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Nonlinear Regime Shifts in Oil Price Hedging Dynamics

Giulio Cifarelli*

Abstract

The interaction between rational hedgers and informed oil traders is parameterized and tested empirically with the help of a complex non linear smooth transition regime shift CCC-GARCH procedure. In spite of their gyrations, futures price changes are usually self-correcting. Well informed producers and consumers will ensure that crude oil prices – and thus the prices of the corresponding futures contracts – fluctuate within a long run equilibrium range determined by market fundamentals. During the 2008 oil price upswing, however, shifts in positions in the futures markets by well informed optimizing agents, that usually dampen price changes, result in destabilizing positive feedback trading. Futures price changes that can be classified as speculative are due to hedgers' reaction to movements in the variability of the return of their covered cash position.

Keywords: oil price dynamics; dynamic hedging; logistic smooth transition; multivariate GARCH.

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The model provides an interpretation of the motion of futures oil prices from January 1990 to January 2010. Oil futures are not easily analyzed since they are affected by both real and financial factors. Their dynamics reacts to fundamentals via a long run relationship with crude oil cash prices (the basis) and to hedging and speculative financial factors. A clear-cut distinction between hedging and speculation, moreover, is not always drawn. In a classic paper Johnson (1960) suggests that hedging and speculation in futures markets are interrelated. Speculation is mainly attributed to traders' expectations on futures price changes that bring about a shift in the optimal hedging ratio, a pattern that is related to the hypotheses of this paper. Ward and Fletcher (1971) generalize this approach to both long and short hedging and find that speculation is associated with optimal futures positions (short and long) that are in excess of the 100 percent hedging level.

This paper does not attempt to explain the determinants of equilibrium futures and spot oil prices. It focuses on the impact of hedging on futures price behavior and tries to shed light on the controversy about the role of speculation in the oil market prompted by the recent price upswing.

The 2007 - 2008 "oil bubble" has attracted a great deal of attention. It has been attributed to various causes, such as the entry of financial entities prone to adopt a speculative behavior (Master, 2008, Cifarelli and Paladino, 2010), to fundamental variables, such as a weak dollar and a low elasticity of supply in the face of a rapidly growing demand from Asia and other developing countries (Hamilton, 2009, Kesicki, 2010), or to a combination of these hypotheses (Kaufmann, 2010, among others).

The main interactions between rational hedgers, informed oil producers, and oil consumers, already discussed in Tokic (2011) with the help of the speculative pricing framework of De Long et al. (1990), are parameterized and tested empirically using a logistic smooth transition regime switching procedure. Feedback trading is found to be a by-product of the dynamic behavior of a futures pricing model in which oil producers and traders play a dominant role. In it futures price changes that can be classified as speculative are mostly due to hedgers' reaction to movements in the variability of the return of their covered cash position. It may happen that shifts in positions in the futures markets by well informed optimizing agents, that usually dampen price changes, bring about destabilizing positive feedback trading.

Noise trading in futures contracts, per se, does not seem to play a relevant role. Informed arbitrageurs ensure mean reversion of futures returns about a long run moving average. It is oil producers and consumers that do, in some cases, generate a speculative positive feedback trading behavior. The paper contributes to the current debate as follows.

a. It identifies a stylized dynamic reaction pattern in the futures oil market. Every week economic agents rebalance their optimally hedged position in order to minimize its variance, going long or short in the futures market as a response to shifts in their cash demand, shifts that are related to standardized price changes of the previous time period.
b. The reaction of traders and producers to volatility shifts in the oil market is modelled using a complex non linear logistic smooth transition regime shift CCC-GARCH approach. In this way the literature is extended by adding a dynamic component to the standard two-step hedge ratio computation.
c. The evolution over time of the weighted coefficient of the volatility of the return of the hedging position is analysed and the reaction of economic agents to the recent oil price gyrations is carefully assessed. It turns out that the informed hedgers' strong and stabilizing reaction during the 2005-2006 cycle is less incisive during the second larger 2007-2008 cycle. An increase in market uncertainty, possibly due to the entry of institutional investors in the commodity markets, is clearly detected. It reduces the informational advantage of informed market makers. The hesitations and uncertainties that characterize oil trading during a bubble are apparent, since destabilizing hedging positions, which result in positive feedback trading, become more frequent.

The analysis is organised as follows. Section 1 introduces the theoretical framework, based on a dynamic model of futures pricing which takes into account some stylized characteristics of spot and futures oil trades. The empirical evidence is presented in Section 2 using a nonlinear logistic smooth transition CCC-GARCH(1,1) parameterization. Section 2.1 provides an estimation of the oil spot and futures price dynamics. Section 2.2 analyses the behavior of the weighted coefficient of the variability of the return of the hedging position. Section 3 concludes the paper.

