Speculation and Commodity Valuations

Investigating the effects of speculation in the markets for oil and gold

Madalet Sessions, BCom (Hons) Economics, UCT

February 2008

Submitted to the University of Cape Town in partial fulfilment

for the degree of Masters in Economics

Abstract

The study uses Vector Error Correction Modelling to identify the influence of speculation[1] on the prices of oil and gold. The motivation for the analysis was a report by Antoshin and Samiei for the IMF World Economic Outlook September 2006 edition on speculative influences on commodity prices. The dissertation presents a critique of this study and offers an alternative specification of the equilibrium equations which are central to the VECM approach. In place of the time trend included in the equilibrium model specified by Antoshin and Samiei, the model specified in the dissertation relies on the arbitrage relationship between spot and futures prices as the equilibrium relationship in the markets for oil and gold. This enabled the study to conclude that the important assertion made by Antoshin and Samiei that, in the market for oil, causality has been from higher prices to increased speculative activity, and not vice versa, cannot be substantiated.

In both markets investigated, the application of the revised equilibrium model finds that speculation has a pervasive and relatively stable effect on prices. In the oil market, speculation only has an effect in the short run, while the long run equilibrium price of oil is independent of the effects of speculation - long run causation in either direction is precluded by the stationarity of speculation. In the market for gold, speculation influences prices in both the short run and long run. The coefficient on speculation in the cointegrating equation is highly significant and, contrary to expectations, negative. This analysis does not investigate the possible reasons for this, but suggest that it would be a useful avenue for future research. The speed of adjustment coefficient on speculation was not statistically significant, indicating that although speculation forms part of the long run equilibrium it is not the way in which equilibrium is achieved. This study finds that, in both the short and long run, speculation in the gold market does not respond to prices. Inventory levels for oil impact equilibrium prices which introduce questions about the appropriateness of the arbitrage relationship as an explanation for price movements in the oil market. This affect is absent in the gold market.

The results indicate that oil and gold prices do not always reflect only demand and supply fundamentals, but also a demand for speculative holdings predicated on the expected change in the value of the commodities.

1 Speculation is defined as per the study by Antoshin and Samiei (2006) in the World Economic Outlook as the number of net long non-commercial contracts as recorded by the Commodity Futures Trading Commission

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1. Introduction

Commodities are important for the South African economy. Approximately 20% of the value of exports are precious metals (own calculations based on National Accounts data). Close to 40% of the market capitalisation of the JSE is resource based, and growth in South African output is highly correlated with global commodity index returns (own calculations based on National Accounts and JSE data). The importance of commodities to the SA economy gives urgent need to understand and evaluate the drivers of commodity prices.

The global economy in the last five years has been expanding at a rapid rate. The increase in global output has seen unusual growth in demand for the resources used as inputs in the production process. This growth in real demand for commodities with no commensurate increase in supply, has led to exceptional increases in the price of commodities.

The International Monetary Fund (IMF) in the World Economic Outlook (WEO) September 2006 edition dedicated a chapter to the boom in non-fuel commodity prices and whether it can be sustained. They conclude that since demand for metals is a consequence of faster global growth and rapid industrial production growth, "the speed and costs of supply additions will determine whether metals prices retreat from the current high levels in the medium term."(Sommer, 2006, p.9)

Borensztein and Reinhart (1994) comment that traditionally commodity price models included two demand variables: the state of the business cycle in industrial countries and the real exchange rate of the US dollar. The authors find that a broader definition of aggregate demand - one that includes output developments in Eastern Europe and former Soviet Union countries - and commodity supplies are further important determinants of commodity prices. This view point is supported by evidence presented in the 2006 WEO regarding demand for commodities from China. The WEO points out that "China has become a key driver of price dynamics in the metals markets. During 2002–05, China contributed almost all of the increase in the world consumption of nickel and tin. In the cases of lead and zinc, China's contribution even exceeded net world consumption growth. For the two most widely traded base metals (aluminium and copper) and for steel, the contribution of China to world consumption growth was about 50 percent." (Sommer, 2006, p.5)

