NATURAL GAS FUTURES CONTRACT PRICING: EVIDENCE FROM SPOT PRICES, SPECULATION AND ARBITRAGE

T. BOUACHERA

The Algerian Petroleum Institute IAP, SONATRACH, Boumerdès - Algeria

ABSTRACT

The growing liberalization of natural gas markets throughout the world has given a new role to financial trading instruments. Flexibility in natural gas contracts, investment in storage capacity and growing LNG trades have revealed significant changes between the futures price and the spot price. These changes have been attributed to the opportunities in arbitrage and speculation activities. This paper investigates the relation between futures price patterns, spot prices and natural gas storage capacities in terms of the activities of arbitrage and speculation. The proposed model was tested for the NYMEX futures contracts. The results showed that arbitrage has great effect than speculation in the determination of futures prices.

Keywords: Natural gas prices, Speculation, Arbitrage and natural gas Storage

1. INTRODUCTION

Liberalization of natural gas industry over the past decades has been seen as an effective way to settle competition that will bring its customers more choice of sustainable supply at affordable cost (Brakman et al., 2009). In this competitive setting, a pricing mechanism has started switching from indexation formulae under purchase and sales agreements to hub pricing based on market fundamentals. Along with of this gas industry liberalization, futures & forward contracts as well other financial instruments have gained substantial attention of market actors due to risk and hedging reasons. Standardized Futures contracts for natural gas delivery at some hubs or pipeline interconnections are now traded on financial places. Futures contracts trading of allows producers, distributors and consumers the opportunity to minimize the impact of large price volatilities and hedge the price risk (Brakman et al., 2009). As pointed out by (Considine, 2000), the availability of natural gas storage has made useful the well-known cost-of-carry relationship that links spot and forward prices to find optimal hedge ratios.

A *forward contract* is an agreement between two parties, a seller (short position), who will provide at a specified future date a commodity to a buyer (long position), who will pay the *forward price (*Hull, 2013). This contract is often traded directly among producers and industrial consumers. Besides, a forward contract specifies the quantities to deliver, the point of delivery at the price (the forward price) to be paid at the time of delivery.

A *futures contract* is also an agreement which is similar to a forward contract to deliver a specified quantity of a commodity at a specified future date, at a price (the futures price) to be paid at the time of delivery. A futures contract differs from a forward contract meanly on the three following features: (a) a futures contract is standardized contract terms determined by a particular exchange, (b) a futures contract is traded over the counter OTC on organized exchanges, such as NYMEX, (c) a futures price settles at the end of each trading day and (d) one of the parties can *close out* or *roll over* his position in order to reduce risks and loses, and therefore, most futures contracts never end in delivery of the underlying commodity. As a result, futures contracts tend to be more liquid than forward contracts (Hull, 2013). For the majority of commodities, however, the difference between the forward and futures prices is insignificant. For instance, one-month contracts on heating oil this difference is less than 0.01% (Pindyck, 2001). This causes that the two prices, forward price and futures price, are treated as equivalent. In the literature, the terms “futures” and “forward,” and “futures price” and “forward price” are often used interchangeably. This is convenient for any empirical studies since futures price data are more available than forward prices.

Meanwhile a futures price is a settled today for future delivery, a *spot price* represents the amount payable to dispose of the commodity immediately. The difference between these two prices, the base, can be positive or negative. In the first case, prices are in contengo and in the second case they are in backwardation. Futures contracts are effectively used in risk management through a comprehensive understanding of factors that define futures dynamics. In particular, several research have tried to capture the changes from backwardation into contango and vice versa in futures markets.

Moreover, several authors asserted that speculation, arbitrage and commodity storability is the utmost fact concerns the development for pricing of the futures contracts. Speculation in commodity markets has a significant economic role by allowing a transfer of price risk from those least willing to bear it (commodity producers and consumers,) to those with the capacity to do so (generically, called speculators). Therefore, it is useful to consider three classes of futures market participants. The first category is producers of commodities whose profits depend positively on prices and are always insuring against price declines. The second category is consumers whose profits depend negatively on prices and want to insure against price increases. The third category is made up of market participants who are not interested in possessing physical commodities, however, they anticipate future price movements, in the hope of making large gains by taking large risks. Main distinction between the two fist classes of market participants and speculators is that speculators are relatively risk-tolerant participants who are rewarded for accepting price risks from risk-averse of other participants (Parsons, 2008). Besides, speculators are considered as participants who do not influence the physical demand for a commodity at all, but they affect price dynamics as they help in the discovery of future prices (Kaufmann, 2009).

On the other hand, arbitrage in futures contracts depends on the capacity to store commodities in inventory and understanding spot prices dynamics. Arbitrageurs have to make a choice between two options: (a) Accept that the current spot price is more profitable to compensate for forgoing the opportunity to hold the commodity in inventory to sell later, (b) accept that stocking commodity and selling it later outweighs the benefits of current spot price. Accordingly, the relationship between futures and spot prices can be derived from the rule out profitable arbitrage opportunities between selling in the spot market and holding commodity in inventory to deliver later at the contracted futures price (Bohl, 2013 and Acharya, 20132).

