 1989 (*1995*) onwards, we provide results starting in 1992 (*1998*) for tests involving the 1-year (*2-year*) contracts. Robustness checks with a one-year initialization period show qualitatively similar results – in particular, there is no evidence of cointegration between the Nearby, 1-year and 2-year contracts until Fall 2003 at the earliest.

Figure 3: Number of Large Traders



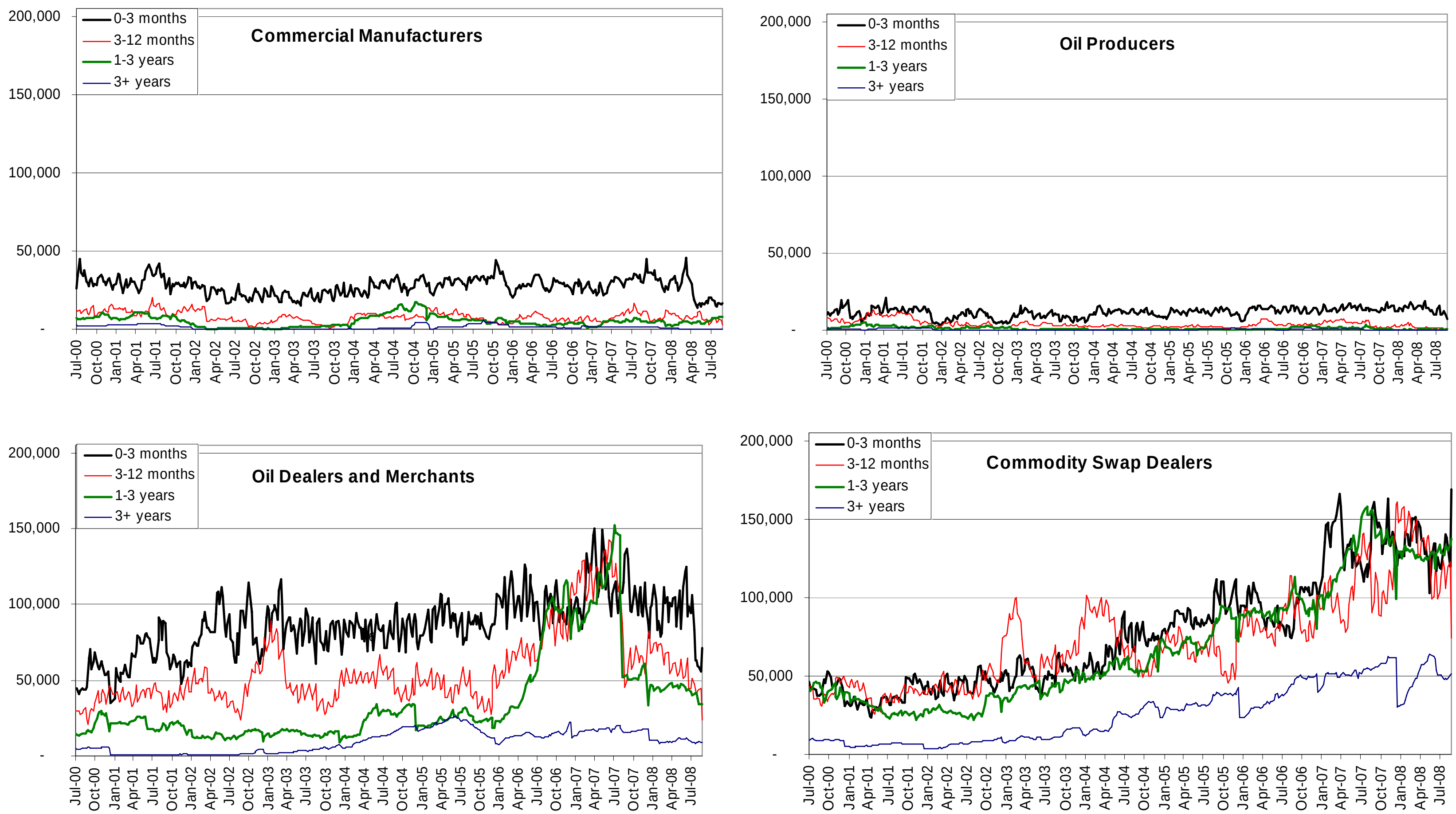
Notes: **Figure 3** shows the total number of NYMEX traders reporting positions to the CFTC for its weekly Commitment of Traders Reports, between July 5 2000 and August 26 2008 (**blue time series**). The figure provides details for non-commercial traders, showing the number of non-commercials holding long (**green time series**), short (**red time series**) or spread positions (**black time series**). The number of non-commercial spread traders doubled between May 2001 and January 2004, and tripled again between February 2004 and July 2007.

