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Abstract

The aim of this paper is to study the oil price volatility in West Texas Intermediate (WTI) market in the US. By using statistical and econometric tools, we first attempt to identify the long-term relationship between WTI spot prices and the prices of futures contracts on the New York Mercantile Exchange (NYMEX). Subsequently we model the short-term dynamic between these two prices and this analysis points up several breaks. On this basis, a short term Markov Switching Vectorial Error Correction model (MS-VECM) with two distinct states (*standard* state and *crisis* state) has been estimated. Finally we introduce the volumes of transactions observed on the NYMEX for the WTI contracts and we estimate the influence of the non-commercial players. We conclude that the hypothesis of an influence of non-commercial players on the probability for being in the *crisis* state cannot be rejected. In addition, we show that the rise in liquidity of the first financial contracts, as measured by the volume of open interest, is a key element to understand the dynamics in market prices.

Keywords: Oil Prices, Futures Markets, Markov Switching Regime models

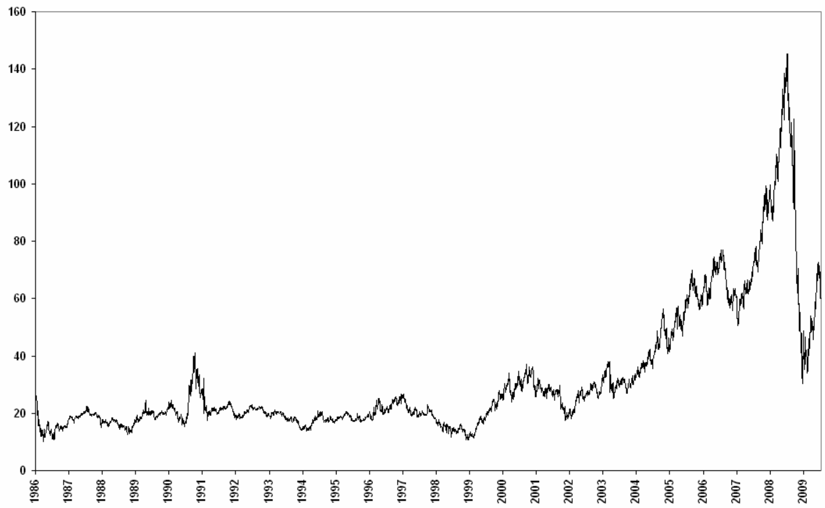
Introduction

An extensive literature exists on the respective roles of macroeconomic factors on the oil prices trend. The impact of the short-term variation of stocks (Fattouh, 2009; Pierru 2010), the monetary policies and by extension the changes in exchange rates (Audigé & all, 2010; Hamilton, 2009; Mignon, 2009) or interest rates (Hamilton, 2009), or the cyclical nature of the petroleum industry (Smith, 2009; Fattouh, 2010, Lescaroux, 2010) are commonly put forward to explain prices movements. The speculation factor is "by definition" difficult to measure. Some authors (Krugman, 2008; Smith, 2009; Hamilton, 2009) reject the hypothesis that speculation has a role to play in the markets. Nevertheless, the introduction of new rules by the Commodity Futures Trading Commission (CFTC) at the end of 2000 and the implementation of expansionary monetary policies after September 11 have triggered a strong growth in the transaction volumes and an increase in the short-term volatility of the oil prices (Chevalier, 2010; Medlock & Jaffe, 2009) in the financial markets, such as the New York Mercantile Exchange (NYMEX).

In this context, we focus on interactions that may exist between a physical crude oil price and the level of activity in financial oil markets. The data studied are relative to the price of crude oil on the North American market: the spot price for WTI (Cushing, Oklahoma), the futures prices on the NYMEX, the transaction volumes and open interest in the same market. These information are all in the public domain, and were drawn from the U.S. Energy Information Administration and from the weekly market business reports of the CFTC.