As result, the determination of futures prices can be described in terms of speculation and arbitrage whose effects are transmitted through distortions in supply and demand for futures contracts. Working (1942) asserted that the futures price is determined purely by arbitrage by the cost of carry theory. This postulate has not been accepted by Weymar (1968) who claimed that Working postulate was valid only if the period between futures prices was not long enough. (otherwise, expectations will come into play). Samuelson (1965) and Stein (1979) introduced the concept of high volatility of futures contracts near to maturity when uncertainty is high. Subsequently, there has been a continuous research efforts to put forward any relevant influence factors on the futures price formation by having a closer look at the relationship between futures, inventory and spot and prices (Pindyck, 2001).

The *storage theory* demonstrates why this may have a significant effect on price formation (Working, 1948). According to the theory, firms hold inventories in order to respond to unexpected high demand by bearing storage and opportunity costs and making profits when commodities are most desired. This advantage commonly called *convenience yield*. In markets (such as natural gas, power or oil market), participants dislike the postponed delivery when market conditions are tight; and prefer to have immediate possession of contracted commodities. As a result, the advantage of commodity availability, the convenience yield, becomes more important than storage and opportunity costs. In such situation, spot prices tend to be greater to futures prices and the market is said in *backwardation*. When the demand is low, however, abundant inventories are unsuitable for market conditions, and the convenience of building stocks is trivial compared to of storage and opportunity costs. Consequently, spot prices quote below futures prices and the market is said in *contango*). The bulk of empirical research on commodity futures pricing have focused on two complementarity approaches. The first one is based on the theory of storage, a cost-of-carry approach, which is centered on the analysis of stock detention through the cost of storage and the notion of a *convenience yield.* This approach determines futures prices from the *current* spot price by estimating the costs and benefits of *storing* the commodity. The second approach intended to determine futures prices by the *expected* spot price at maturity of the contract based on stochastic modelling. Both valuation approaches, formulated essentially between 1930 and 1958, are still the subject of much research.

The objective of this paper is to investigate futures prices determination based on the previous approaches by highlighting the effect of speculation and arbitrage on Natural Gas Futures. This would be of interest to the market actors, commodity exchanges and policy makers and regulators etc . A Moosa model combined with Schartwz-Smith model is developed to provide a connection between the expected futures prices and spot prices and to highlight the fact that spot price, costs and benefit of storage, characteristics of the spot price process, the level of inventories, all play a role in Natural Gas futures pricing. Further this study provides useful insight for the market activity with respect to price volatility.

2. SCHWARTZ & SMITH MODEL

The mean features of natural gas spot and futures prices are the stochastic behavior which plays a central role in models for evaluating commodity-related projects and financial instruments (Schawrtz et al., 2000). These models are often developed based on the mean reversion process with the incorporation of a random walks. Besides, it can be noticed from the natural gas time series (figure 1) that prices have long-term changes due disruption in production technology (Shale & Tight Gas production has a significant effect on the level of prices), and short-term shocks caused by weather and other temporary disturbances. The two-factor model of Schwartz & Smith (2000) therefore is a well-known model to capture price dynamics taking into account the above characteristics.

The Smith-Schwartz two factor model posits a spot price under the risk-neutral process:

$\ln(S_t) = X_t^* + \xi_t^*$ (1)

Where X_t^* represents the short-term deviation in log prices and ξ_t^* represents the long-term equilibrium level for log prices. Both X_t^* and ξ_t^* are unobservable state variables that can be estimated by a Kalman filtering technique process as described in Section 5 below. The short-run deviations X_t^* are assumed to revert following an Omstein-Uhlenbeck process and the equilibrium level ξ_t^* is assumed to follow a Brownian motion process.

$dX_t^* = (-\kappa X_t^* - \lambda_x)\mathrm{dt} + \sigma_x \; dz_x^*$

$d\xi_t^* = \mu_\xi^*\mathrm{dt} + \sigma_\xi \; dz_\xi^*$

$\kappa, \lambda_x, \sigma_x, \mu_\xi, \lambda_\xi, \sigma_\xi$: are model parameters to be estimated and dz_x^*, dz_ξ^* are random walks following normal distribution. The solution to partial differential equations above with the appropriate boundary conditions gives the forward price for any investor. Kalman filtering technique is used to determine the parameters for Smith-Schwartz two factor model, and to produce filtered estimates of the state variables the spot price and forward prices (Harvey, 1989 and West et al., 1996).

The futures prices $F_{t,T}$ which denote the current market price for a futures contract with time maturity T are equal to the expected future spot price. Under risk-neutral valuation theory and assuming that interest rates are deterministic (Cox et al., 1981 or Duffie, 1992).

