Oxford Energy Comment

March 2011

Uncertainty, Expectations, and Fundamentals: Whatever Happened to Long-Term Oil Prices?

By Bassam Fattouh, Oxford Institute for Energy Studies & Pasquale Scaramozzino, DeFIMS, University of London and Dipartimento di Economia e Istituzioni, Universita' di Roma Tor Vergata

Introduction

While the policy debate of the 2002-2009 oil price cycle has focused on the behaviour of the spot price or prices of near-term contracts, the price at the back end of the futures curve (referred to in this comment as the long-term oil price) has also witnessed some sharp movements. One of the major features of the oil market during the 1990s was the relative stability of the long-term oil price. While the spot price and the price of near-term futures contracts sometimes exhibited sharp price volatility induced by geopolitical events such as the first Gulf War in 1990-1991, the Asian financial crisis in 1998, the September 11 attacks on the US in 2001, and the US invasion of Iraq in 2003, that volatility was only partially transmitted to the back end of the futures curve which was anchored around the $20-$22/barrel range. That price served almost as a cantilever: new information hit the front of the curve and caused volatility while the long-term price remained stable and anchored to the wall.[1] That stability affected oil price behaviour: as spot prices drifted far from the long term price, the perception that they would eventually revert towards that long-run 'equilibrium' was built into market participants' expectations.

As oil prices rose sharply during the boom years of 2002-mid 2008, the consensus on what oil price would balance the long-term fundamentals of the oil market broke down. The whole futures curve became subject to a series of shifts, sometimes parallel, sometimes weighted to the front and sometimes to the back, but the key change was that the curve as a whole had been set in motion: the cantilever had broken free of the wall. Since 2003 and during most of 2008, changes in the prices at the front end of the curve were generally associated with very similar changes in prices at the back end of the futures curve. This indicated that market participants had virtually no expectations that the oil price would revert towards some long-run equilibrium within the near-term horizon. In effect, long-term expectations had a neutral effect on short-term expectations and the price of near-term and long-term contracts became jointly determined. In the following, we suggest an interpretation of the long-term behaviour of oil prices, based on a shift to a regime of increased uncertainty about oil market fundamentals.

Feedbacks, Expectations and Oil Price Dynamics

During the early phase of the boom in the early 2000s, market players' expectations rested on the assumption that oil price changes would induce a response or feedback from oil supply, oil demand or policy, or from a combination of these. These feedbacks were expected to prevent prices from rising above a certain ceiling or

[1] Gabillon, J. (1991), "The Term Structures of Oil Futures Prices", OIES WPM 17, Oxford: Oxford Institute for Energy Studies.