Figure 4: Market Shares



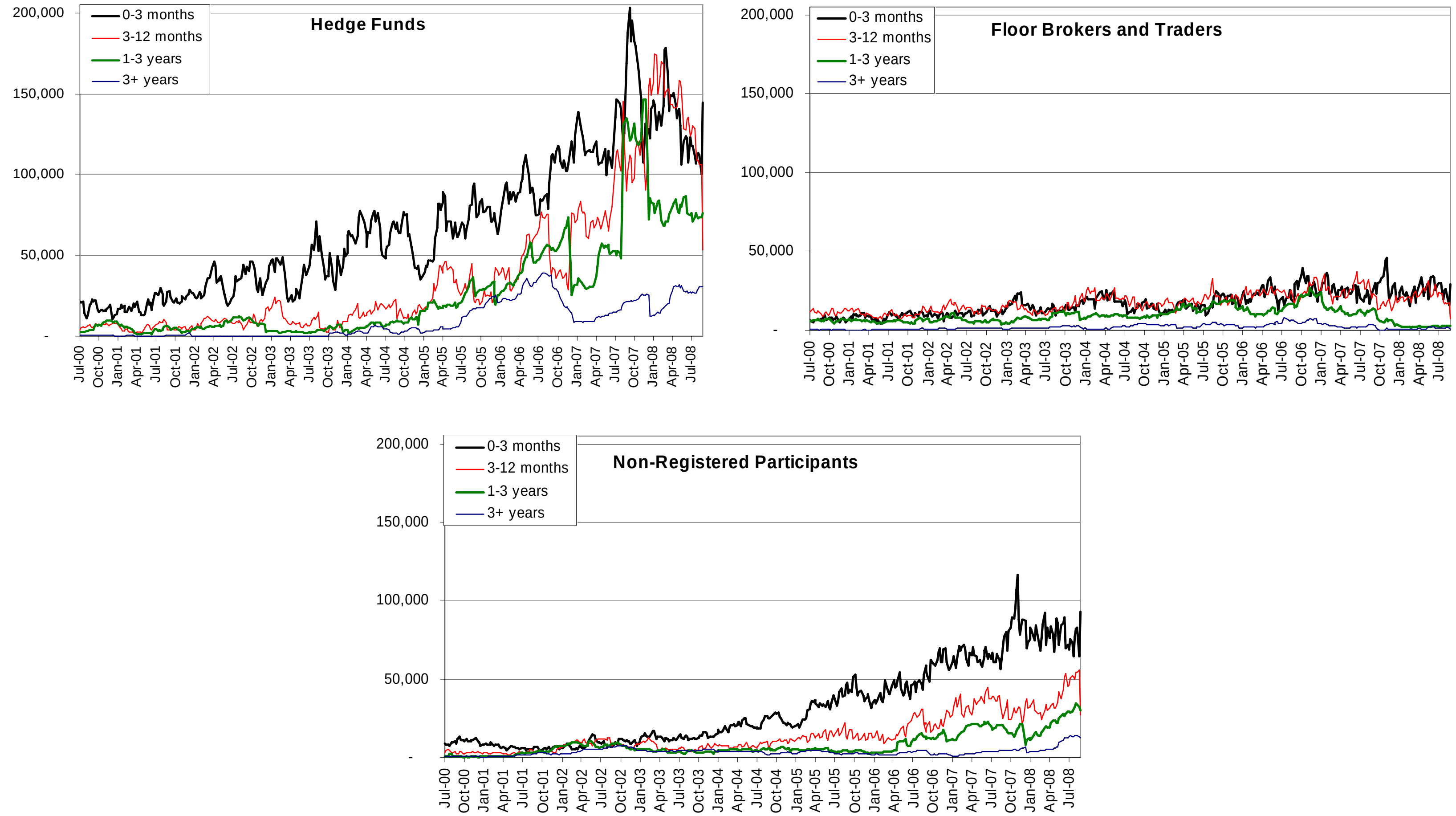
Notes: **Figure 4** compares the contributions to the WTI futures open interest of eight types of large traders between July 5 2000 and August 26 2008. Commercial types include "Dealers/Merchants" (AD), "Manufacturers" (AM), "Producers" (AP), and "Commodity Swaps/Derivatives Dealers" (AS). Non-commercial types are "Hedge Funds" (HF), "Floor Brokers & Traders" (FBT), and "Non-Registered Participants" (NRP). Prior to August 2003, the "NC" category sums the positions of presently inactive commercial traders.