$\ln(F_{t,T}) = ln[E(S_t)]$ (2)

According to Schwartz et al. (2000), The futures prices

$$\ln(F_{t,T}) = E(X_t^*) + \frac{1}{2} Var(X_t^*)$$
$$\ln(F_{t,T}) = e^{-\kappa \mathrm{T}}(X_t^*) + \xi_t^* + A(T)$$

Where

$A(T) = \mu_\xi^* T - (1 - e^{-\kappa \mathrm{T}})\frac{\lambda_x}{\kappa} + \frac{1}{2}\left[(1 - e^{-2\kappa \mathrm{T}})\frac{\sigma_x^2}{2\kappa} + \sigma_\xi^2 T + 2(1 - e^{-\kappa \mathrm{T}})\frac{\rho_{x\xi}\sigma_x \sigma_\xi}{2\kappa}\right]$

In this model, the volatility of the futures price $\sigma(F_{t,T})$ is given as:

$\sigma^2(F_{t,T}) = e^{-2\kappa \mathrm{T}}\sigma_x^2 + \sigma_\xi^2 + 2\, e^{-\kappa \mathrm{T}}\rho_{x\xi}\sigma_x \sigma_\xi$ (3)

Thus, when T= 0 the futures price volatility is equal to the sum of the short- and long-term volatilities $\sigma_x^2 et\ \sigma_\xi^2$. As the maturity of the contract increases, the futures price volatility will tend to the volatility of the equilibrium price level σ_ξ^2 and the short-term deviations make less contribution to the volatility of the futures prices.

Kalman filtering technique

The Kalman filter works with discrete time steps and defines two equations describing the evolution of the state variables and the relationship between the observed variables. The state variables are the short-term deviation and equilibrium level $X_t = [X_t^*, \xi_t^*]$ and the observations are the log of the prices of futures contracts with different maturities.

The evolution of the state variables is described by the *transition equation* which can be written as:

$X_t = c + Q\, X_{t-1} + \eta_t$ (4)

where:

$$c = [0\,,\ \mu_\xi^* \Delta t]$$
$$Q = \begin{bmatrix} e^{-\kappa \Delta t} & 0 \\ 0 & 1 \end{bmatrix}$$

η_t is a 2 x I vector of serially uncorrelated, normally distributed disturbances with $E[\eta_t] = 0$ and

$$Var(\eta_t) = W = \begin{bmatrix} (1 - e^{-2\kappa \Delta t})\dfrac{\sigma_x^2}{2\kappa} & e^{-\kappa \Delta t}\rho_{x\xi}\sigma_x \sigma_\xi \\ e^{-\kappa \Delta t}\rho_{x\xi}\sigma_x \sigma_\xi & \sigma_\xi^2 \Delta t \end{bmatrix}$$

The *measurement equation* describes the relationship between the state variables and the observed prices (futures prices).

$y_t = d_t + Z_t X_t + \varepsilon_t$, t=1,…,n_T (5)

where:

$y_t = [\ln(F_{T1}), \dots, \ln(F_{Tn})]$

$d_t = [A(T1), \dots, A(Tn)]$

$Z_t = [e^{-\kappa T_1} \quad 1, \dots, e^{-\kappa T_n} \quad 1]$

ε_t *is a n* x 1 vector of serially uncorrelated, normally distributed disturbances with $E[\varepsilon_t] = 0$ *and* $cov[\varepsilon_t] = H$

n_T the number of time periods in the data set.

Since the Kalman filter is an iterative procedure, it should starts with some initial values regarding all parameters to estimate θ={κ,$\sigma\chi$,$\lambda\chi$,$\mu\xi$,$\sigma\xi$,$\mu\xi*$,$\rho\xi\chi$,σH}, the transition equation $X_0 = [X_0^*, \xi_0^*]$ and its covariance matrix. Then, the mean and covariance matrix of $X_t = [X_t^*, \xi_t^*]$ is calculated using the following conditional equation based on known estimates at period t-1 (starting at (t-1) = 0):

$E[(X_t, \xi_t)|(X_{t-1}, \xi_{t-1})] = a_t = c + Q\, m_{t-1}$ (6)

$Cov[(X_t, \xi_t)|(X_{t-1}, \xi_{t-1})] = R_t = G_t\, C_{t-1}\, G_t{}' + W$ (7)

The forecast error of the observed futures prices at time t is computed by:

$u_t = y_t - E(y_t|y_{t-1}) = y_t - (d_t + Z_t{}'\, a_t)$

The best estimate for the parameter set θ is found by maximizing this log-likelihood function with respect to the model's parameter set.