1. A dynamic model of futures pricing

It is assumed, following Westerhoff and Reitz (2005), that futures prices are set in an order driven market with heterogeneous agents. Futures price changes from t to t+1 are a positive function of excess demand by fundamentalist (rational) arbitrageurs and by oil traders, consumers and producers, involved in dynamic hedging.

$$f_{t+1} = f_t + a_1(D_t^F + D_t^H) + e_{t+1} \tag{1}$$

where f_t is the logarithm of the futures price F_t and a_1 is a positive reaction coefficient. D_t^F and D_t^H denote the excess demand of fundamentalists and hedgers.

Informed arbitrageurs base their expectations on futures price movements on the divergence between a long run (normal) equilibrium futures price rate of change based on oil market fundamentals and the current futures price rate of change

$$D_t^F = a_2(r_{ft}^F - r_{ft}) \tag{2}$$

where $r_{ft} = \Delta \log F_t = \Delta f_t$ and r_{ft}^F is the equilibrium futures price rate of change. It will be assumed that $r_{ft}^F = (\sum_{i=0}^{N-1} r_{ft-i})/N$. Coefficient a_2 is positive since current returns are believed to converge to their long run equilibrium value. Arbitrageurs increase (reduce) futures demand if the current rate of return lies below (above) its long run equilibrium fundamental value r_{ft}^F and generate a dynamic mean reverting behavior.

Hedging transactions by oil producers and consumers are intended to reduce the risk of unwanted crude oil price changes. An investor who takes a long (short) position of one unit in the cash market will hedge by taking a short (long) position of β units in the corresponding futures market, which he will buy (sell) back when he sells (buys) the cash. The hedge ratio β can be seen as the proportion of the long (short) cash position that is covered by futures sales (purchases).

The return of this hedging position r_{Ht} is given by

$$r_{Ht} = r_{ct} - \beta r_{ft} \tag{3}$$

where the crude oil rate of return is the logarithmic first difference of the crude oil price C_t ($r_{ct} = \Delta \log C_t = \Delta c_t$).

The variance of the hedged position is given by

$$\sigma_{r_H t}^2 = \sigma_{r_c t}^2 + \beta^2 \sigma_{r_f t}^2 - 2\beta \sigma_{r_c t} \sigma_{r_f t} \rho_{r_c r_f t} \tag{4}$$

where $\sigma_{r_c t}^2$ is the variance of r_{ct}, $\sigma_{r_f t}^2$ is the variance of r_{ft}, and $\rho_{r_c r_f t}$ is the correlation between r_{ct} and r_{ft}.

The optimum hedge ratio β is derived from the first order condition of the hedging position variance minimization and reads as

$$\beta = \frac{\sigma_{r_c t}\sigma_{r_f t}\rho_{r_c r_f t}}{\sigma^2_{r_f t}} \quad (5)$$

The optimum hedge ratio depends upon both the covariance between the changes in futures and cash prices, $\sigma_{r_c r_f t} = \sigma_{r_c t}\sigma_{r_f t}\rho_{r_c r_f t}$, and the variance of the futures price changes.[1]

In order to analyze the reactions of hedgers to shifts in commodity returns, the hedging model is extended by introducing a dynamic component. The expected utility of hedgers is assumed to be an inverse function of the variability of their optimally hedged position. The variance of the returns of this position can be rewritten, replacing in equation (4) the optimal hedge ratio β by its determinants, set out in equation (5), as

$$\sigma^2_{r_H t} = \sigma^2_{r_c t} - \frac{(\sigma_{r_c r_f t})^2}{\sigma^2_{r_f t}} \quad (6)$$

The demand of futures contracts of a trader wishing to minimize the variance of her optimally hedged position is defined as

$$D^H_t = b^H \sigma^2_{r_H t-j} = b^H [\sigma^2_{r_c t-j} - \frac{(\sigma_{r_c r_f t-j})^2}{\sigma^2_{r_f t-j}}] \qquad j = 0,...,v. \quad (7)$$

A time lag is introduced since a shift in a hedged position will require a costly and possibly time consuming decision process. The sign of the b^H coefficient may change over time and calls for an accurate investigation.

An increase in $\sigma^2_{r_H t}$ may be due to a rise in the variance of the cash price rate of change and/or to a decrease in the correlation between cash and futures

[1] We are using here the standard optimum hedge ratio coefficient, adapted to a conditional volatility context by Ballie and Myers (1991) and Kroner and Sultan (1993) among many others.

returns, which we decide to disregard.[2] An increase in $\sigma^2_{r_c t}$ can in turn be produced either by an increase or by a decrease in crude oil prices. b^H is expected to be negative if in the previous period(s) the cash price rate of change is positive and positive if in the previous period(s) the cash price rate of change is negative. Long positions in a commodity (by producers) are associated with short positions in futures contracts, whereas short positions in a commodity (by e.g. traders or consumers) are covered by long positions in futures contracts.