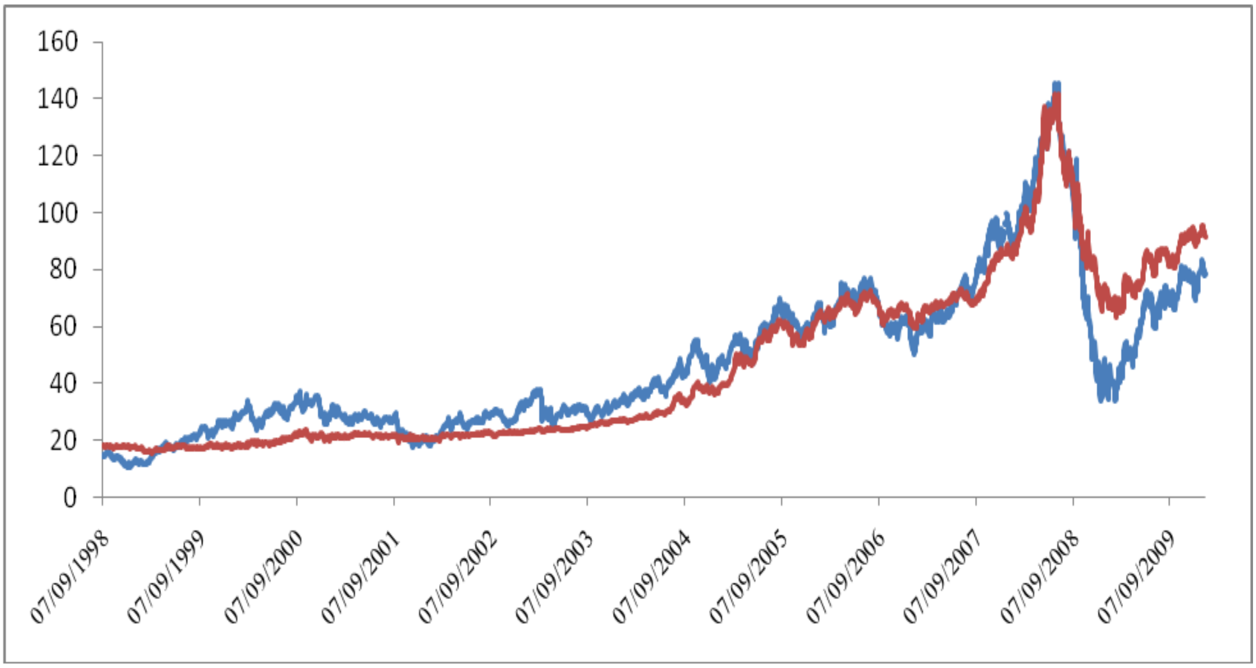
falling below a certain floor. Though such adjustments were not expected to occur instantaneously given the highly inelastic nature of crude oil and petroleum products' demand and the long gestation lags in investments in the oil sector, there was a wide market belief that in the long run, consumers, the oil industry and its various players possess enough flexibility and have the incentive to induce supply/demand responses to keep the long-term price within a stable range. Oil importers, exporters, and participants in financial markets all shared a common range of expectations of future fundamentals which stabilised long-term expectations about oil prices.

However, as oil prices rose sharply between 2004 and 2008, uncertainty about the existence and timing of feedbacks from prices to oil supply and demand increased markedly. The perception of strong feedbacks in the oil market was replaced by the perception of weak and limited feedbacks. This led market participants to revise their expectations about future fundamentals and to the breakdown of the consensus on long-term prices. By 2004, there was a wide market belief that the $20-$22 price range could no longer equilibrate the long-term fundamentals of the oil market. While market participants expected the long-term oil prices to adjust upward from this range, there was wide uncertainty as to the new price or price range needed to stabilise long-term expectations.

Short-Term and Long-Term Prices: The Empirical Evidence

Figure 1 shows the evolution of the daily front-month oil price (the short-term price) and the 60th month oil price (the long-term price) over the period 1998 to 2009. As seen from this figure, between 1998 and 2002 the short-term price exhibited high volatility while the long-term price remained fairly stable. During this period, a reversion mechanism seemed to have existed in the oil market: short-term oil prices drifted away, but eventually reverted to the long-term price.

Figure 1: 1st Month and 60th Month Price of the Light Sweet Crude Oil Contract ($/barrel)



Source: Bloomberg

During the 2002-2008 oil market cycle, this relationship was subject to a structural change. Between 2002 and early 2005, the short-term price hovered above the long-term price with the price differential between the short-term and long-term price reaching more than $10 per barrel on many occasions. This indicated that oil for immediate delivery was being sold at a large premium to oil for future delivery during that period. Either the spot price or the long-term price needed to adjust to correct for this 'disequilibrium'. Eventually, it was the long-term price that made the adjustment and towards the end of 2003 it started drifting upwards. Annualized long-term price returns amounted to 31% and 46% in 2004 and 2005 and the long term-price more than doubled increasing from $27 at the beginning in 2004 to $58 at the end of 2005.

Starting in mid-2005 and until the oil price peaked in July 2008, changes in short-term prices were generally associated with very similar changes in long-term prices and consequently the forward curve started shifting upward almost in a parallel fashion. This lasted until the collapse of the oil price towards the end of 2008. While both short-term and long-term prices declined sharply during the last quarter of 2008, the decline in the long-term price was less pronounced which gave rise to a large price differential reaching $30 per barrel in some instances. Concerns about long-term fundamentals placed a limit on how much market players were willing to discount the price at the front end relative to the price at the back end of the futures curve. On the one hand, the oil price was relatively high given the market fundamentals at the time. On the other hand, the oil price was relatively low compared to the expected future fundamentals. Thus, the oil market reached a point at which either the long-term price had to adjust downward or the front end curve had to adjust upwards. In contrast to the earlier period, during the recovery phase in 2009 it was the front end of the curve that moved up.