$\ln L(y_t, \theta) = -\frac{T*n}{2}\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}\ln|H + Zt'\ Rt\ Zt| - \frac{1}{2}\sum_{t=1}^{T} u_t |H + Zt'\ Rt\ Zt|^{-1}\ u_t'$ (8)

A Matlab algorithm is developed to perform Kalman filtering through following the same steps described above. The algorithm iterates continuously between each observation of the futures curve, through the prediction and estimation step, assigning value to the log-likelihood function. The new parameter set θ is obtained by maximizing the log-likelihood function using matalb subroutine fmincon.

MOOSA MODEL

Moosa (2000) tried to evaluate arbitrage and speculation effects on the determination of futures prices. His work presented a model that is based on the idea that the futures price are explained in terms of arbitrage (as depicted by positive cost of carry equation) and spot speculation which is represented by the expected spot price. He defined the demand function of futures contracts by arbitrageurs by the following equation:

$X_t^a = a_1(\widetilde{F_t^{t+1}} - F_t^{t+1}), \quad a_1 > 0$ (9)

Where:

X_t^a is the excess demand of arbitrageurs, F_t^{t+1} is the futures price determined at time t for delivery at time t+1 and $\widetilde{F_t^{t+1}}$ is the predictable futures price by arbitrageurs considering only positive cost of carry equation, given by : $\widetilde{F_t^{t+1}} = S_t + C_t$ with S_t actuel spot price and C_t is the cost of carry incurred by holding the physical commodity in the period between t and t + 1.

If $\widetilde{F_t^{t+1}} = S_t + C_t > F_t^{t+1}$ arbitrageurs will gain by selling the commodity at t (spot price), and buying it for delivery at t + 1. On the other hand, an excess demand of futures contracts made by speculators can be written as:

$X_t^s = b_1(E_t S_{t+1} - F_t^{t+1}), \quad b_1 > 0$ (10)

Where $E_t S_{t+1}$ is the expected spot price to prevail at t + 1 based on the information available at time t. if $E_t S_{t+1} > F_t^{t+1}$ Speculators will be interested in buying the commodity futures at t and selling it spot at t + 1, making a profit of $E_t S_{t+1} - F_t^{t+1}$. Under the assumption that there is only arbitrageurs & speculators actors in the markets (hedgers will be assigned as implicit speculators with similar objectives), the equilibrium in demand of futures contracts is established when

$X_t^a + X_t^s = 0 \quad or \quad a_1(\widetilde{F_t^{t+1}} - F_t^{t+1}) + b_1(E_t S_{t+1} - F_t^{t+1}) = 0$ (11)

The corresponding futures price will be a weighted average of the futures price derived from the arbitrage equation and the expected spot price, $F_t^{t+1} = \frac{a_1}{a_1+b_1}\widetilde{F_t^{t+1}} + \frac{b_1}{a_1+b_1}E_t S_{t+1}$

Following the same development as above, the futures price based on two-period futures contracts will be:

$$F_t^{t+2} = \frac{a_2}{a_2+b_2+c_{21}}\widetilde{F_t^{t+2}} + \frac{b_2}{a_2+b_2+c_{21}}E_t S_{t+2} + \frac{c_{21}}{a_2+b_2+c_{21}}E_t F_{t+1}^{t+2} \quad (12)$$

Coefficients $a_2,\ b_2 and\ c_{12}$ are defined by the following equations:

1- Arbitrage equation : $X_t^a = a_2\left(\widetilde{F_t^{t+2}} - F_t^{t+2}\right), \quad a_2 > 0$

2- Speculation equation : $X_t^s = b_2(E_t S_{t+2} - F_t^{t+2}), \quad b_2 > 0$

3- One-period to Two-period speculation equation: $X_t^f = c_{21}(E_t F_{t+1}^{t+2} - F_t^{t+2}), \quad c_{12} > 0.$

This equation signifies that it is also possible to speculate on the one-period futures price expected to prevail at t + 1 for delivery at t + 2, i.e. the same delivery date as that of the two-period contract initiated at time t. in this case, the equilibrium is found when: $X_t^a + X_t^s + X_t^f = 0$.

The generalisation of futures prices equation may, therefore, be written as

$$F_t^{t+n} = \frac{a_n}{a_n+b_n+\sum_{i=1}^{n-1} c_{ni}}\widetilde{F_t^{t+n}} + \frac{b_n}{a_n+b_n+\sum_{i=1}^{n-1} c_{ni}}E_t S_{t+n} + \sum_{i=2}^{n-1}\frac{c_{ni}}{a_n+b_n+\sum_{i=1}^{n-1} c_{ni}}E_t F_{t+n-i}^{t+n} \quad (13)$$

This equation (13) can be put in the following regression form:

$$F_t^{t+n} = \alpha + \beta\,\widetilde{F_t^{t+n}} + \gamma E_t S_{t+n} + \sum_{i=2}^{n-1}\delta_i\, E_t F_{t+n-i}^{t+n} + \varepsilon_t \quad (14)$$

Where:

$\alpha = 0.$

The coefficients $\beta,\ \gamma$ and δ_i measure the roles played by arbitrage, speculation on the futures price respectively. Since $\beta + \gamma + \sum_{i=1}^{n-1}\delta_i = 1,$ the bigger a coefficient is the larger the role played by the activity represented by the coefficient is. A value close of any coefficient means the dominance role of its activity.