In the first section, we briefly define the major changes introduced by the new regulations of the CFTC in 2000 and the consequences in term of transaction volumes. In the second section, we identify the interactions between the physical and the financial crude oil prices and the impact of the short-run trader's behavior by using econometric analysis. The main conclusions are summarised in the last section.

Figure 1: Spot price for WTI crude oil (US dollars per barrel)



Source: Energy Information Administration, US Department of Energy

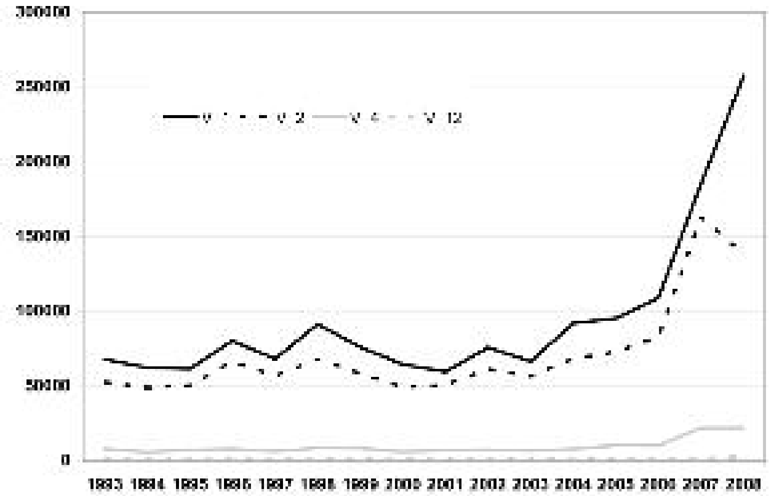
1. A new deal in the financial markets after 2000

Following the introduction at the end of December 2000 of the law modernising commodities markets, the Commodity Futures Modernization Act[1](CFMA), two major changes have been observed. On the one hand, by studying available data from January 1993 to January 2009, we observed a marked rise in transaction volumes. Measured in batches of 1 000 barrels (a standard financial contract for WTI on the NYMEX), these transactions have risen, for two-month term contracts, from around 52 000 in 1993 to 136 000 in 2008, i.e. multiplied by a factor of two and a half, with a peak of 165 000 in 2007[2]. On the other hand, the share of non-commercial[3] players increased from around 20% before 2001, to over 50% on average since 2006. In addition, their share in the volume of global transactions reached almost 60% at the beginning of the third quarter of 2008, a period during which crude prices reached record levels. According to Medlock & Jaffe (2009), during the 1990s we could observe ten active contracts on NYMEX, representing in barrel equivalents (1 contract = 1 000 barrels) over 150 million barrels per day, or more than twice the global demand for crude oil at that time. In recent years, this figure has changed to almost seven, with around 600 million barrels being exchanged through financial contracts. During the previous two decades and especially in the initial phase of construction of the commodities markets, the main objective of the different derivatives marketplaces was to attract and concentrate the liquidity required for commercial

[1] For more information, see the CFTC website at http://www .cftc.gov/lawandregulation/index.htm
[2] During the same period of time, consumption of petroleum products only increased by 12% in the United States, and by 20% world-wide.
[3] Thanks to the obligatory declarations that must be made by the various traders on NYMEX in order to operate in the financial markets, it is possible to determine the volumes for each trader, and to make so-called “open” positions (open interest) more comprehensible. Until September 2009, the CFTC classified the various parties into three categories of traders (See the breakdown up to 2009 produced by the CFTC at http://www.cftc.gov/marketreports/commitmentsoftraders/cot_about.html#P16_3370) so-called "commercial" traders (Commercial traders are those who are active in the petroleum supply chain (producers, stockholders and refiners), and who are in the market to achieve arbitrage between a physical position and a financial one. Non-commercial traders act in the market without any physical counterpart for their deals), "non-commercial" traders, and "others", with this last category corresponding to small volumes of transactions which it is impossible to attribute to one or other of the first two.

traders to achieve hedging activities. Nevertheless, the rise in transaction volumes has been accompanied by a concentration of traders' liquidity on the shortest maturity contracts exchanged in the commodities markets. This factor has been observed and studied in the past (Lautier, 2005), but it seems to be reinforced since 2000.