To more formally explore these price dynamics, we use the Johansen cointegration analysis to estimate the long-run relationship between the short-term and the long-term price.[2] This technique allows the identification of multiple long-run relationships and is an efficient method for testing causality[3]. The Johansen method is based on a vector error correction (VECM) representation of vector autoregression VAR(p) model, which can be written as:

$$\Delta x_t = \Gamma_1 \Delta x_{t-1} + \Gamma_2 \Delta x_{t-2} + \ldots\ldots + \Gamma_{p-1} \Delta x_{t-p+1} + \Pi x_{t-p} + u_t \qquad (1)$$

$$u_t \sim IN(0,\Sigma)$$

where $\mathbf{x_t}$ is an $n\times 1$ vector of n potentially endogenous first order integrated variables ($n=2$ in our case), $\Gamma_1, \Gamma_2, \ldots, \Gamma_n$ are $n\times n$ matrices of unknown parameters, p is the length of the VAR, and $\mathbf{u}$ is a vector of normally and independently distributed errors with zero mean and constant variance . The steady state (equilibrium) properties of equation (1) are characterized by the rank of $\boldsymbol{\Pi}$, a square matrix of size n. The existence of a cointegrating vector implies that $\boldsymbol{\Pi}$ is rank deficient. Johansen derives the trace statistics for testing the rank of Π. If Π is of rank ($0<r<n$) then it can be decomposed into two matrices $\boldsymbol{\alpha}$ $(n\times r)$ and $\boldsymbol{\beta}$ $(n\times r)$ such that:

$$\Pi = \alpha\,\beta' \qquad (2)$$

The rows of β are interpreted as the distinct cointegrating vectors whereby $\boldsymbol{\beta}'\mathbf{x}$ form stationary processes. The columns of α are the error correction coefficients which indicate the speeds of adjustment towards equilibrium. Substituting (2) into (1), we get:

[2] For details of the technique, please see Johansen, S. (1988), " Statistical Analysis of Co-Integrating Vectors", *Journal of Economic Dynamics and Control*, Vol 12, 231-254; Johansen, S. (1992), "Testing for weak Exogeneity and the Order of Cointegration in the UK Money Demand Data", *Journal of Policy Modeling*, Vol.14, 313-34; Johansen, S. and K. Juselius (1992), " Some Structural Hypotheses in a Multivariate Cointegration Analysis of Purchasing power Parity and Uncovered Interest Parity for the UK", *Journal of Econometrics*, Vol.53, 211-244; Johansen, S. (1996), Likelihood-Based Inference in Cointegrated Vector Autoregressive Models, 2nd edition. Advanced Texts in Econometrics, Oxford University Press: Oxford.

[3] See for instance, Hall, S.G. and A. Milne (1994), " The Relevance of P-Star Analysis to UK Monetary Policy", *The Economic Journal*, Vol.104, 587-604; Toda, H.Y. and P.C.B. Phillips (1993), " Vector Autoregression and Causality ", *Econometrica*, Vol. 61, 1367-1393.

$$\Delta x_t = \Gamma_1 \Delta x_{t-1} + \Gamma_2 \Delta x_{t-2} + \ldots + \Gamma_{p-1} \Delta x_{t-p+1} + \alpha (\beta' x_{t-p}) + u_t \qquad (3)$$

This is a basic specification that allows us to test for long-run rekationships and causality. A test of zero restriction on the columns of α is a test of weak exogeneity when the parameters of interest are long run. The null of $\alpha ij=0$, $i=1,..., n; j=1,..., r$ can be tested by standard likelihood ratio (LR) test.

We employ the following two variables in our empirical analysis: the logarithm of the front-month oil price (LSHORT) and the logarithm of the 60^{th} month oil price (LLONG) for the Light Sweet Crude Oil Futures Contract. The data set consists of daily data from September 1998 to January 2010.