If the commodity price rises (falls) the producer is likely, in the subsequent time period, to increase (reduce) his output and to increase (reduce) his planned future sales. In order to hedge against future spot price declines he is going to raise (decrease) his hedging position by selling more (less) futures contracts. The futures price will fall (rise) and the coefficient of the hedged position variability b^H will be negative (positive). The behavior of either traders or consumers causes the same sign shifts. If the commodity price declines (rises) traders will, in the following period, face an increase (decrease) in demand and increase (reduce) their short positions commitments in the cash market and, in order to hedge against future price rises, will raise (cut) their long positions in the futures market, bringing about a futures price increase (decrease).

We have a regime shift whenever the transition variable – here the crude oil rate of change divided by its conditional variance – crosses a threshold. In periods of market stress and of high return variability the signal to noise ratio declines and the impact of a given shift in crude oil prices is likely to be smaller than in low volatility periods. In the discussion above the threshold was assumed to be zero. A change in the hedging position may well be costly and the threshold will be positive.

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[2] Equation (6) can be rewritten as $\sigma^2_{r_H t} = \sigma^2_{r_c t}(1-\rho^2_{r_c r_f t})$ where $\rho_{r_c r_f t} = \sigma_{r_c r_f t} / \sigma_{r_c t}\sigma_{r_f t}$. The correlation between cash and futures returns is large and stable in the case of the liquid type 1 close to maturity futures contract used in the paper.

The behavior of hedgers, assumed to be well informed oil consumers and oil producers, can be modelled as

$$D_t^H = b_1^H[1-S(w_{t-l})]\sigma^2_{r_H t-j} + b_2^H[S(w_{t-l})]\sigma^2_{r_H t-j} \quad (8)$$

with $j = 0,...,v$ and $l = j+1,...,m$.

The coefficients b_1^H and b_2^H measure the impact of $\sigma^2_{r_H t}$ shifts on the demand for futures contracts over the two regimes. w_t is the transition variable $(r_{ct}/\sigma^2_{r_c t})$. The delay, l, with which it brings about a regime shift is assessed empirically and depends upon the structure of the crude oil market. $S(.)$ is the smooth transition function, which drives the motion from one regime to the other. The selection of this parameterization is justified, according to Teräsvirta (1994), by the plurality of the economic agents that are involved in the decision process. Even if a single hedger takes a dichotomous decision, it is unlikely that all agents act simultaneously. Since the price series provide information on the aggregate decision process only, the regime shift will be smooth rather than discrete.

$S(w_{t-l})$ is parameterized as the standard logistic function of a LSTAR model, a selection based on the empirical tests below, and reads as

$$S(w_{t-l}) = [1+e^{-\gamma(w_{t-l}-c)}]^{-1} \quad (9)$$

where c is the threshold and $\gamma > 0$ denotes the speed and the smoothness of the transition between regimes.[3]

At any given time t the impact of a shift in the volatility of the hedged position on futures demand will be a weighted average of the coefficients b_1^H

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[3] Both the absolute value of difference between w_t and c and its sign influence the transition process. The γ coefficient captures the curvature of equation (9). The larger is γ the stronger is the synchronization of oil traders' shifts in hedging positions.

and b_2^H. If w_{t-l} is large and positive, $S(w_{t-l})$ will tend to 1 and the weighted coefficient will take a value close to b_2^H; if w_{t-l} is large and negative, $S(w_{t-l})$ will tend to 0 and the weighted coefficient will take a value close to b_1^H. If $w_{t-l} = c$, $S(w_{t-l}) = 0.5$ and the weighted coefficient will be the arithmetic average of b_1^H and b_2^H.

Substituting equations (2) and (8) into equation (1), we have the following futures pricing relationship

$$r_{ft+1} = \theta_1[r_{ft}^F - r_{ft}] + \theta_{21}[1 - S(w_{t-l})]\sigma^2_{r_H t-j} + \theta_{22}[S(w_{t-l})]\sigma^2_{r_H t-j} + u_{r_f t+1} \quad (10)$$

where $\theta_1 = a_1 a_2$, $\theta_{21} = a_1 b_1^H$, $\theta_{22} = a_1 b_2^H$, and $j = 0,...,v$ and $l = j+1,...,m$.

Equation (10) relates futures price returns to the deviation of the previous periods returns from their fundamental equilibrium value and to the past variability of the optimally hedged positions of oil traders and of oil producers.