Moosa in his work assumed that $E_t F_{t+n-i}^{t+n} = F_{t+n-i}^{t+n}$and $E_t S_{t+n} = S_{t+n}$to estimate the effect of speculation and arbitrage in the dertimantion of futures prices. In this paper, however, both $E_t F_{t+n-i}^{t+n}$and $E_t S_{t+n}$are evaluated according to Schwartz and Smith model where $\ln(E_t S_{t+n})$ and $\sigma^2(F_{t,T})$ are given by:

$$\ln(E_t S_{t+n}) = e^{-\kappa T}(X_t^*) + \xi_t^* + A(T) \quad (15)$$

$$A(T) = \mu_\xi^* T - (1 - e^{-\kappa T})\frac{\lambda_x}{\kappa} + \frac{1}{2}\left[(1 - e^{-2\kappa T})\frac{\sigma_x^2}{2\kappa} + \sigma_\xi^2 T + 2(1 - e^{-\kappa T})\frac{\rho_{x\xi}\sigma_x\,\sigma_\xi}{2\kappa}\right] \quad (16)$$

$$\sigma^2(F_{t,T}) = e^{-2\kappa T}\sigma_x^2 + \sigma_\xi^2 + 2\,e^{-\kappa T}\rho_{x\xi}\sigma_x\,\sigma_\xi \quad (17)$$

The expectation variables $E_t F_{t+n-i}^{t+n} = F_{t+n-i}^{t+n}$and $E_t S_{t+n} = S_{t+n}$are proxied by:

$E_t S_{t+n} = \exp(e^{-\kappa T}(X_t^*) + \xi_t^* + A(T))$ and $E_t F_{t+n-i}^{t+n} = E_t S_{t+n} + \frac{1}{2}\,\boldsymbol{var}(F_{t+n-i}^{t+n}) = \exp(e^{-\kappa T}(X_t^*) + \xi_t^* + A(T)) + \frac{1}{2}(e^{-2\kappa T}\sigma_x^2 + \sigma_\xi^2 + 2\,e^{-\kappa T}\rho_{x\xi}\sigma_x\,\sigma_\xi) \quad (18)$

On the other hand, entails that the futures price, $F_{t,T}$, is determined at date t for a delivery date T by adding to the current spot, S_t, the inventory and opportunity cost of holding in the stock a commodity from the present to the delivery period. Thus, the futures price, $F_{t,T}$, can be expressed as follow (Fama, et al., 1987 and Milonas, et al., 2001):

$$F_{t,T} = S_t + S_t * r_t + C_t - \psi_t \quad (19)$$

Where: $P_t * r_t$: the interest foregone due to the investment in stocking the commodity;
C_t : Per-unit cost of physical storage from the present to delivery date;
ψ_t: the convenience yield.

The equation (1) must hold in equilibrium to delimit the areas of no-arbitrage. The equation (19) can be put in the following form:

$$\frac{F_{t,T} - S_t}{S_t} = r_t + \frac{C_t - \psi_t}{P_t} \quad (20)$$

In this equation, the convenience yield can be regarded as an option to sell stocks in the market when prices are high, or to preserve it in storage when prices are low.

In order to calculate the predictable futures price by arbitrageurs $\widetilde{F_t^{t+1}} = S_t + C_t$ daily data on the Treasury-bill (T-bill) yields of the corresponding maturities is collected from US Federal Bank. Subsequently, we define futures price by arbitrageurs : $\frac{\widetilde{F_t^{t+1}} - S_t}{S_t} = r_t + \frac{C_t - \psi_t}{P_t}$ Where $\frac{C_t - \psi_t}{P_t}$ is assumed in our work to vary according to inventory level Invt . To this end, we estimate for each maturity T the following regression:

$$B_{t,T} = \alpha_0 + \alpha_1 r_{t,T} + \alpha_2 Inv_t + \mu_{t,T} \quad (21)$$

Where: $B_{t,T} = \frac{\widetilde{F_t^{t+1}} - S_t}{S_t}$ is the relative basis, α_0, α_1 $and \alpha_2$ regression coefficients, r_t interest rate proxied by the Treasury-bill (T-bill) yields, and Inv_t inventory level and $\mu_{t,T}$ is the error term, which is assumed to be normally distributed.

3. DATA, RESULTS & DISCUSSION

The model developed in our work is tested for the Natural Gas futures contracts traded on the New York Mercantile Exchange NYMEX, using the data reported by US energy information agency which cover the period July 2004 to July 2014. Four different maturities are used: one, two, three and four. The dataset included daily observations for all four natural gas futures contracts, namely NGCR1, NGCR2, NGCR3 and NGCR4. The same dataset included weekly data on storage levels in USA. Interest rates are proxied from US Federal Bank by US Treasury Bill (T-Bills) Yields. For each basis observation, the corresponding weekly average with the same maturity is calculated.