The first step in estimating the model involves choosing the appropriate lag length for the VAR model. In our model, the number of lags is chosen to ensure that residuals from the estimated VAR model are not auto-correlated. As seen from Table 1, at two lags, the LM test for autocorrelation suggests that we cannot reject the null hypothesis of no first-order and second-order serial auto-correlation. We next test for the rank of the VAR model using the trace statistics. This enables us to determine whether there is a long relationship between the short-term and the long-term price. As expected and as can be seen from Table 1, the Trace Statistic indicates the existence of one cointegrating vector. Hence a cointegration rank of one is imposed on the VAR. For robustness, we also check whether any of the variables in the cointegrating vector should be excluded based on a likelihood ratio test procedure. The statistics in Table 1 show that none of the variables should be excluded from the long-run cointegrating vector. Since the Johansen procedure can only be applied to non-stationary variables, it is important to check whether the individual series contain unit roots. As seen from Table 1, based on LR test, we could easily reject the null of stationarity for both series. Thus, based on these various test statistics, we can be confident that there exists a long-run equilibrium relationship between short-term and long-term prices.

We next test for the weak exogeneity of each of the variables in the system. This involves testing whether the speed of the adjustment coefficient (α) is significantly different from zero. Generally, if the coefficient α which is related to variable x_1 is zero, then when estimating the parameters of the model there is no loss of information of not including Δx_1. Tests for weak exogeneity show some interesting results. They indicate that *LSHORT* is weakly exogenous to the system: While the long-term price *(LLONG)* adjusts towards the long run equilibrium, the short-term price (LSHORT) does not show any adjustment dynamics. In other words, if there is any disequilibrium between the short-term and the long-term price, it is the long-term price that tends to adjust to retain the long-run equilibrium. We impose this weak exogenous restriction and re-estimate the model. The last section of Table 1 shows the resulting cointegrating vector normalised with respect to the long-term price. The long-run relationship between LLONG and LSHORT suggests that one percentage increase in the logarithm of short-term price is associated with more than one percentage increase in the long-term price.

Table 1-The Long Run Equilibrium Relationship Between Short-Term and Long Term Oil Prices
(Method: the Johansen Procedure)
(*Sample period: 07/09/1998-18/01/ 2010)*

Lag Length of VAR
p = 2

Test for residual correlation:

LM(1):	$\chi^2(4)$= 6.786	*p-value=0.148*
LM(2)	$\chi^2(4)$= 7.091	*p-value=0.131*

Test for rank of VAR

Ho: Rank = r	Trace Statistics	*p-value*
r=0	26.160	0.006
r =1	4.440	0.398

Test of exclusion	LR test	
LSHORT	$\chi^2(1)$= 16.135	*p-value=0.000*
LLONG	$\chi^2(1)$= 14.876	*p-value=0.000*
Constant	$\chi^2(1)$= 6.403	*p-value=0.011*

Test of Stationarity	LR test	
LSHORT	$\chi^2(1)$= 14.876	*p-value=0.000*
LLONG	$\chi^2(1)$= 16.135	*p-value=0.000*