Antoshin and Samiei (2006) estimated the effect of speculation on commodity spot and futures prices. They argue that the anecdotal evidence that speculation has driven prices above levels suggested by fundamentals has focused on "correlations rather than tests of causality, and has tended to be anecdotal or circumstantial." (Antoshin and Samiei, 2006, p.16) The authors attempt to asses the empirical validity of the direction of causality between movements in prices and changes in speculation. They employ a rolling Vector Error Correction Model (VECM) to capture the recent run up in commodity prices and the changes in the relationships over time. They find that the increased speculative activity in the commodity markets they investigate is the result of higher prices. That is causality has been from higher prices to increased speculative activity. "Subject to data limitations...the results for the five commodities in the sample provide little support for the hypothesis that speculative activity ...affects either price levels over the long run or price swings in the short run. In contrast there is evidence (both across commodities and over time) that speculative positions follow price movements." (Antoshin and Samiei, 2006, p.18)

The purpose of this dissertation is to examine closely the Antoshin and Samiei (2006) study and in particular the specification of the model used and the methodology applied. The results of this study[2] suggest that the authors misspecified the long run equation and consequently the results of their study may be questioned. An alternative specification is suggested and evaluated. The aim of the study is to establish how an alternative specification of the long run equilibrium model of commodity prices, one that is regarded as more appropriate, might alter the conclusions reached by the authors.

The dissertation has the following structure. In section 2 the reader is introduced to the concepts of short selling and futures contracts as this is the way in which the hypothesis regarding speculation and its effects on prices are evaluated The section outlines the theoretical relationship between futures prices and spot prices. Section 3 derives the spot-future parity relationship. Section 4 introduces Vector Error Correction Modelling to familiarise the reader with concepts important for understanding the methodology and the results. In section 5 Antoshin and Samiei's methodology and results for oil are presented. Section 6 estimates the same relationship using an alternative specification and the results are then compared and contrasted with those of Antoshin and Samiei (2006). The effect of speculation on the equilibrium price of gold is also estimated. The study concludes that speculation does influence the prices of the commodities investigated. The conclusions are summarised in section 7.

2 The analysis is conducted within the framework specified by Antoshin and Samiei (2006). No alternative theoretical framework is developed to explain the relationship between speculation and prices.

2. The theories of futures and spot price relationships

The spot price is the price of an asset for immediate delivery. A futures contract calls for delivery of a commodity at a specified maturity date at an agreed upon price - the futures price. A trader taking a long position agrees to purchase the commodity, while the trader taking the short position agrees to sell the commodity at contract maturity. Assuming no transaction or holding costs, the profit from the long position is equal to the losses from the short position (and vice versa) and equals the spot price at maturity less the original futures price (Hull, 2006).

Profits and losses accrue to traders in a process known as marking to market. At the initial execution, each trader is required to deposit cash or near-cash securities in a margin account. "Margin" varies between 5% and 15% of the total value of the contract and more volatile commodities have higher margin requirements. The deposit of near-cash securities means that there is little opportunity cost to the traders in posting margin. Both the buyer and the seller are exposed to losses and so both are required to post margin. The clearinghouse requires that losses and gains be recognized daily. This ensures that as the price changes, proceeds accrue to the trader's margin account immediately (NYMEX). It is possible that the leverage inherent in marking to market has the unintended consequence that traders might have to liquidate arbitraged portfolios before the mispricing corrects.

2.1. *Modern portfolio theory*

Bodie, Kane and Marcus (2002) explain how modern portfolio theory "fine-tunes" the notion of risk premiums and the determination of asset prices through the insight that any asset that has positive systematic risk must trade at a discount to its expected value. Instead of the traditional hypotheses (outlined below) where speculators enter into the futures market if they are sufficiently compensated by expected profits, all asset prices are determined by the aggregation of risk preferences and return expectations. The value of the asset today is it's expected future value discounted by an appropriate risk adjusted rate. Formally $S_0 = \frac{E(S_T)}{(1+k)^T}$ where S_0 is the spot price, E is the expectations operated, S_T is the spot price expected to prevail at time T and k is the appropriate risk adjusted return. It is also known from the spot futures parity theorem, with no transaction costs, that $S_0 = \frac{F_0}{(1+r_f)^T}$. By solving for F_0, one finds that $F_0 = E(S_T)(\frac{1+r_f}{1+k})^T$. F_0 is the current futures price on a contract that matures at time T, and r_f is the risk free rate.