Economic theory suggests that the prices of cash assets and of the corresponding futures contracts are jointly determined (Stein, 1961). The empirical estimation thus includes a relationship that describes the behavior of cash returns, along a futures returns relationship, and analyses the behavior of the covariance between these two variables. Equilibrium prices are ultimately determined in the cash market as commodity futures prices at delivery converge to the cash price. In the long run an equilibrium relationship between cash and futures prices holds and accounts for the presence of the basis. This behavior justifies the existence of a cointegration relationship between futures and cash prices and the use of an error correction term in the dynamic parameterization of the cash returns relationship, where cash prices adjust to futures prices (the forcing variable).[4] Futures and cash price rates of change are heteroskedastic when data are sampled, as is the case in this paper, with a weekly frequency, and a GARCH approach is introduced in order to model the second moments that enter equation (10). The following non linear bivariate GARCH model – system (1) below – for oil futures and spot returns is thus estimated. The conditional mean of the futures returns is modelled over two regimes by equations (10′), (6′) and (9′), while the conditional mean of the cash returns is parameterized by an autoregressive error correction relationship, equation (11), and the conditional second moments are quantified by a bivariate CCC-GARCH(1,1) structure.

$$r_{ct} = \phi_0 + \sum_{z=1}^{x} \phi_z r_{ct-z} + \sum_{k=1}^{y} \varphi_k r_{ft-k} + \varepsilon(f_{t-1} - d_0 - d_1 c_{t-1}) + u_{r_c t} \quad (11)$$

$$\begin{aligned} r_{ft} &= \theta_0 + \theta_1[r^F_{ft-1} - r_{ft-1}] + \theta_{21}[1 - S(w_{t-l-1})]h^2_{r_H t-1-j} \\ &\quad + \theta_{22}[S(w_{t-l-1})]h^2_{r_H t-1-j} + u_{r_f t} \end{aligned} \quad (10')$$

$$j = 0,\ldots,v; \qquad l = j+1,\ldots,m; \qquad r^F_{ft} = (\sum_{i=0}^{N-1} r_{ft-i})/N$$

$$h^2_{r_H t-1-j} = h^2_{r_{ct-1-j}} - \frac{(h_{r_c r_f t-1-j})^2}{h^2_{r_f t-1-j}} \quad (6')$$

$$S(w_{t-1-l}) = [1 + e^{-\gamma(w_{t-1-l} - c)}]^{-1} \quad (9')$$

System (1)

$$u_t = \begin{bmatrix} u_{r_c t} \\ u_{r_f t} \end{bmatrix}$$

$$u_t | \Omega_{t-1} N(0, H_t)$$

$$H_t = \Delta_t R \Delta_t$$

$$R = \begin{bmatrix} 1 & \rho_{u_{r_c} u_{r_f}} \\ \rho_{u_{r_f} u_{r_c}} & 1 \end{bmatrix} \qquad \Delta_t = \begin{bmatrix} h_{r_c t} & 0 \\ 0 & h_{r_f t} \end{bmatrix}$$

$$h^2_{r_c t} = \varpi_c + \alpha_c u^2_{r_c t-1} + \beta_c h^2_{r_c t-1}; \quad h^2_{r_f t} = \varpi_f + \alpha_f u^2_{r_f t-1} + \beta_f h^2_{r_f t-1}$$

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[4] On this point, see Figuerola–Ferretti and Gonzalo (2010). They successfully apply a VECM approach to cash and futures commodity relations where cash prices adjust to futures prices, in line with the approach mentioned in the text.

2. The empirical evidence

2.1 The model estimates

The weekly data span from 2 January 1990 to 26 January 2010. The crude oil spot prices – West Texas Intermediate (WTI) Spot Prices fob, US dollars per Barrel – and the futures oil prices are provided by the EIA database. All the contracts are traded on the NYMEX (New York Mercantile Exchange). Futures prices correspond to the highly liquid nearest to delivery futures contract 1.[5]

< Insert Table 1 about here >

Summary statistics are presented in Table 1. Percentage returns are computed multiplying by 100 the first differences of the logarithms of the price levels. Average weekly returns are positive, small but far from negligible. Both time series distributions are asymmetric (skewed) and leptokurtic, the deviations from normality being stronger for the cash than for the financial futures contract.[6] Intertemporal dependency of weekly returns and of squared weekly returns is confirmed by the Ljung Box Q-statistics. Volatility clustering affects both time series, a finding that supports the choice of a GARCH parameterization of the conditional second moments.

Table 2 presents parsimonious ML estimates of the bivariate logistic smooth transition regime switching CCC-GARCH(1,1) system (1) set out in the previous section. The specification of the model is justified by a painstaking preliminary investigation which follows a three-step strategy set out by Teräsvirta (1994). At first the lag of the variability of the return of the hedged position entering equation (10′) is selected. A one week lag ($j=0$)

[5] Futures contract 1 expires on the 3rd business day prior to the 25th calendar day of the month preceding the delivery month. If the 25th calendar day of the month is a non-business day, trading ceases on the third business day prior to the business day preceding the 25th calendar day.