Figure 5a: Daily Open Positions of the Major Commercial Trader Types, July 2000 to August 2008



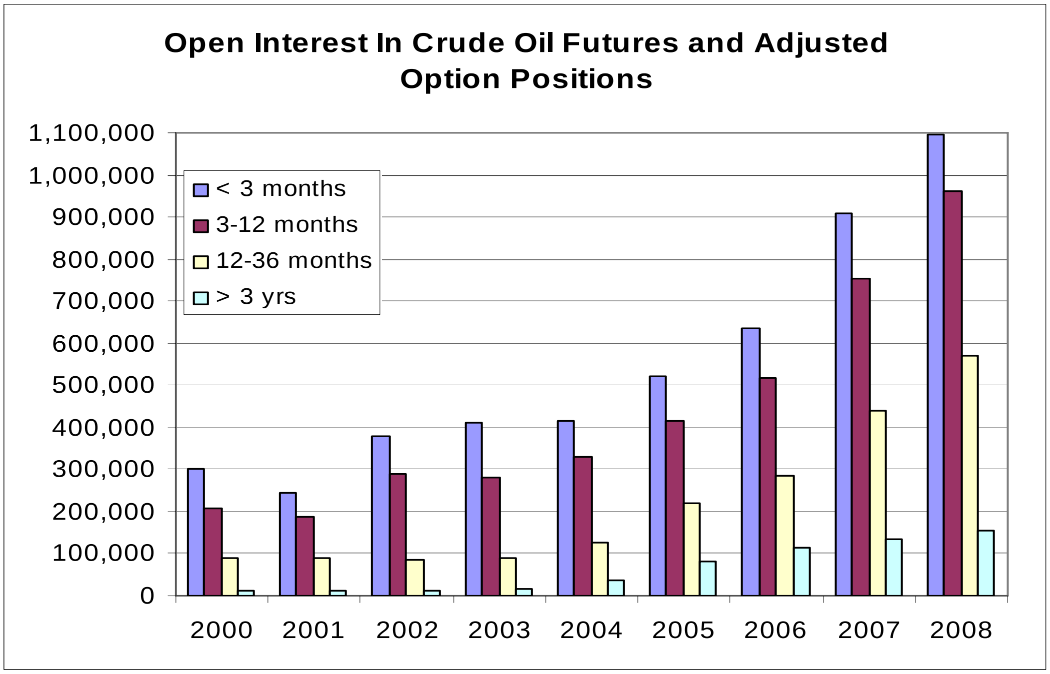
Notes: **Figure 5a** shows the open positions, by contract maturity, of the four most important commercial crude oil futures trader types: AD = Dealer/Merchant, AM = Manufacturer, AP = Producer, and AS = Commodity Swaps/Derivatives Dealer (which includes FS = Financial Swaps / Derivatives Dealer and FA = Arbitrageur or Broker/Dealer). Every Tuesday between July 2000 and August 2008, for each trader and each futures delivery month, we measure the trader's **open interest** in that contract as the average of the trader's long and short positions. The open interests of all reporting traders in a given category are then summed up appropriately (e.g., for all contracts with less than 3 months until maturity, etc.), and the Tuesday figures are then plotted. The graphs are scaled to allow for easy comparisons of the relative sizes of the open positions held by different trader categories. Figure 5a is directly comparable to Figure 5b below.