The insights of modern portfolio theory do not take into account the effect of temporary supply shortages or gluts. We turn to the theories of normal backwardation and contango for insights on the reaction of the market to temporary supply shocks.

2.2. Normal backwardation

The theory of backwardation is associated with John Maynard Keynes (1930) and John Hicks (1939). They argued that for most commodities there are natural hedgers who would like to reduce risk. Producers of a commodity would prefer to take the short position and sell their goods at a guaranteed price in the future. In order to entice speculators to take the long position, producers need to offer speculators an expected profit. The desire of the producer to reduce the risks of production coupled with the desire for expected profit by the speculator results in the futures price of the commodity trading below the expected spot price. The expected profit to the speculator equals $E(S_T) - F_0$. The expected profit of the speculator is the expected loss of the producer, but the producer is willing to bear the expected loss on the contract in order to reduce the risks involved in production.

Normal backwardation thus suggests that the futures price will be bid down to a level below the expected spot price ($k > 0$) and will rise over the life of the contract until at maturity $S_T = F_T$.

When a temporary supply glut occurs, the producer of the commodity will accept a lower price and the market will be in normal backwardation.

2.3. Contango

The opposite of normal backwardation is contango. Keynes (1930) and Hicks (1939) explained contango by the fact that hedgers are the purchasers (as opposed to producers) of the commodity.

Where a commodity is an important input, purchasers of the commodity would like to reduce risk and lock in the price that must be paid for the commodity. Processors, or purchasers, of commodities are natural long hedgers of the commodities. As such, it is expected that they will pay a premium to reduce risk and speculators will enter the opposite side of the contract for the expected profit.

Contango thus suggests that the futures price will be bid up to a level above the expected spot price ($k<0$) and will fall over the life of the contract until at maturity $S_T=F_T$.

When temporary supply shortages occur, the market will be in contango as consumers of commodities will be willing to pay a premium.

3. The Spot-futures parity relationship

Bodie, Kane and Marcus (2002) offer the following explanation for the relationship between spot and futures prices: An investor who buys a commodity in the spot market and enters the short side of a futures contract locks in the difference between the spot and futures price. The return on this portfolio, of holding the commodity and agreeing to sell at some future time at an agreed upon price, is without risk and so the appropriate return is the risk free rate. Where storage costs are incurred, the return of the portfolio after storage costs must equal the risk free rate. In order to create a hedged portfolio the underlying commodity needs to be borrowed at a cost to the borrower. This borrowing rate is known as the lease rate (London Bullion Market Association).

$$r=\frac{F_0-S_0-cS_0}{S_0} \qquad (1)$$

Where r is the risk free rate, F_0 is the futures price, S_0 is the spot price, and c is the lease rate.

Eq. (1) can be rewritten as

$$S_0(1+r+c)=F_0$$
$$\ln((S_0)(1+r+c))=\ln(F_0)$$
$$\ln(S_0)-\ln(F_0)=-\ln((1+r+c))$$
$$s_0-f_0=k \qquad (2)$$

Where f_0 is the natural logarithm of the futures price, s_0 is the natural logarithm of the spot price, k is the continuously compounded return required ($e^{-k} = 1 + r + c$). Note that k includes the risk free rate and the lease rate.

The long run equilibrium relationship between spot and futures prices is given by Eq. (2). In equilibrium, the difference between the logged futures price and the logged spot price should equal the continuously compounded risk free return plus the cost of creating the portfolio.