Figure 2: Average volume of transactions of future prices for WTI by term

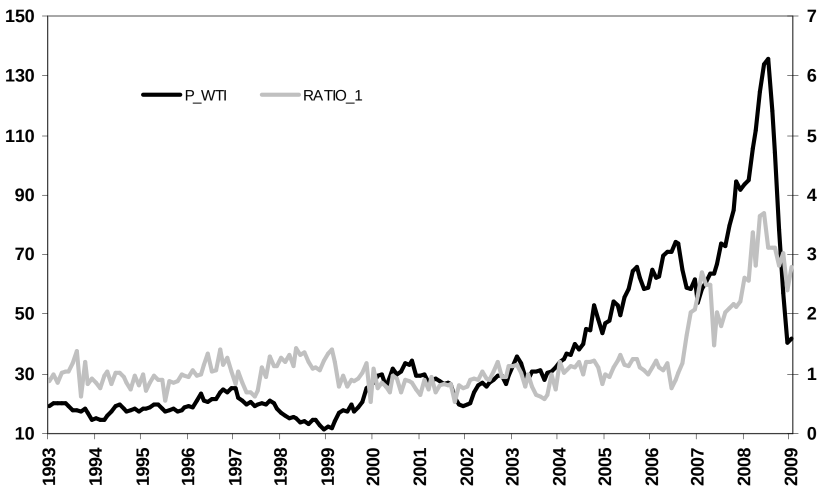


V_i stands for the volume of transaction for the future contract of month i

Unit: 1000 barrels
Source: SEC

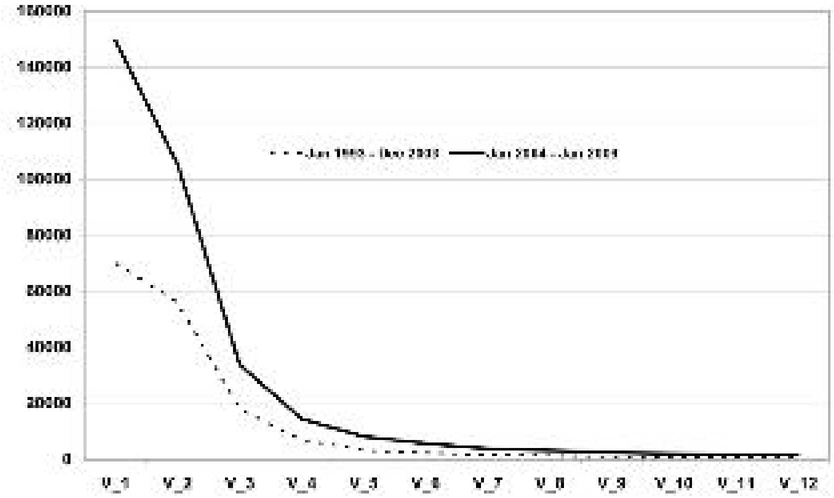
For WTI futures prices, we observed between 1993 and 2008 a decrease in transaction volumes as contract terms grew longer, and a virtual absence of liquidity for long-term contracts (Figure 2). In fact, the inadequate information available at any given moment t on contracts whose maturity period is greater than one year does not give traders the incentives to trade in the market. In consequence, the liquidity for distant contracts -a maturity greater than 4 months – decreases sharply. We have split our sample into two sub-periods, the first one from January 1993 to December 2003, and the second from January 2004 to February 2009. This segmentation does not help to highlight the introduction of the CFMA (December 2000) as a catalyst for new trader behaviour. Nevertheless, it enables us to focus both on the actual increase and on the starting point of the acceleration in transaction volumes in the markets observed from January 2004. This breakdown has also demonstrated very different decrease profiles of the transaction volumes between the two chosen sub-periods. The profile is thus distinctly more pronounced over the more recent period (Figure 4), which highlight that the share of transaction volumes dealing with short-term contracts has risen strongly since 2004.