Table 1 provides summary statistics of each used variable. Table shows that prices on natural gas appear to be most volatile as indicated by the large maximum and minimum values (in absolute terms) and the highest standard deviation. Finally, all distributions are skewed to the right and show excess kurtosis (i.e., leptokurtosis).

Table1: Descriptive statistics of used variables

	INVENTORY (Billion Cubic Feet)	**SPOT**	**FUTURES1**	**FUTURES2**	**FUTURES3**	**FUTURES4**	**T-BILLS**	**T-BILLS2**	**T-BILLS3**	**T-BILLS4**
Mean	2636.134	5.467180	5.620518	5.793138	5.955184	6.064956	1.455000	1.455000	1.455000	1.455000
Median	2699.500	4.670000	4.715000	4.794500	4.855000	5.030000	0.140000	0.140000	0.140000	0.140000
Maximum	3929.000	15.02000	14.31200	14.43100	14.77100	14.51100	5.250000	5.250000	5.250000	5.250000
Minimum	822.0000	1.820000	1.927000	2.015000	2.134000	2.211000	0.000000	0.000000	0.000000	0.000000
Std. Dev.	743.0514	2.425099	2.440738	2.496277	2.545012	2.526321	1.859443	1.859443	1.859443	1.859443
Skewness	-0.233498	1.269110	1.179196	1.130018	1.051016	0.911727	0.882110	0.882110	0.882110	0.882110
Kurtosis	2.129322	4.774074	4.260731	4.093072	3.805475	3.310451	2.153063	2.153063	2.153063	2.153063
Jarque-Bera	20.33680	199.7896	148.9887	131.3034	105.5694	71.27844	79.78700	79.78700	79.78700	79.78700
Probability	0.000038	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Observations	500	500	500	500	500	500	500	500	500	500

Figure 1 displays as exemplars two commodities' (spot and two-month futures) price series. The figure illustrates a considerable variability of the natural gas prices. It can clearly be identified the period of the plentiful supply due to Tight & Shale Gas reservoirs where the prices fluctuate between 2 and 5 $/MMBTU less than those quoted before 2010. The price of natural gas in the U.S. had never be below 4 $/MMMBTU until the beginning 2009 mid-2004.

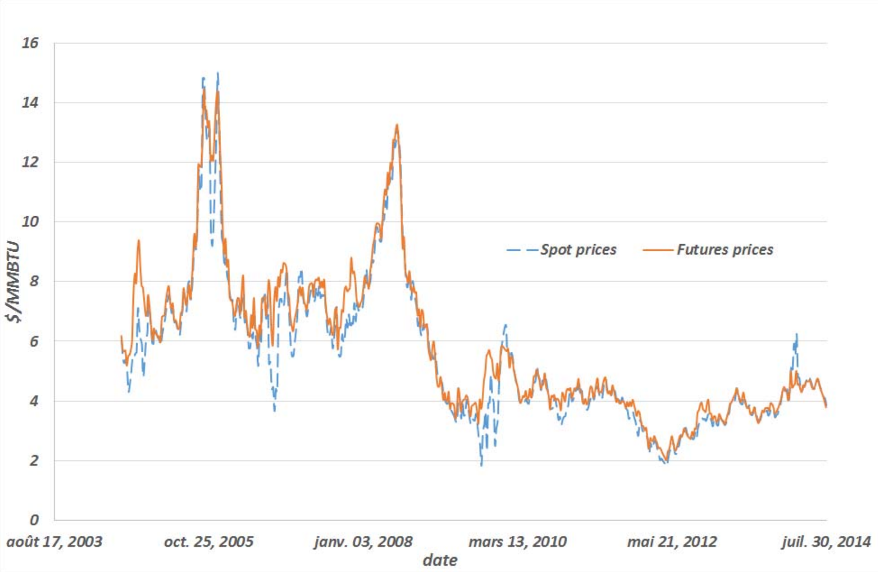

Figure1: Weekly Spot and Futures prices of Natural Gas at NYMEX exchange.