The mechanism by which these two market reach equilibrium is arbitrage. When the risk free portfolio does not offer the risk free rate, traders will enter the market and sell the relatively expensive asset in order to buy the cheap asset. When the difference between the futures and spot price exceeds the risk free rate (adjusted for costs), one expects to see an adjustment in prices as the expensive futures contract is sold and the asset is purchased at the lower spot price. Any disequilibrium will be bid away by *arbitraguers*.

The application of the spot-futures parity relationship is limited to commodities where there is unlimited supply of the commodity. In instances where a supply shortage occurs, the spot price will rise to reflect the demand and supply conditions. If however the supply shortage is expected to be temporary the futures price of the commodity need not necessarily adjust in line with the parity relationship. This is because it is not possible to bring future supply to the market. In these instances the supply shortage and the impossibility of arbitraging supply across time, could lead to the breakdown of the spot futures parity relationship. In commodities or assets where no such supply constraints exist, the spot futures parity relationship is expected to hold as *arbitraguers* will bid away any out-of-equilibrium profits.

4. Vector error correction modelling (VECM)

Cointegration was introduced by Granger (1981). Nonstationary series are said to be cointegrated if a linear combination of these series are stationary (Fedderke, 2003). The inability of single equation techniques to identify the number of cointegrating relationships and the imposition of *a priori* structure on the data has seen the increasing use of multiple equation techniques to estimate equilibrium relationships between macroeconomic time series variables. Multiple equation techniques offer many advantages. These include identifying the number of cointegrating relationships, the long run equilibrium coefficients , out-of-equilibrium adjustments and short run dynamics.

4.1. Johansen approach[3]

The general n dimensional VAR specification is given by $Z_t = A_1 Z_{t-1} + \ldots + A_m Z_{t-m} + \delta + \epsilon_t$. Where m is the lag length, δ deterministic trends and ϵ_t a Gaussian error term.

Reparametrization provides the general VECM specification:

$$\Delta Z_t = \sum_{i=1}^{l-1} \Gamma_i \Delta Z_{t-i} + \Pi Z_{t-j+1} + \epsilon_t . \qquad (3)$$

The hypothesis that $H_1(r): \Pi = \alpha \beta'$ amounts to a test for the existence of r cointegrating relationships. Π is a $n \times n$ and α, β are $n \times k$ matrices of full rank. Therefore $H_1(r)$ is the hypothesis of reduced rank of Π. Issues of identification arise where $r > 1$. See Wickens (1996), Johansen and Juselius (1990, 1992) and Pesaran and Shin (1995a, 1995b) and Pesaran, Shin and Smith (1996). Restrictions on the loading matrix (α), the cointegrating space (β) and the matrix (Γ) (representing the short run dynamics) can resolve the issue of identification.

VECM[4] estimation allows one to identify the long run equilibrium equation and the short run out of equilibrium dynamics. (See Eq. 4 below for the specification of the VECM in this analysis). The β vector identifies the long run equilibrium relationships, while the α matrix contains the speed-of-adjustment coefficients. These coefficients provide the speed with which each variable's deviation from the long run equilibrium is eliminated and the variable adjusts back towards the equilibrium when out of equilibrium. The inclusion of the $\sum_{i=1}^{L-1} \Gamma \Delta y_{t-i}$ terms allows the researcher to investigate the short run dynamics of the system.

$$\Delta y_t = \alpha \beta' y_{t-1} + \sum_{i=1}^{L-1} \Gamma \Delta y_{t-i} + \epsilon \qquad (4)$$

3 This discussion closely follows the notes of Fedderke J., Times Series Econometrics, 2003

4 VECM, in contrast to single ECM, also allows one to test for the number of cointegrating relationships present in the data

In order to calculate the number of cointegrating vectors, the standard Johansen approach requires that only nonstationary I(1) variables be included in the VAR. Stationary I(0) processes may be included, but each stationary variable will provide a cointegrating vector. When estimating the system one needs to control for each I(0) variable included. Stationarity can be identified with Augmented Dickey Fuller unit root tests (Dickey and Fuller, 1979).