provides the best fit of the system in terms of value of the log likelihood function and of significance of the relevant parameters.
A test of linearity against the nonlinear parameterization of equation (10′) is then performed adopting the procedure of Luukkonen et al. (1988). The transition function $S(w_{t-1-l})$ is replaced in equation (10′) by a third order Taylor series approximation and the following auxiliary equation is estimated

$$r_{ft} = \lambda_0 + \lambda_1[r^F_{ft-1} - r_{ft-1}] + \lambda_2 h^2_{r_H t-1} + \lambda_3 h^2_{r_H t-1} w_{t-1-l} + \lambda_4 h^2_{r_H t-1} w^2_{t-1-l} + \lambda_5 h^2_{r_H t-1} w^3_{t-1-l} + u_{r_f t} \qquad (12)$$

where $w_{t-1-l} = r_{ct-1-l} / h^2_{r_c t-1-l}$, $l = j+1,...,m.$

The linearity hypothesis $H_0: \ \lambda_3 = \lambda_4 = \lambda_5 = 0$ is assessed with the help of F-tests for various values of l.[7] H_0 is rejected most strongly ($F(3,1033) = 6.9152[0.0001]$) with a two week lag ($l = 1$). The third step allows to determine whether the transition function has to be modelled by a logistic or by an exponential function, as in the ESTAR models. It involves a F-test of the null $H^*_0: \ \lambda_5 = 0$ in equation (12), against the alternative $H_1: \ \lambda_5 \neq 0$. The test statistic $F(1,1033) = 15.8464[0.0000]$ strongly rejects the exponential transition function parameterization.[8]

< Insert Table 2 about here >

The overall quality of fit is satisfactory. The parameters of both the conditional mean and conditional variance relationships have the appropriate signs and are significantly different from zero. The usual misspecification

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[6] The logarithms of the prices of the cash and futures contracts are always I(1). The test results are not reported for lack of space.
[7] The same test has been repeated assuming that also coefficient θ_1 tends to shift from one regime to the other. It is marginally significant. The value of θ_1 over the two regimes, however, is almost identical, and it is maintained, for the sake of simplicity, that it is invariant.
[8] The use of the ratio between the crude oil cash return and its conditional variance as transition variable deals with both the possible biases and the slow convergence problems of

tests suggest that the standardized residuals υ_t are well behaved and that the serial correlation and heteroskedasticity of the original return time series are captured by the model ($E(\upsilon_t)=0$, $E(\upsilon_t^2)=1$, and both υ_t and υ_t^2 are serially uncorrelated).[9] The estimates of equation (11) reflect the autocorrelation of the spot and cash return time series detected in Table 1. The tenets of the efficient markets theory do not apply to the oil market. The coefficient of the error correction term is rather large and indicates that price shocks to the basis are not persistent.

The estimates of equation (10') are more informative.[10] Coefficient θ_1 is small and positive and reflects a rather slow mean reversion pattern of futures returns to their normal value r_{ft}^F, quantified by an eight week futures returns moving average ($N=8$). The reaction of futures returns to shifts in the conditional variance of the return of the hedged position has a rich dynamic pattern which corroborates the a priori hypotheses set out in the previous section. The threshold c is positive; it indicates that oil producers/consumers are loath to modify their hedging positions because of transaction costs and possibly of risk aversion. The value of the γ coefficient, however, is rather large and suggests a rapid transition from one regime to the other. In the oil market hedgers tend to move together.

At any point in time the $h_{r_H t-1}^2$ coefficient is a weighted average of the regime one and of the regime two coefficients. The signs of these coefficients are

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the joint estimation of the coefficients γ and c of the logistic function (9') discussed in Teräsvirta (1994, page 213).

[9] The J.T.A. sign bias tests of Engle and Ng (1993) support the choice of a symmetric conditional variance parameterization. The strong asymmetry of the original return time series detected in Table 1 is filtered out by the specification of the conditional means. The conditional normality of the standardized residuals, however, is rejected by the Jarque Bera test statistics. The t-ratios reported in Table 2 are therefore based on the quasi-maximum likelihood estimation procedure of Bollerslev and Wooldridge (1992). The F-test for no remaining nonlinearity (see Eitrheim and Teräsvirta, 1996, pages 63-65), suggests that the model accounts for the nonlinearities of the data. The estimated statistic is $F(3,1031)=1.6014[0.1906]$, which fails to reject the null.

explained by the reaction of oil producers/consumers to the crude oil price shifts of the previous time period mentioned above. Regime one holds if the standardized crude oil return lies below the threshold and regime two if it exceeds the threshold. The deeper the decline in the t-2 standardized crude oil price rate of change, the larger the number of hedgers that are in regime one, and the closer the $h^2_{r_H t-1}$ coefficient will be to the upper bound $(\theta_{21} = 0.640)$. The larger, on the other hand, the increase in the t-2 standardized oil price rate of change, the larger the number of hedgers that are in regime two and the closer the $h^2_{r_H t-1}$ coefficient will be to the lower bound $(\theta_{22} = -0.533)$.