Figure 3: Price of crude oil and financial versus physical ratio in the WTI market



Units: $/b (left scale); ratio_1 : Volume of financial contracts for the first term at time t divided by the physical demand at time t (right scale)
Source: CFTC Commitment of Traders Reports, Energy Information Administration

Figure 4: Average transaction volumes as a function of the term in the price of WTI (NYMEX)



Units: 1000 barrels
Source: SEC

In this particular context, we attempt to identify the long-term relationship between West Texas Intermediate (WTI) spot prices and the prices of short-term futures contracts on the NYMEX.

2. Methodology

The econometric analysis covers the relationship between the spot price and the future price of WTI. As transaction volumes have risen in particular for the shortest terms, we have focused on the relationship between the spot price (spott) and the price for two-month forward contracts (p2t)4.

The data cover the period from 4th April 1999 to 26th January 2009. The sample thus contains 511 weekly observations.

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4 It's also possible to study the relationship between the spot price and the one-month forward contract (the shortest maturity), but the authors considered the very close proximity of quotation values between these two “terms” could potentially affect the econometric results.

As an initial stage, we carried out unit root tests on each of the series studied. However, the period covered by the analysis was marked by contrasting price movements, which may show up as possible breaks. This led us to implement the testing procedure suggested by Perron (1997), which grew out of the work of Perron and Vogelsang (1992a,b) as well as that of Zivot and Andrews (1992). In these tests, the null hypothesis is that the temporal series is characterised by the presence of a unit root and a constant, which may be null, with the presence of a break. We distinguished between an instantaneous effect (denoted by AO for “Additive Outlier”) and an effect with a transition affecting the constant (c) or both the constant and the slope (c,s) in the Dickey-Fuller regression (respectively denoted by IO(c) and IO(c,s) for “Innovational Outlier”).

Subsequently, we tested for the existence of a long-term equilibrium (a cointegration relationship) between the future price and the spot price. As with the tests for unit root, we tested for the presence of a potential break during the period under study with a Gregory and Hansen test (1996a,b). Furthermore, we tested for changing variability of the error term (an autoregressive conditional heteroscedasticity - ARCH test) in the estimated relationship.

Estimating the short-term dynamic between the two prices is more difficult, and manifests several changes that are shown up by the structural break tests. Nevertheless, econometric estimation over several sub-periods shows similar empirical results for non-adjacent sub-periods.

Thus we tried to build a short-term model allowing for two distinct states. To do so, we estimated a Markov chain model allowing for changes in the short run dynamic. We briefly describe the Markov Switching Vector Error Correction (MSVEC) model below.

A Markov chain is a random process {Yt,t=0,1,2... } which takes its values from a finite state-space E. This sequence has the Markov property, according to which, when Yt is known, it is possible to ignore the past when predicting the future. The change from one state to another is governed by a transition function.

In our case, for every sequence of random variable (Yt), we suppose that this follows a Markov process with two states E={E1,E2}, corresponding to the two presumed states of price movements. Around the long-term equilibrium, we therefore allow two short-term dynamics with a probability of switching from one state to the other.

Consequently, the model can be expressed as:

$$\Delta Y_t = \mu(z_t) + \sum_{j=1}^{p} A_j(z_t)\, \Delta Y_{t-j} + \Pi(z_t) Y_{t-1} + u_t \qquad (1)$$

where

zt is the Markov state, which is a member of E={E1,E2},

$$Y_t = \begin{bmatrix} \ln(spot_t) \\ \ln(p_{2t}) \end{bmatrix},$$

μ(zt)is the term vector, which is constant for each state zt,

$A_j(z_t)$ is the matrix of coefficients for the delayed terms ΔY_{t-j} for delays j=1,...p,

$\Pi(z_t)$ is the matrix of coefficients for the cointegration model for each of the states z_t,

and ut designates the residuals.