In a first step, the short and long term relationship between spot and futures prices over time is estimated based on the Schwart-Smith model. The recursive procedure suggested by Kalman (1960) is applied to estimate the model coefficients in Equation (16). After running, he Kalman filter optimizing procedure, using initial estimates of the parameter set θ, $[\chi 0, \xi 0]$ and $C0$ based on table 1 values, we got the following results:

Table 2: Schwartz-Smith model output:

κ	$\sigma\chi$	$\lambda\chi$	$\mu\xi$	$\sigma\xi$	$\mu\xi *$	$\rho\xi\chi$	σH			
2,738611	0,688220	-0,517473	0,007266	0,529031	0,013330	-0,555798	0,023283	0,016072	0,00	0,038012
0,051300	0,020700	0,175700	0,137500	0,019100	0,050280	0,046600	0,000120	0,000300	0,00	0,000110

Here we notice from Figure 2 that the model fits the observed futures prices quite well, the standard errors for the measurement equation are less than3%. Overall, all estimated parameters are statistically significant except $\mu\xi *$. The short-term and long-term volatilities, $\sigma\chi$ *and* $\sigma\xi$, are estimated with confidence, and Samuelson hypothesis seems valid for this data set where short term volatility $\sigma\chi$ is greater than long term volatility $\sigma\xi$. Figure shows the estimated values of the equilibrium spot price (given as $\exp(X_t^*)$ and spot price ($\exp(X_t^* + \xi_t^*)$). The natural gas spot and excepted futures prices quoted at NYMEX exchange can be written as:

$dX_t^* = (-2.738611\, X_t^* + .517473)\mathrm{dt} + 0.68822\ dz_x^*$

$d\xi_t^* = .01333\mathrm{dt} + 0.529031\ dz_\xi^*$

$S_t = \exp(X_t^* + \xi_t^*)$

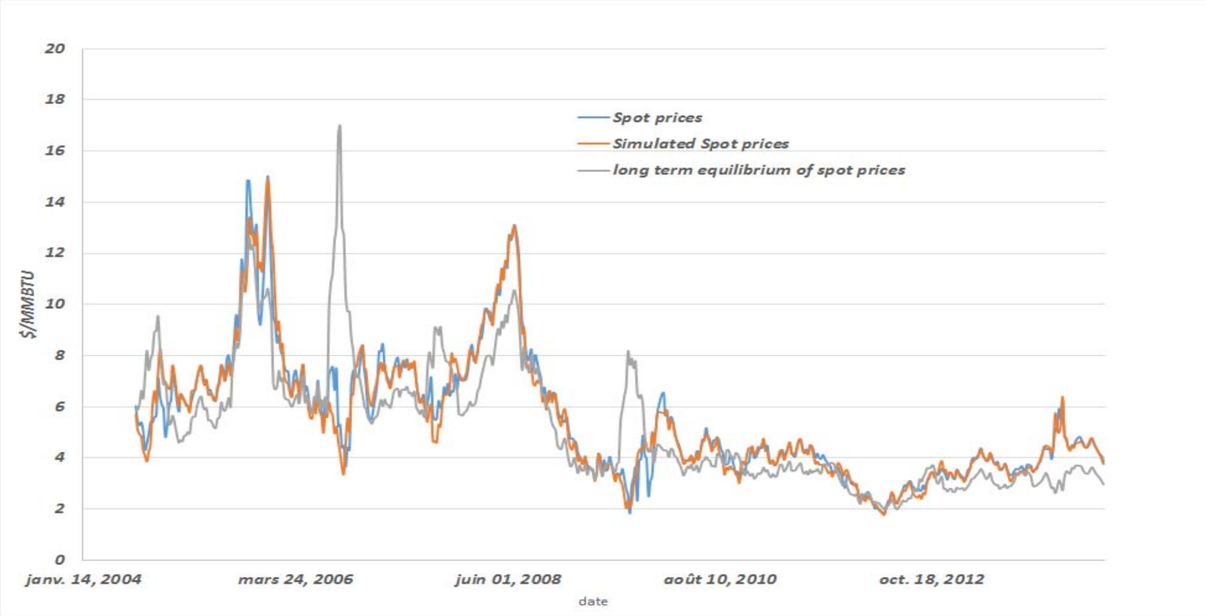

Figure 2: Real and simulated spot prices with long term equilibrium prices (output of running Schwartz-Smith model)

The pattern in the relationship between the futures and storage, described above by equation 14, is consistent with the idea that storage levels affect the cost of storage and convenience yield of the commodity. Specifically, in the context of US natural gas markets, this evidence is represented by the following regression:

$$\frac{\widetilde{F_t^{t+1}} - S_t}{S_t} = -0.089264 + 0.004888 * r_t + 0.000044 * Inv$$

Table 4 : Futures Price regression

	Coefficients	*Erreur-type*	*Statistique t*	*Probabilité*
Constante	(0,089264)	0,015753	(5,666349)	0,000000
Inventory level	0,000044	0,000006	8,055336	0,000000
T-bill rate	0,004888	0,002202	2,219811	0,026883
R2	0,344256			

Table 4 reports the results of a regression of the basis on futures. The significance of this relationship, somehow low R^2=34%, is the result of missing other variables such as : weather conditions, interest rate proxied only by T-bills rate, and the information about the cost of storage, among others. Even though these limitations, this regression could be the best way to estimate arbitrage futures prices.