The first step in estimating a system of equations is to test for the order of integration of the variables to be included in the system. Once the order of integration has been established the lag length (L) needs to be determined. The appropriate number of lags is selected to ensure that the VECM has Gaussian errors. An unrestricted VECM is then estimated.

VECM estimation requires the determination of whether the system needs to be conditioned on any stationary variables, including indicator variables. Before proceeding with estimation, the number of cointegrating relationships needs to be specified. The maximum eigenvalue and trace statistics test for the reduced rank of the system.

Following estimation of the unrestricted VECM, one can test for exogeneity and linear hypotheses on the cointegrating relationships. The cointegrating vectors identified in the data as this stage are statistical artefacts. These relationships are not necessarily economically meaningful. Restrictions, motivated by economic theory need to be imposed on the cointegrating space. Once the restrictions have been imposed the researcher can test whether the cointegrating vectors are identified. A zero row in the loading matrix (α) indicates that that variable is weakly exogenous.

The explicit dynamics and the analysis thereof is one of the key advantages of VECM. Generalised impulse response functions are derived from the VAR structures. The dynamics of a shock to the system and the evolution of the variables post the shock to a new equilibrium can be evaluated graphically.

5. Antoshin and Samiei's methodology and results

To asses the empirical validity of the claims that speculation has driven commodity valuations, Antoshin and Samiei (2006) provide an econometric assessment of the direction of causality between movements in spot and futures prices and speculative positions in commodities. They investigated the effect of speculation on prices for the following commodities: light sweet crude oil, copper, sugar, coffee and cotton.

In the analysis of whether speculation has contributed to higher prices the number of net long non-commercial positions serves as a proxy for speculation and is available on a weekly basis only. Consequently it is not possible to capture the impact of intra week activity (Antoshin and Samiei, 2006). The Commodity Futures Trading Commission (CFTC) assembles "on a weekly basis the number of contracts for two categories of traders: commercial and non-commercial. Commercial traders are defined as those who use futures contracts for the purpose of hedging (e.g., oil producers, merchants, and major consumers, such as airlines)." (Antoshin and Samiei, 2006, p16) All other participants are classified as non-commercial.

Non-commercial traders are engaged in speculative activity, however some commercial traders may also be speculating. For instance, commodity index traders (classified as commercial traders) may take positions that are driven by speculative motives rather than hedging. The CFTC classification cannot distinguish amongst trader types within the commercial category. This has implications for the proxy for speculation, but cannot be controlled for.

Each contract comprises a fixed volume of the underlying commodity so using the number of contracts is equivalent to using volumes. The number of non-commercial positions tracks the volume of contracts that are entered into for the purpose of betting on price changes in the underlying commodities. Net long positions (the number of long contracts less the number of short contracts) indicate whether speculators expect prices to rise or fall. When prices are expected to rise ($E(\frac{dS}{dt})>0$), the number of net long non-commercial positions will exceed zero. Conversely, when prices are expected to fall ($E(\frac{dS}{dt})<0$), the number of net long non-commercial positions will be less than zero.

As the CFTC does not report the number of contracts by time to maturity it is impossible to match speculation with time to maturity of the futures contract. Antoshin and Samiei (2006) state that the one year market is the most actively traded and so they expect speculation to be most active in this market. The analysis, therefore, makes use of the one year futures price.

Antoshin and Samiei (2006) employ a Vector Error Correction Modelling (VECM) to test for causality. A VECM allows the examination of both long-run and short-run causality through the significance of the coefficients. Short run causality is determined by the significance of the coefficients on the first difference terms, while long run causality is determined by the significance of the coefficients on the error correction term (α) when a long run equilibrium relationship in levels exists (Antoshin and Samiei, 2006).