2.2 An interpretation of the 2005-2008 oil price fluctuations

The model reproduces in this way some stylized characteristics of oil market pricing and suggests that, in spite of their gyrations, futures price changes are usually self-correcting. Indeed, as pointed out by Tokic (2011), well informed producers and consumers will ensure that crude oil prices – and thus the prices of the corresponding futures contracts – fluctuate within a long run equilibrium range determined by market fundamentals.

How are we to interpret the large 2007-2008 crude oil price upswing and the subsequent abrupt collapse? As shown in previous studies (see e.g. Cifarelli and Paladino 2010, 2011, and the literature quoted therein) crude oil pricing is increasingly affected by financial and portfolio management risk reduction considerations. The unprecedented encroachment by institutional and money market investors during the recent financial crisis has distorted oil market pricing and affected its stabilization process. A careful inspection of the dynamics of the model provides some useful insights on this phenomenon.

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[10] System (1) was re-estimated either replacing $(r^F_{ft-1} - r_{ft-1})$ in equation (10') by the error correction term $(f_{t-1} - d_0 - d_1 c_{t-1})$ or adding it as new regressor. In both cases the estimation

< Insert Figure 1 about here >

Figure 1 spans the 2005 - 2010 time period. In it are reported the standardized values of the crude oil WTI spot price (fob) and of the corresponding weighted average of the estimated coefficients of the conditional variance of the return of the hedged position over the two regimes

$$\hat{\theta}_2 = \hat{\theta}_{21}[1 - S(w_{t-2})] + \hat{\theta}_{22}[S(w_{t-2})] \tag{13}$$

Two price cycles are identified, a small one, from January 2005 to December 2006, and a much more pronounced cycle from January 2007 to December 2008, often interpreted as a price bubble. The behavior of the weighted hedging coefficient provides some revealing results on market opinion. The closer is $\hat{\theta}_2$ to $\hat{\theta}_{21}$, the larger the fraction of hedgers that are in regime one rather than in regime two. The opposite holds the closer is $\hat{\theta}_2$ to $\hat{\theta}_{22}$. Hedgers seem to be, ceteris paribus, more confident during price downswings, in which the positive values of the coefficients are pronounced and persistent, than during price upswings, when a more hesitant behavior can be detected. In the first period the reaction of hedgers seems to be more pronounced as relatively small price shifts are associated with large stabilizing hedging positions. Especially during the downswing of the second half of 2006, hedgers went long heavily in the futures market, in order to lock in the profits arising from the price decreases.

The pattern of the coefficient during the second cycle is different and reflects the higher average variability of the return of the hedging position, which raises uncertainty. During the price upswing the hedging coefficient fluctuates between negative values and – admittedly smaller in absolute value – positive ones. The former stabilize oil prices while the latter result in destabilizing feedback trading behavior as hedgers misinterpret the oil price

process failed to converge.

changes of the previous period. Oil producers, faced by unwarranted price increases, reverse their usual futures shorting policies and purchase additional futures contracts as do consumers who, in this confusing context, hedge expected future oil price increases.[11] In the same way, the sharp oil price decline of the second semester of 2008 corresponds to large swings of the hedging coefficient from stabilizing positive to destabilizing negative values. The model reproduces in this way a stylized bubble behavior, characterized by sharp price increases and tentative exits from the market by increasingly concerned investors.[12]

< Insert Table 3 about here >

In table 3 are set out the correlation coefficients between the weighted coefficient of the variability of the hedging return and the spot and futures returns over the two cycles. As expected the signs of the coefficients are negative in the January 2005 – December 2006 sub-period, as hedgers' reaction dampen the oil price shifts. Over the January 2007 – December 2008 sub–period too, the signs are negative, even if the coefficients are smaller in absolute value. If, however, we restrict the analysis to the January 2007 – June 2008 subsample, we detect a positive correlation between the weighted coefficient $\hat{\theta}_2$ and the return time series, conducive to the hypothesis of a destabilizing feedback trading behavior. It should be noticed, however, that during the subsequent price decline (from July to December 2008) the coefficients are once more negative, as traders try to cash in the price decrease. This finding corroborates the suggestion made above, of

[11] See Tokic (2011, pages 2057-2058). Kesicki (2010, page 1603) points out that between July 2007 and May 2008 the Nymex is in backwardation, spot prices exceeding futures prices, which corroborates his hypothesis that the upswing is not to be attributed to speculation.

[12] A word of caution is called for here. As pointed out by Krapels (1997) price shifts per se cannot draw a distinction between the hypothesis that hedgers drive market pricing and speculators merely take the other side of the trades and the opposite view, in which speculators determine price movements. The findings of this section, however, point to a hedger driven market in the first cycle and possibly to a speculator driven market in the second. The same trader may shift over time from a hedging to a speculative behavior (and vice versa).

hedger uncertainty being greater during price upswings than during downswings.[13]

In each table are also reported the corresponding correlation coefficients between the hedged position return variability impact $\hat{\theta}_2 h^2_{r_H t-1}$ and the spot and futures returns over the same time sub-periods. The signs do not change, but the absolute values are smaller during the first cycle and larger during the second. A volatility size effect seems to reinforce, in the latter period, the hypotheses set out above.