Constructing the model also supplies the probability of switching from one state to the other, hence we can deduce the unconditional probability p* of being in state E2. Having constructed the model (1), we then sought to explain the probability of being in each of the states through the use of indicators linked to transaction volumes and to traders' positions.

3. Empirical results

The two series $spot_t$ and $p2_t$ are first-order integrated, I(1) as is demonstrated by the unit root tests (Augmented Dickey-Fuller, Phillips-Perron, and Kwiatkowski-Phillips-Schmidt-Shin) shown in Table 1. Table 1: Unit root tests

Variables	ln(spot)	Δln(spot)	$\ln(p2_t)$	$\Delta\ln(p2_t)$
ADF (c,t)	-1.702	-25.455***	-1.354	-24.436***
number of lags	0	0	0	0
ADF (c)	-1.790	-25.382***	-1.825	-24.361***
number of lags	3	0	0	0
ADF (none)	0.458	-25.384***	0.511	-24.353***
number of lags	1	0	0	0
PP (c,t)	-1.565	-25.388***	-1.413	-24.373***
number of lags	7	7	8	
PP (c)	-1.879	-25.295***	-1.820	-24.295***
number of lags	6	7	7	8
PP (none)	0.422	-25.292***	0.524	-24.287***
number of lags	6	7	7	8
KPSS (c)	2.526***	0.226	2.564***	0.234
number of lags	17	6	17	7

Note: The superscripts "*" "**" "***" indicate the degree of significance associated with the 10%, 5% and 1% quantiles.

However, the unit root test with structural breaks (AO and IO(c) versions) reveals such breaks for respectively May and July 2008 when prices reach their maximum values. The IO(c,s) test reveals different break dates for $spot_t$ and $p2_t$, respectively in March at the beginning of the sharp rise, and in December as prices plummeted (table 2). Nevertheless, the structural breaks should be included in the interval [15%; 85%], i.e., the sub-period [sept. 26 - 2000; July 31-2007] to be interpreted, which does not match with the dates highlighted by the tests.

Table 2: Tests for unit root with break (Perron)

Variables	$\ln(spot_t)$	$\Delta\ln(spot_t)$	$\ln(p2_t)$	$\Delta\ln(p2_t)$
IO(c)	-3.491	-7.664***	-3.241	-8.011***
Break date	Dec. 07-2004	July 08-2008	Dec. 07-2004	July 08-2008
IO(c,s)	-3.172	-7.453***	-2.679	-7.970***
Break date	June 13-2000	March 25-2008	May 15-2001	Dec. 30-2008
AO	-3.526	-7.225***	-3.466	-7.623***
Break date	Jan. 13-2009	May 13-2008	Jan. 13-2009	May 06-2008

Note: The superscripts "*" "**" "***" indicate the degree of significance associated with the 10%, 5% and 1% quantiles.

The cointegration test enables us to identify an equilibrium relationship between the spot price and the forward price (Table 3).

Table 3: Test of cointegration between $\ln(spot_t)$ and $\ln(p2_t)$

H_0 : order = r	Intrinsic value	Statistical Test λmax	Threshold value Test λmax 5%	Statistical Test Trace	Threshold value Test Trace 5%
r=0	0.0368	19.068	11.225	19.415	12.321
r≤1	0.0006	0.347	4.130	0.347	4.129

Thus the relationship may be written:

$$\ln(p2t)=1.000787 \ln(spott) \qquad (2)$$

(0.00158)

(): Standard deviation

Nevertheless, we performed a test of cointegration with a structural break on the long term relationship between the prices including a constant (Table 4). This led us to envisage a possible break, for both the constant and the variable at the same time, at the end of 2004 (Dec. 28-2004). The other break date found in Model (c) is above the highest 85% of observations. Incidentally, we evaluated the cointegration model using a regression method (Engle and Granger), and carried out an ARCH test ($F(1,503) = 7.9347$, prob(F)=0.00504). This enables acceptance of the alternative hypothesis of change in the variance of the error terms around the equilibrium relationship. Finally, we decided to keep the equilibrium between the spot price and the forward price over the whole sample, considering that the short-term dynamic should change over different sub-periods.