The authors estimate the following VECM:

$$\Delta y_t = \alpha(\beta' y_{t-1} + \mu + \rho t) + \sum_{i=1}^{L-1} \Gamma \Delta y_{t-1} + \gamma + \epsilon \qquad (5)$$

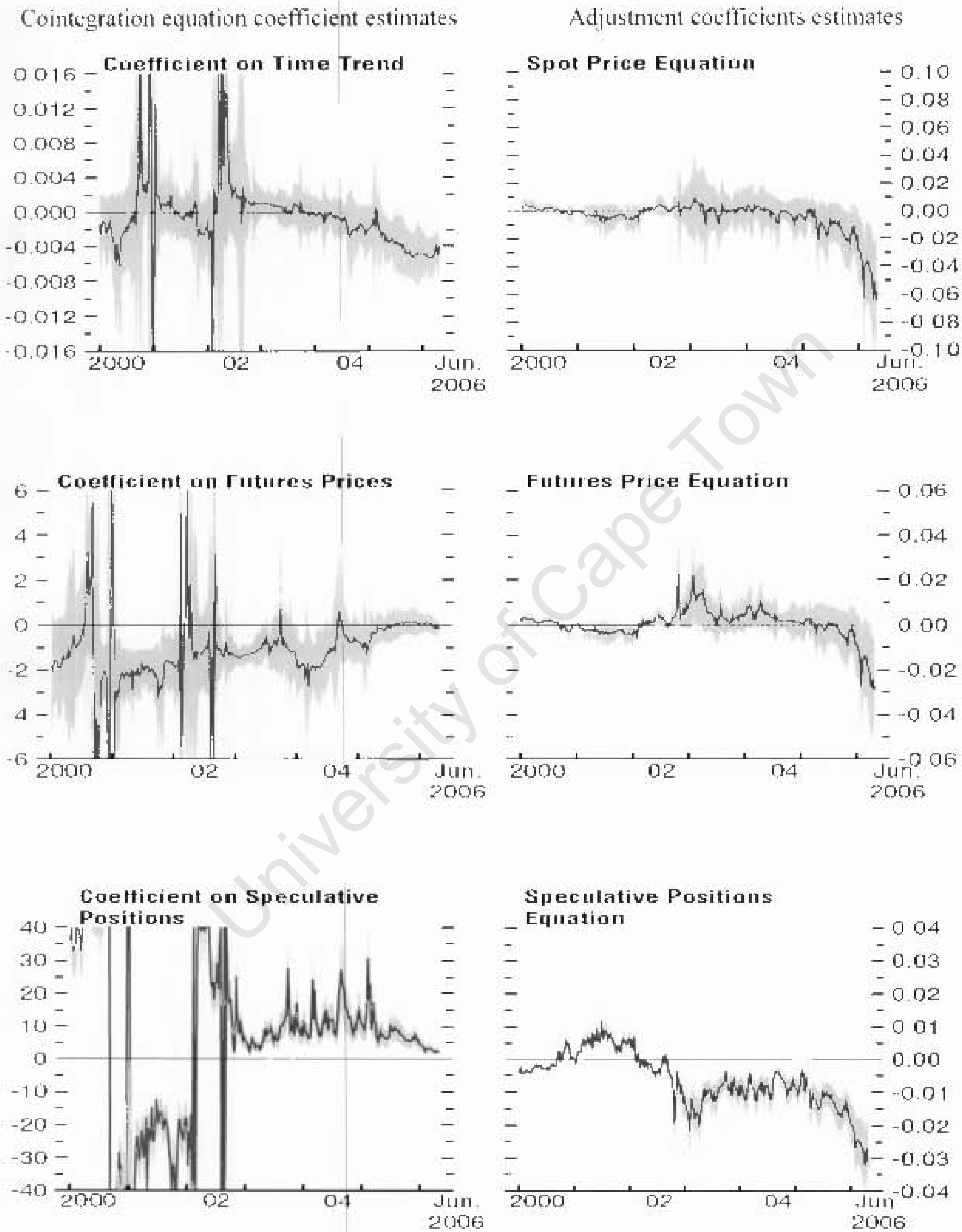
Where $y_t = \begin{pmatrix} s_t \\ f_t \\ n_t \end{pmatrix}$.

s_t is the natural logarithm of the spot price, f_t is the natural logarithm of the futures price, and n_t is the level of net long non-commercial positions.