3. Conclusions

A smooth transition regime shift dynamic model of oil futures pricing has been developed and tested over the 1990 – 2010 time period. Every week economic agents are assumed to rebalance their optimally hedged position in order to minimize its variance, going long or short in the futures market as a response to shifts in their cash demand, shifts that are related to standardized price changes of the previous time period. The empirical estimates are then used to analyze the recent oil price gyrations. In spite of its relative simplicity, the model provides some interesting insights on the role of dynamic hedging.

The paper focuses on the oil market only and does not take explicitly into account the stock exchange and exchange rate behavior. As a consequence it cannot analyze directly the increasing interrelation between financial and commodity markets. The empirical findings, however, can accommodate the hypothesis of a growing impact of non commercial traders, such as institutional investors, on oil pricing. Their 2007 - 2008 purchases cause an unwarranted oil price increase which reduces the informational advantage of

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[13] If an artificial weekly portfolio is computed where an investor is assumed to buy (sell) one unit on the spot market and to sell (buy) β units in the futures market, a comparison of the hedging performance of the optimally rebalanced and naïve ($\beta = 1$) portfolios set out in equation (3) corroborates this hypothesis. Over the January 2007 to June 2008 time interval the unconditional standard error of the optimally rebalanced hedge is larger than the standard

informed oil consumers/producers and brings about a positive feedback trading response. An accurate analysis of the response of the oil market to the inflow and outflow of funds from the financial and exchange rate markets, however, requires their simultaneous analysis and provides the scope for further research.

error of the naïve hedged position. The reverse is the case during the July to December 2008 downswing. The results are not reported for lack of space.

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Table 1. Descriptive statistics

	Crude oil spot price rate of change	**Oil futures price rate of change**
Mean	0.11297	0.11298
Std. Dev.	5.5484	5.3719
Skewness	-0.3700	-0.2323
Ex. Kurt.	5.3686	3.1336
Jarque-Bera	1281.275 [0.000]	437.803 [0.000]
ADF	-36.691 [0.000]	-37.095 [0.000]
$Q_x(1)$	16.863 [0.000]	19.836 [0.000]
$Q_x(10)$	39.202 [0.000]	39.034 [0.000]
$Q_x^2(1)$	77.519 [0.000]	40.671 [0.000]
$Q_x^2(10)$	287.000 [0.000]	236.930 [0.000]
J.T.A.	55.179 [0.000]	35.266 [0.000]

Notes: Ex. Kurt. Excess Kurtosis; ADF Augmented Dickey Fuller unit root statistic; $Q_x(k)$ is the Ljung Box Q-statistic for k^{th} order serial correlation of the x variable; $Q_x^2(k)$ is the Ljung Box Q-statistic for k^{th} order serial correlation of the squared variable x^2; J.T.A. is the Joint Wald test of the null hypothesis of no asymmetry distributed as χ^2 with 3 degrees of freedom (Engle and Ng, 1993). The data have a weekly frequency over the sample period 2/01/1990 - 26/01/2010. The sample includes 1048 observations. Probability values are in square brackets.

Table 2. Logistic smooth transition regime switching CCC-GARCH(1,1) System (1)

Conditional means			
Crude oil price rate of change		Futures price rate of change	
Equation (11)		Equations (9') and (10')	
ϕ_0	11.391 (338.849)	θ_0	0.229 (6.532)
ϕ_1	-0.100 (-17.498)	θ_1	0.036 (5.589)
ϕ_2	-0.195 (-23.903)	θ_{21}	0.640 (18.389)
ϕ_3	-0.122 (-10.467)	θ_{22}	-0.533 (-15.100)
φ_1	0.078 (13.496)		
φ_2	0.109 (13.667)	c	0.026 (2.416)
φ_3	0.131 (13.978)	γ	6.816 (8.311)
ε	0.885 (289.763)		
d_0	0.124 (342.731)		
d_1	1.001 (11471.6)		
Conditional variances			
ϖ_c	0.757 (20.366)	ϖ_f	0.931 (22.239)
α_c	0.161 (121.216)	α_f	0.161 (81.511)
β_c	0.830 (698.727)	β_f	0.820 (449.787)
$\rho_{u_{rc}u_{rf}}$	0.973 (3398.7)		
LLF	-4748.782		
Residual diagnostics			
	$u_{rct}/\sqrt{h_{rct}^2}$		$u_{rft}/\sqrt{h_{rft}^2}$
$E(\nu_{rct})$	-0.029	$E(\nu_{rft})$	-0.0294
$E(\nu_{rct}^2)$	1.010	$E(\nu_{rft}^2)$	1.0099
Skew.	-0.426	Skew.	-0.4461
Ex. Kurt.	3.068	Ex. Kurt.	2.7564
$Q_x(1)$	0.721 [0.396]	$Q_x(1)$	2.588 [0.107]
$Q_x(10)$	12.243 [0.269]	$Q_x(10)$	13.272 [0.209]
$Q_x^2(1)$	2.719 [0.100]	$Q_x^2(1)$	1.488 [0.222]
$Q_x^2(10)$	8.660 [0.565]	$Q_x^2(10)$	7.967 [0.632]
J.T.A.	8.679 [0.034]	J.T.A.	6.529 [0.088]
J.B.	437.105 [0.000]	J.B.	361.988 [0.000]