Let us recall that, in Moosa model, the futures prices are linear with expected spot prices and aribitrage futures prices and expected futures prices.

$$F_t^{t+n} = \alpha + \beta\ \widetilde{F_t^{t+n}} + \gamma E_t S_{t+n} + \sum_{i=2}^{n-1} \delta_i\ E_t F_{t+n-i}^{t+n} + \varepsilon_t$$

Right hand variable of this equation are calculated previously by carry-cost model and Schwartz-Smith model. Taking into account the optimal parametric values of table 1and the regression of arbitrage futures prices, we obtain the coefficient values of relation (14), defining the effect of speculation and arbitrage on the determination of futures price levels. The results also show a credible goodness of fit. The interpretation of these results is as follows: Since the coefficient β is much greater than γ and δi means that arbitrage plays a significant role in the determination of futures prices, this role represent more than 77% for all maturities.

Variable	Ft+1	Ft+2	Ft+3	Ft+4
α	0,05390	0,02761	0,01298	0,19372
	(0,03804)	(0,10018)	(0,17420)	(0,22224)

β	0,88412	0,83951	0,79991	0,77512
	(0,01542)	(0,05076)	(0,07852)	(0,08918)
γ	0,11460	0,07242	0,03499	0,09281
	(0,01751)	(0,03850)	(0,06256)	(0,07667)
$\delta 2$		0,09938	- 0,06854	- 0,10816
		(0,05707	(0,09317)	(0,13218)
$\delta 3$			0,23270	0,13460
			(0,11585)	(0,17224)
$\delta 4$				0,02410
				- 0,13406
$R2$	0,84751	0,95862	0,85517	0,76810

Concluding Remarks

To better understand the dynamics of commodity futures prices, we investigate the issue of commodity futures pricing in term of spot, inventory, arbitrage and speculation effect. After endogenizing these economic factors, the model with both Schwartz-Smith model and Moosa model adequately approximates the dominance of arbitrage and speculation in the futures contract pricing. The Schwartz-Smith model is shown to be capable of providing a satisfactory identification of the stochastic variables defining shot term fluctuations and long term equilibrium explain the dynamics of natural spot prices. Recent natural gas price shale and Tight Gas production appear to have triggered price changes in 2 to 5$/MMBTU range. Besides, we found clear indications of arbitrage dominance in the determination of futures prices.

References

Acharya,V. Lochstoer L. and Ramadorai T., 2013, “Limits to Arbitrage and Hedging: Evidence from Commodity Markets”, Journal of Financial Economics Volume 109, Issue 2, August 2013, Pages 441–465

Bohl M. and Stephan P., 2013, “Does Futures Speculation Destabilize Spot Prices? New Evidence for Commodity Markets” Journal of Agricultural and Applied Economics, 45,4(November 2013):595–616

Brakman s.; Van Marrewijk c. and Van Witteloostuijn A., 2009,” Market Liberalization in the European Natural Gas Market, The Importance of Capacity Constraints and Efficiency Differences” CESIFO WORKING PAPER NO. 2697

Considine, T. J., & Heo, E. (2000). Price and inventory dynamics in petroleum product markets. Energy Economics, 22, 527–547.

Fama, F. and Kenneth R. French, 1987, “Commodity Futures Prices: Some Evidence on Forecast Power, Premiums, and the Theory of Storage,” The Journal of Business, 60(1) 55-73.

Kaufmann, R., and B. Ullman. 2009. “Oil Prices, Speculation, and Fundamentals: Interpreting Causal Relations among Spot and Futures Prices.” Energy Economics, forthcoming.

Hull, J., 2013,” Fundamentals of Futures and Options Markets”, Pearson.

Milonas, N. T., & Henker, T. (2001). Price spread and convenience yield behavior in the international oil markets. Applied Financial Economics, 11, 23–26.

Moosa I., 2000, “Arbitrage, Hedging, Speculation and The Pricing Of Crude Oil Futures Contracts”, KEIO ECONOMIC STUDIES 37(1), 53-61 (2000)

Parsons, J., 2008, “Black Gold & Fool’s Gold:Speculation in the Oil Futures Market” the MIT Central Bank Research Network Fall Conference in December 2008

Pindyck R., 2001,”The Dynamics of Commodity Spot and Futures Markets: A Primer,” The Energy Journal, Vol. 22, No. 3.

Samuelson, P. A. (1965) Proof that Properly Anticipated Prices Fluctuate Randomly, Industrial Management Review, 6, 41-49.

Schwartz, E. S., & Smith, J. E. (2000). Short-term variations and long-term dynamics in commodity prices. Management Science, 46, 893–911.

Stein, J. L. (1979) Spot, Forward and Futures, Research in Finance, 1, 225-310.

Weymar, H. F. (1968) The Dynamics of the World Cocoa Market, in A.E. Peck (ed) Selected Writing on Futures Markets, Chicago Board of Trade, Chicago.

Working, H. (1942) Quotations on Commodity Futures as Price Forecasts, Econometrica, 10, 39-52.