Table 4: Gregory and Hansen test

Model	ADF	Date	k[a]
c	-6.261***	25-11-2008	2
c,s	-6.042***	28-12-2004	2

Note: The superscripts "*" "**" "***" indicate the degree of significance associated with the 10%, 5% and 1% quantiles.
a: The number of lags is determined from the AIC criterion

The Markov Switching Vectorial Error Correction Model (1) has been estimated according to the long term equilibrium (2). From the unit root test with structural break, we decide to introduce a dummy variable (du04) to improve the parameters estimation (du04t=0 until Dec 7-2004 and du04t=1 after).

Two different states are clearly identified through the MS-VECM estimation as observed in table 5.

Table 5: MS-VECM model of the dynamic between spot prices and 2-month forward prices

		State 1				State 2			
		Coeff	Std Dev.	T-Student	Sign.	Coeff	Std Dev.	T-Student	Sign.
	Prob(E2/E1)	0.030	0.011	2.644	**				
	Prob(E1/E2)					0.224	0.078	2.654	***
Δ(ln(p_spot(t)) =	du04					-0.048	0.029	-1.630	*
	Δ(ln(p_spot(t-1))	-0.107	0.049	-2.177	**	0.241	0.224	1.074	
	Δ(ln(p_2(t-1))					-0.607	0.336	-1.803	*
	ε_{LT}(t-1)	-0.114	0.024	-4.825	***	-0.546	0.255	-2.134	**
Δ(ln(p_2(t)) =	Δ(ln(p_spot(t-1))	0.103	0.061	1.692	*	0.484	0.248	1.949	*
	Δ(ln(p_2(t-1))	-0.217	0.042	-5.117	***	-0.529	0.330	-1.600	*
Residuals	Var(u_{spot})	0.002	0.000	12.323	***	0.010	0.003	3.290	***
	Var(u_{p_2})	0.002	0.000	12.273	***	0.007	0.002	3.069	***
	Cov(u_{spot},u_{p_2})	0.002	0.000	12.440	***	0.007	0.002	3.471	***