Notes: $\nu_{zt} = u_{zt}/\sqrt{h_{zt}^2}$, $z_t = r_c, r_f$; t-statistics are in parentheses and probabilities in square brackets; the t-ratios are based on the robust standard errors computed with the Bollerslev and Wooldridge (1992) procedure.

Table 3. Correlation between weighted hedging return variability coefficient, impact, and futures and spot rates of return

1/02/2005 - 12/26/2006

	r_{ct}	r_{ft}
$\hat{\theta}_2$	-0.0890	-0.1058
$\hat{\theta}_2 h^2_{r_H t-1}$	-0.0621	-0.0753

1/02/2007 - 12/30/2008

	r_{ct}	r_{ft}
$\hat{\theta}_2$	-0.0766	-0.0704
$\hat{\theta}_2 h^2_{r_H t-1}$	-0.2339	-0.1654

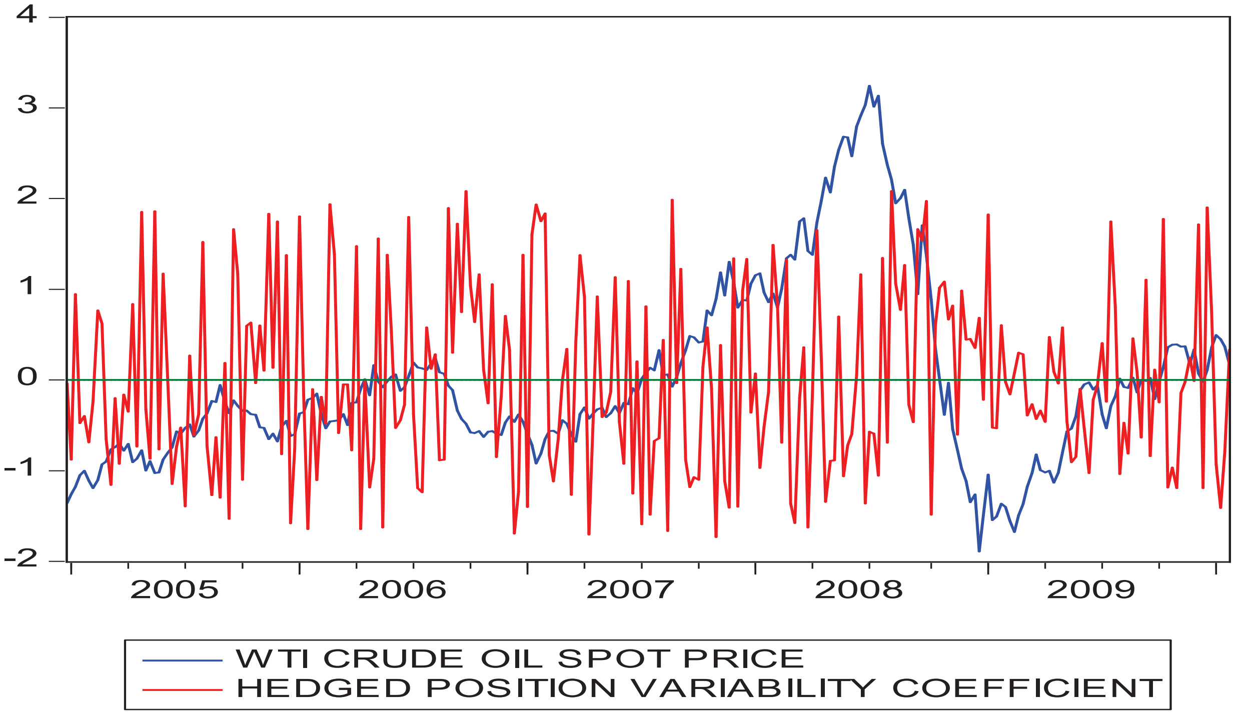
1/02/2007 – 6/24/2008

	r_{ct}	r_{ft}
$\hat{\theta}_2$	0.0952	0.0657
$\hat{\theta}_2 h^2_{r_H t-1}$	0.1571	0.1459

7/01/2008 -12/30/2008

	r_{ct}	r_{ft}
$\hat{\theta}_2$	-0.1208	-0.0560
$\hat{\theta}_2 h^2_{r_H t-1}$	-0.2681	-0.1435

Figure 1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