Figure 5b: Daily Open Positions of the Major Non-Commercial Trader Types, July 2000 to August 2008



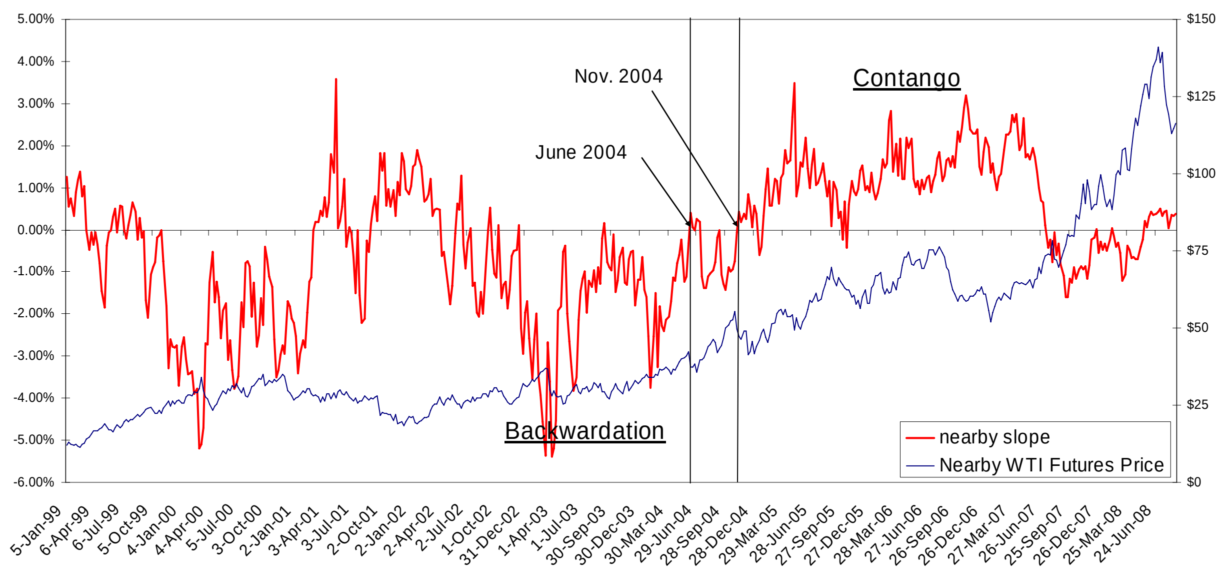
Notes: **Figure 5b** shows the open positions, by contract maturity, of the three most important non-commercial crude oil futures trader types: HF = Hedge Fund, and FBT = Floor Broker/Floor Trader. Every Tuesday between July 2000 and August 2008, for each trader and each futures delivery month, we measure the **trader's open interest** in that contract as the average of the trader's long and short positions. The open interests of all reporting traders in a given category are then summed up appropriately (e.g., for all contracts with less than 3 months until maturity, etc.), and the Tuesday figures are then plotted. The graphs are scaled to allow for easy comparisons of the relative sizes of the open positions held by different trader categories. Figure 5b is directly comparable to Figure 5a above.