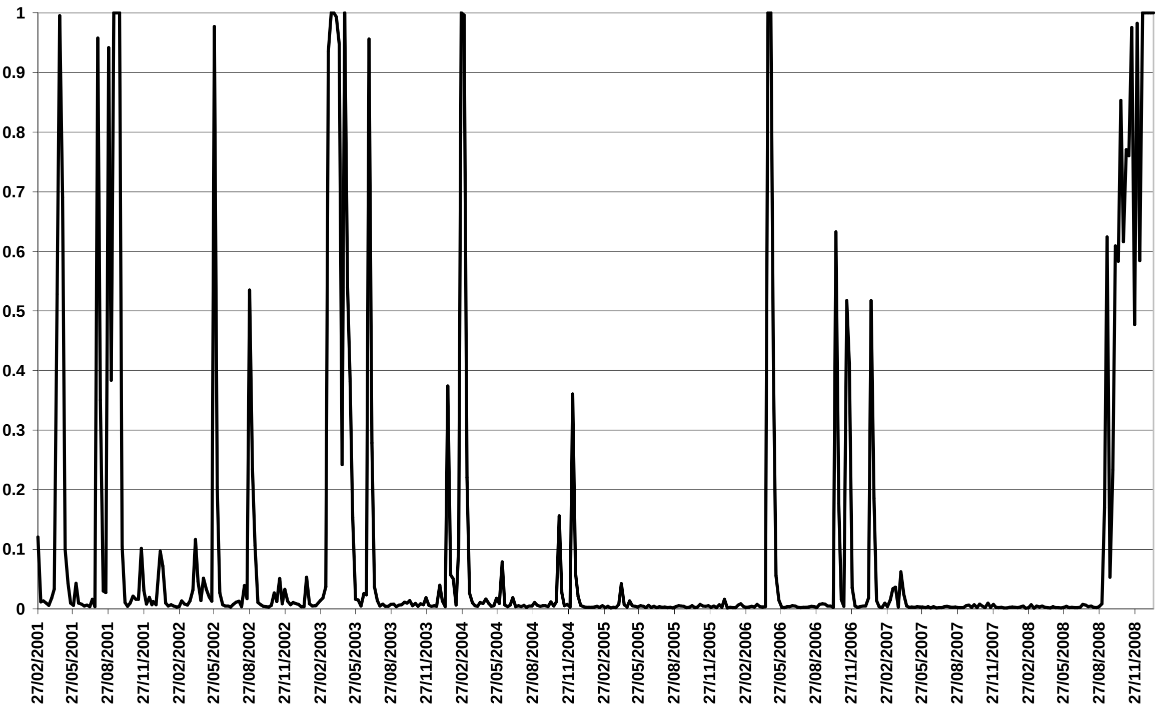
Source: calculations by the authors

The first state can be observed over the greater part of the sample, while the second state corresponds to specific events: September 11, 2001, the start of the Iraq conflict in 2003, the winter peak observed in 2006, and movements observed during spring and early summer 2008. Considering the observations for which p* is greater than 0.9, this state represents 6% of the observations from the period under study (and 9.7% for p*>0.5).

The probability to move from state 1 to state 2 is low (0.03), whilst there is more important probability (0.22) to come back from state 2 to state 1. In the second state, the lagged residual of the long term equilibrium has an important impact on the short term dynamic of prices (-0.588) and the variances of the residuals are largest for both spot and future price variations than they are in the first state. Thus , this second state can therefore be regarded as a *crisis* state.

On the contrary, the first state (*Standard* state) , which is more commonly observed over the sample, is characterized by a moderate effect of the lagged long term residuals (-0.139), which indicates that the spot price and 2-month forward price will return steadily to their long-term equilibrium. The estimated coefficients are lowest, in absolute value, in state E1 than in state E2 which denotes a smoothest evolution over this standard state.

Figure 5: Unconditional Probability of state 2 (Crisis state)



Source: calculations by the authors

Into our model we subsequently introduced data concerning the transaction volumes observed depending on the probability of being in one or other of the two short-term states. To this end, we subdivided the observations according to whether the probability p* was above or below 0.5 (Table 6). It would appear that average transaction volumes for 1-month contracts rise sharply in line with p* whereas average volumes associated with other terms remain approximately stable.

Table 6: Average transaction volumes associated with short-term states

	1 month	2 months	3 months	4 months
p*≤0,5 (state 1)	116513	87491	28173	11687
p*>0,5 (state 2)	142334	92268	30057	11953
Whole sample	119020	87955	28356	11713

Units: 1000 barrels

Table 7: Average amount of open interest associated with short-term states

	Commercial	Non commercial	Others
$p^*\leq 0,5$ (state 1)	-14040	19721	-5680
$p^*>0,5$ (state 2)	-4324	8587	-4263
Whole sample	-13097	18640	-5543

Units: 1000 barrels

Consequently, we estimated the probability of being in the state E_2 according to a set of variables related to the transactions on the future markets by using a logit model. For this purpose, the following explanatory variables were selected :

- the ratio $\frac{V\_1_t}{OI_{t-4}}$ of the transactions for the first forward contract V_1_t to the one month lagged open interest OI_{t-4} (4 weeks before).

- the volume of transactions V_1_t

The following adjustment was performed on the sub-sample from January 2007 to January 2009, a period marked by acceleration in the rise of crude oil prices:

$$\text{Prob}\{E_2\} = \underset{(0.895)}{-1.722} + \underset{(27.83)}{120.338}\frac{V\_1_t}{OI_{t-4}} - \underset{(0.23\times10^{-1})}{0.963\times10^{-4}}\, V\_1_t$$

$$\text{PseudoR}^2 = 0.555$$

n= 107

It thus appears that the variable $\frac{V\_1_t}{OI_{t-4}}$ has a significant influence on the switch to state E_2. The abrupt increase in the ratio between the short-term transaction volumes and the open interest drives the switch in the *crisis* state.