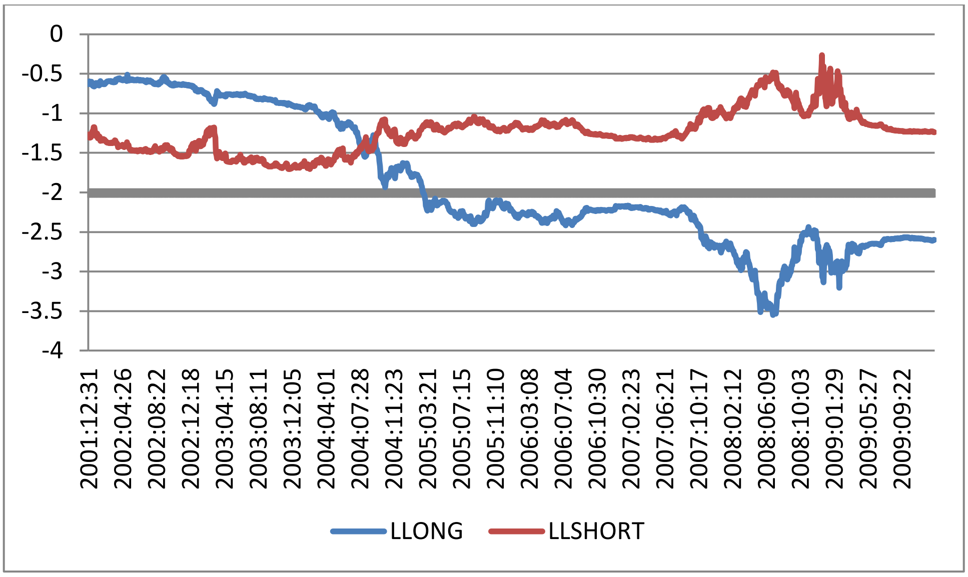
Test of weak exogeneity	LR test	
LLSHORT	$\chi^2(1)$= 1.978	*p-value=0.160*
LLONG	$\chi^2(1)$= 4.341	*p-value=0.037*

The cointegrating vector normalized with respect to LLONG

LLONG= 0.908 + 1.254 LSHORT

To explore the dynamics of the adjustment mechanism over the latest price cycle, we re-estimate the model recursively using the period 1998 to 2001 as the base period. This allows us to check whether the adjustment coefficient α is stable or whether it has changed over the cycle. Figure 2 shows the statistical significance of the adjustment mechanisms for both LSHORT and LLONG. As expected, LSHORT does not show strong adjustment dynamics where the adjustment coefficient is not significant at the 5% level. In contrast, LLONG shows some interesting dynamics. In the early years of the sample, the adjustment coefficient was insignificant indicating that during this period, there was no evidence of a long-run relationship between short-term and long-term oil prices. Movements in the prices at the front end of the curve were not associated with movements in prices at the back end of the futures curve. These dynamics changed in early 2005 when the adjustment coefficient becomes significant indicating a long-run relationship between the two series. These results are consistent with our anecdotal evidence discussed above.

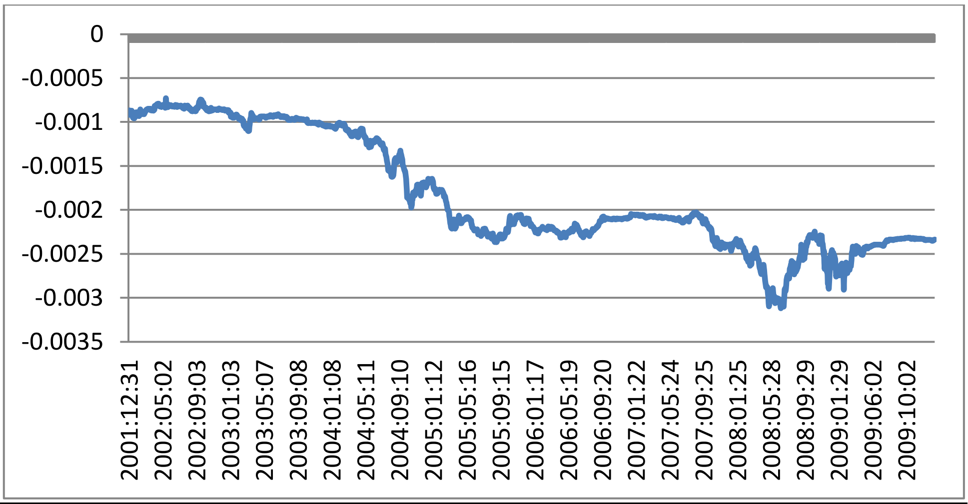
Figure 2: Significance of the Adjustment Coefficient



Notes: The thick grey line represents the critical value at the 5% level (-1.96).