Figure 6: Open Interest at different Maturities: Changes, 2000-2008



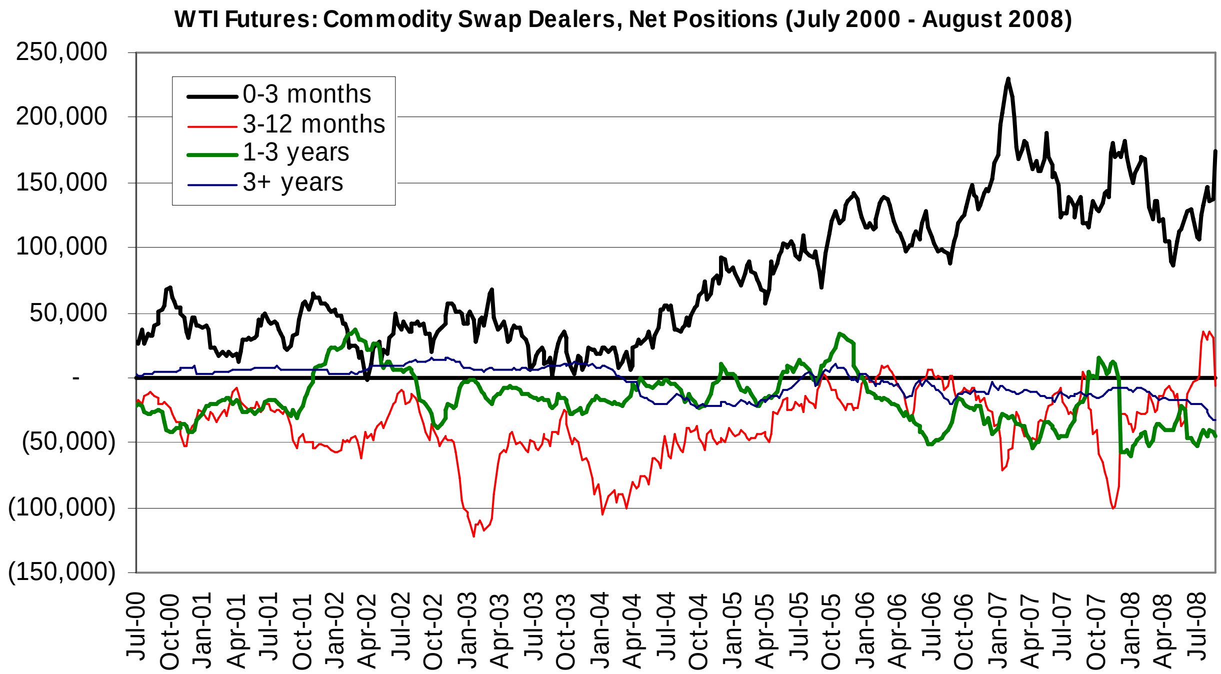
Notes: **Figure 6** shows annual open interest estimates for all reporting (i.e., large) traders by contract maturity. Every Tuesday from January 2000 through May 2008, for each trader and each futures delivery month, we measure the **trader's open interest** as the average of the trader's long and short positions in that contract. The open interests of all reporting traders are then summed up by maturity (all positions less than 3 months, etc.) and the annual averages are then computed.

Figure 7: Cost of Rolling a Nearby Long Futures Position Forward, 2000-2008



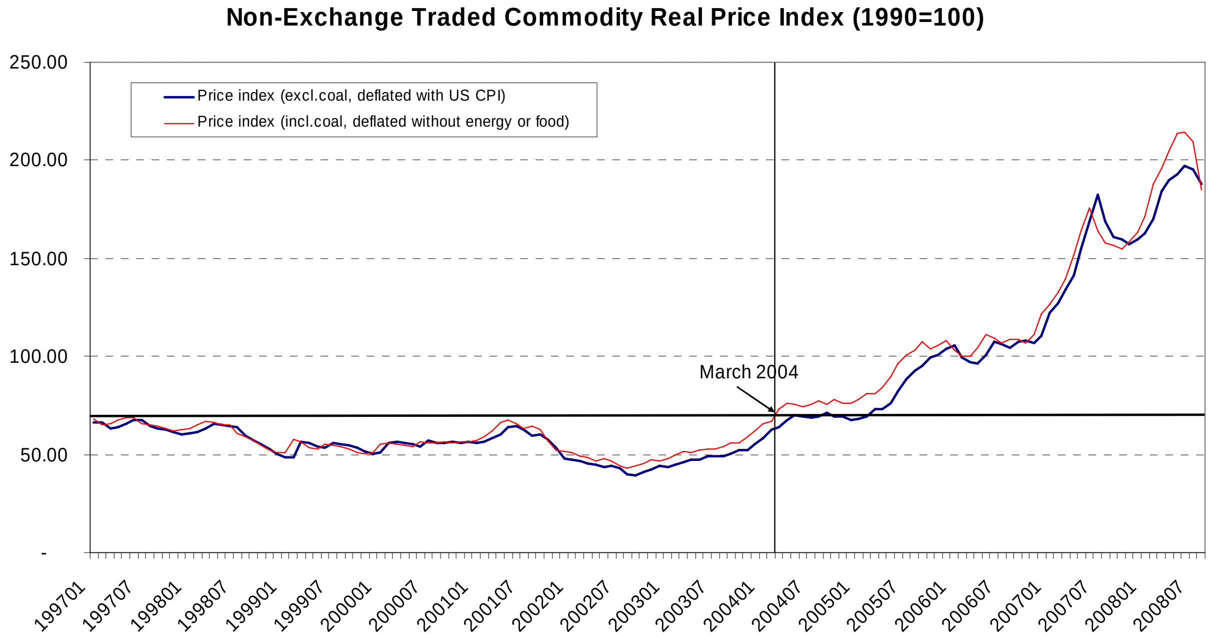
Notes: **Figure 7** shows the nearby WTI futures price (**blue line**, U.S. dollar; right scale) and the cost of rolling forward a nearby futures position, measured as the percentage difference between the nearby and next-nearby futures prices (**red line**, left scale). A negative value of the spread indicates a "backwardated" market, in which a trader holding a long futures position would realize a positive return from rolling the position forward (into the cheaper next-nearby contract). Conversely, a positive value of the spread indicates a "contangoed" market.