The change in the open interest relative to the observed demand for crude oil during this period explains the change in the explanatory variables and the state change. The ratio between open interest and demand, as well as the price of crude, both increase progressively – this dual phenomenon is explained by the low short-term price elasticity of demand. When demand falters, position-closing shows up as a sharp rise in the relative ratios of volumes to open interest and the switch to the *crisis* state.

Conclusion

Recent events in the crude oil markets, such as the sharp rise in prices between January and July 2008, to almost $147 per barrel and the collapse a few weeks later to under $35 per barrel, have left many analysts and researchers puzzled by the underlying explanations for determination of prices. The analysis carried out of the crude oil market through our work on spot and forward prices for West Texas Intermediate (WTI) leads us to the following conclusions. The increased volatility of WTI prices since the beginning of the 2000s, which has recently been studied (Chevallier, 2010; Fattouh, 2010), is a significant clue in understanding market prices volatility. Furthermore, this development should be linked to that observed in the major commodities markets (e.g. NYMEX), that is, a marked rise in transaction volumes dealing with futures contracts, in particular on the shortest maturities (2 to 4 months), and more especially since 2004. From the cointegration test, we could not reject the hypothesis of a long term equilibrium between spot and future prices. Nevertheless, two distinct states (so-called "standard" and "crisis" states) should be distinguished for the short term dynamic. Subsequently, we cannot reject the hypothesis that variations in the positions of non-commercial players in the financial markets for crude oil may affect the probability that the standard state will prevail. The behaviour of non-commercial players may thus play a destabilising role in petroleum markets. Additionally, our probit model shows clearly the importance of changes in the amount of open interest in the switch between states.

The increase in the volume of transactions on financial trading floors should nevertheless be kept in perspective. In fact, as we discussed in the first section, the main objective of the Commodities Exchange is to attract and to concentrate the liquidity for hedging and trading purpose. The first contract for heavy fuel oil in the NYMEX was launched in 1978 and was abandoned because of inadequate liquidity's volume. Furthermore, the transactions volume figures must be handled with care, for at least two reasons. The strategy of non-commercial players is partly based on managing price differentials over a certain period of time (calendar spread), between different commodities or by-products (intra or inter market spread), these activities create a high degree of fluidity for these contracts. It enables the commercial player to be able to achieve a physical arbitrage on time and enables also many non-commercial players to close their positions before the expiration of the contract. On Commodity Exchange we observe a feedback effect between the degree of liquidity, the probability of closing a position with a very low transaction cost (The Exchange often requires an added-margin if the position is open near the expiration date) and the volume of transactions. Keeping the market liquid needs the non-commercial players to "feed" the market.

Because the oil future market has been characterized by a growing spread between the number of transactions and the oil demand in volume term when it raises up, the uncertainties on the oil demand leads to an increasing price volatility associated to an inflating number of transactions. During such instable period, the number of future contracts sold during the previous periods appears too high related to the real economic activity that contributes to increase the price volatility.

In this context, it would seem particularly appropriate to assess whether there might exist, at least theoretically, an optimal level of liquidity in the financial markets, with a view to regulating this. This liquidity index could depend on the number of participants, the volume of transactions, the degree of concentration of seller and buyer, the historical volatility and the observed price of the underlying commodity during a determined period of time.

We could also focus on margins requirement issues. Indeed the initial margin and the maintenance margin (which represents around 75 % of the initial margin in average) are in practice based on historical or implied volatility of the contracts (based on the underlying commodity). Their level are set by the Exchange and are subject to change depending on the market conditions but not on a daily basis (or intra-day basis)[5]. The implementation of a daily basis change on Margin Requirement could send a clear message to the players in term of market limitation and also a valuable information about market risk.

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[5] For example CME Group raised Crude Oil Contracts Margin on February 24th and on March 9th 2011.

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