Figure 3 which plots the size of the adjustment coefficient allows us to identify the following main phases. During the first phase which spans from 2002 until the beginning of 2004, the adjustment coefficient was low and not significant. As discussed earlier, during this phase while short-term prices began their upward march, long-term prices resisted following suit and the relationship between the two prices weakened. In phase 2, which spans from the beginning of 2004 until May 2008, the relationship strengthened as reflected in the size of the adjustment coefficient which tripled during this period. In 2004, the resistance was finally broken and long-term prices started closely following short-term price movements. During the sharp rise in oil price in 2008, the movement between short and long-term prices strengthened further. However, the relationship weakened in the aftermath of the oil price collapse as short-term prices undershot and long-term expectations of tightened market fundamentals kept long-term prices from declining to very low levels. As a result, the long-term price movements dislocated from short-term price movements, causing the adjustment coefficient to decline in absolute value. However, in the recovery and stabilisation phase in the first quarter 2009, the adjustment dynamics between the two series started to strengthen and stabilised towards the end of 2009.

Figure 3: The Size of Adjustment Coefficient



Current and expected future oil prices: Theoretical Considerations

In a forthcoming paper,[4] we suggest an interpretation of the long-term behaviour of oil prices based on a shift to a regime of increased uncertainty about oil market fundamentals. We explore the role of uncertainty on long-term oil prices in terms of two distinct but complementary models. The first model is based on a signal extraction mechanism and shows that, when the private beliefs by investors about the long-run determinants of oil prices become less precise relative to the information contained in the current spot price, then the expected future oil price moves closer to the current spot price. Specifically, it is possible to show that the structural break in the forecasting process for future oil prices can be explained in terms of a perceived change in the relative precision of the information conveyed by the signals on the long-run price, relative to the intrinsic variability of the fundamental price itself. As a result of the increased inaccuracy of the signals about the long-term price, investors have been relying more heavily on the information contained in the current price. Hence, the expected future oil price has moved closer to the current spot price.

The second interpretation is based on Bayesian updating and shows that a combination of a sequence of positive price shocks and heightened uncertainty will lead to the expected future price being closer to the current spot price. Specifically, we find that the key for the increased role of current prices in predicting future prices lies in the interaction of increased uncertainty with price surprises. Hence, if the observed values of the spot price remain higher over a sustained period of time relative to what investors had anticipated, and/or if the variability of the spot price is perceived to have increased, then the probability distribution on the autoregressive parameter will shift to the right and the expected future price will move closer to the current spot price.

An underlying common theme behind both interpretations is the role of increased uncertainty about long-term fundamentals and the impact of such uncertainty on the formation of market participants' expectations. It is important to stress that in both these models the prices of near-term contracts can be affected by a variety of factors, including expectations of future fundamentals. These models only propose a way to account for the joint determination of prices over different maturities without the need to account explicitly for the specific factors that enter the formation of these prices.

Conclusions

In an environment of high uncertainty, the informational content of the current price becomes more relevant relative to investors' beliefs about long-run fundamental values. As a result, investors rely more heavily on the information contained in the current price and the expected future oil price will move closer to the current spot price. Furthermore, when the volatility of the spot price is perceived to have increased and the current oil price is systematically higher than anticipated over a period of time, then the expected future oil price will converge to the current price. In a way, the short-term and long-term prices become co-determined. The recent behaviour of short-term and long-term prices is broadly consistent with these predictions. One of the structural changes in the oil price formation process has been the unlocking of the back end price of the futures curve. Perception of lack of feedbacks from oil prices to supply and demand increased uncertainty and caused a structural shift in how expectations are formed. This caused the expected future price to move closer to the current spot price. These dynamics might have changed in the aftermath of the 2008 financial crisis where the long-term price seems to have pulled up the short-term price. But as noted above, the relationship between short-term and long-term prices has stabilised which suggests that the underlying mechanism that produced a strengthened relationship in the latest price cycle is still in operation. This is expected as the market has not yet found the anchor that could balance long-term oil market fundamentals as reflected in the continuous adjustment of the long-term prices in recent months. Our analysis predicts that in the face of increased uncertainty, the long-term and short-term prices are bound to exhibit similar movements with important consequences on the oil price formation process.

---

[4] Fattouh, B. and P. Scaramozzion, "Uncertainty, Expectations, and Fundamentals: Whatever Happened to Long-Term Oil Prices?", Oxford Review of Economic Policy, Forthcoming.