Figure 8: Net Positions of Commodity Swap Dealers at Different Maturities, 2000-2008



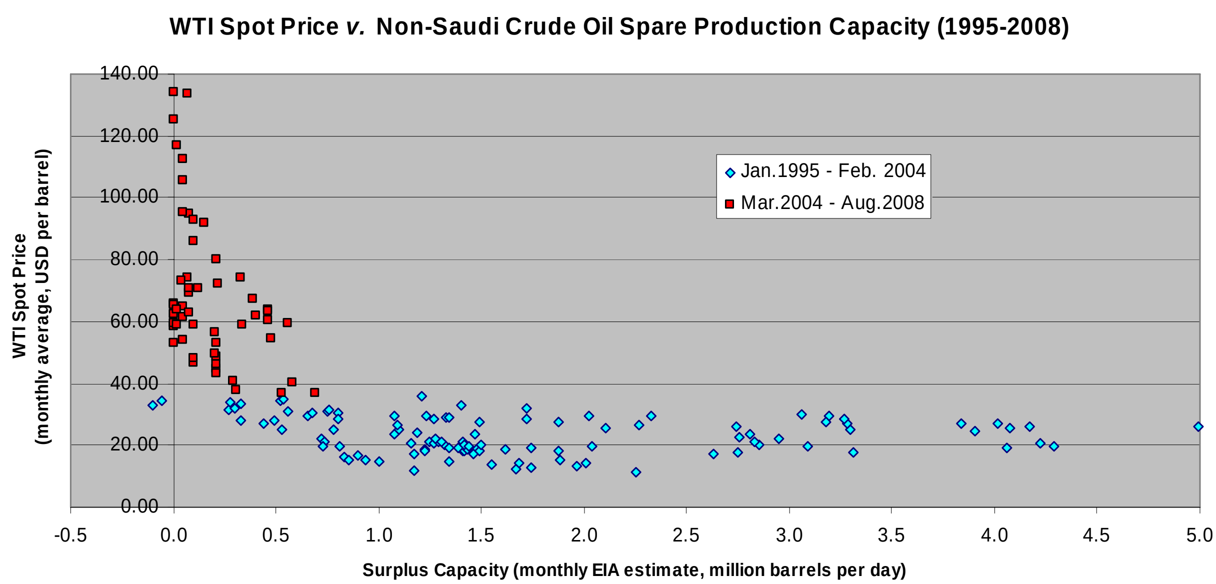
Notes: **Figure 8** shows the net positions, by contract maturity, held by all commodity Swap Dealers. Every Tuesday between July 2000 and August 2008, for each trader and each futures delivery month, we measure the trader's **net position** in that contract. The net positions of all reporting traders in a given category are then summed up appropriately (e.g., for all contracts with less than 3 months until maturity, etc.), and the Tuesday figures are then plotted.

Figure 9: Commodity Fundamentals



Notes: **Figure 9** displays an equally-weighted index of spot prices for seven non-exchange traded agricultural and industrial commodities (1990 = 100). The index covers rice, coal, and five industrial metals: manganese, rhodium cadmium, cobalt and tungsten. To abstract from absolute price-level differences across these commodities, we compute the index by compounding an equally-weighted average of the individual commodity returns, and deflating the resulting series. The spot price data are from Bloomberg; price indices, from the US Bureau of Labor Statistics.

Figure 10: Crude Oil Market Fundamentals



Notes: **Figure 10** displays the spot price for West Texas Intermediate crude oil (U.S. dollars per barrel) against the crude oil spare production capacity outside of Saudi Arabia (million barrels per day). All data are from the Energy Information Administration (U.S. Department of Energy).