In estimation, Antoshin and Samiei (2006) specify the cointegration rank as 1, the number of VAR lags L is 3, α is a 3x1 vector of adjustment coefficients, β is a 3x1 cointegrating vector and $(\Gamma_i)_{i=1}^{L-1}$ are 3x3 matrices of VAR coefficients and t is the time trend.

The model is estimated using rolling regression with window lengths of 234 weeks (4.5 years) as a reasonable duration for a business cycle and to cover the recent run in commodity prices (Antoshin and Samiei, 2006). We reproduce the estimation results for oil below.

Figure 1: Antoshin and Samiei (2006) coefficient estimates

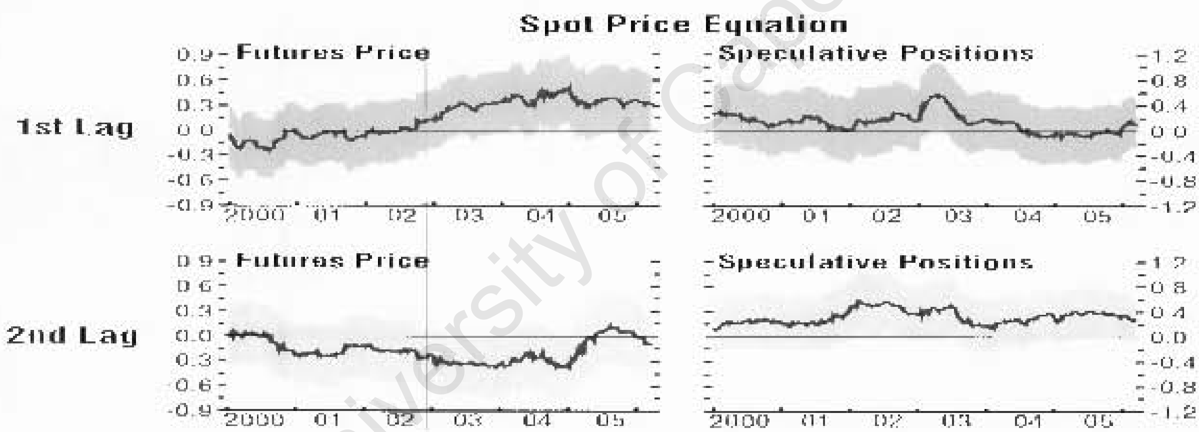


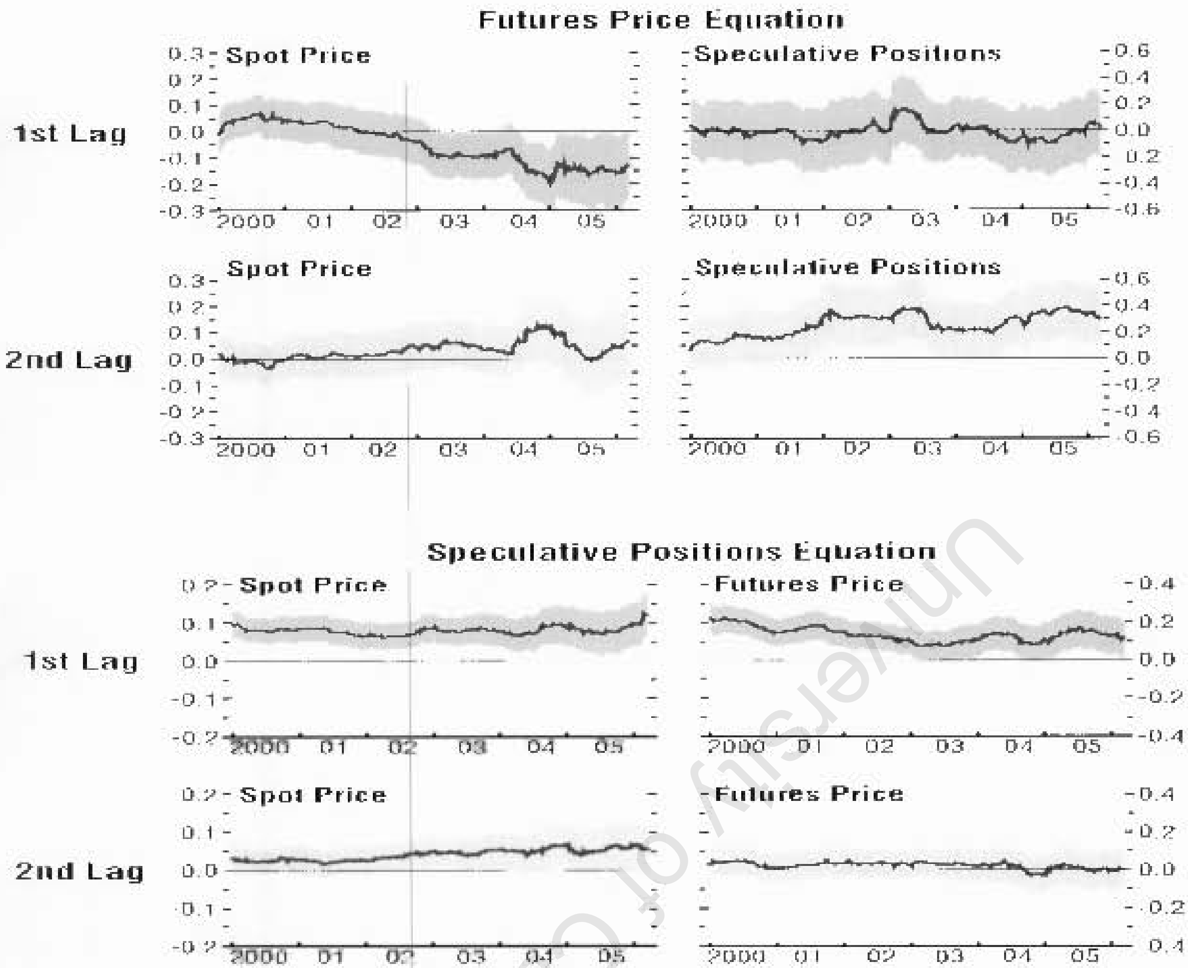
Source: Antoshin and Samiei (2006) estimates – Shaded areas are 90% confidence bands. Dates on the x-axis correspond to period ending dates.

The authors find that the adjustment coefficient in the speculative positions equation is significantly different from zero for most of the period, while the opposite is true for the two price equations. They conclude that the interpretation of this is that "when a long-run relationship holds, causality is from spot and futures prices to speculation." (Antoshin and Samiei, 2006, p.27)

From the rolling estimates of the model's short-run parameters, only the coefficients in the speculative positions equation, for both price variables, are statistically different from zero for any length of time. The coefficients on speculative positions in both the spot and futures price equation, for the first two lags, were mostly not statistically different from zero. That is, speculative positions respond to changes in the price variables, while the price variables do not respond to changes in the level of speculation. Antoshin and Samiei (2006) conclude that speculation has not been an influence on commodity prices, but that higher prices has influenced speculative activity.

Figure 2: Antoshin and Samiei estimates of short run parameters





Source: Antoshin and Samiei (2006) estimates. Shaded areas are 90% confidence bands. Rolling window length is 234 weeks. Dates on the x-axis correspond to period ending dates.

As discussed previously Bodie, Kane and Marcus (2002) argue that the appropriate return on the arbitrage risk-free portfolio is the risk free rate, see section 3. From this argument follows the spot-futures parity relationship, which the above specification does not consider. Antoshin and Samiei's (2006) study does not pay sufficient attention to the theoretical and practical importance of these equilibrium notions.

6. An alternative approach

The Antoshin and Samiei (2006) study is replicated in this section. A number of key differences between the specification used by Antoshin and Samiei (2006) and this analysis exist. The primary difference is that instead of including a time trend in the long run equation, a required return variable is included as demanded by the spot-futures parity relationship. Secondly, where supply constraints exist that may have perverse effects on the parity relationship, as may be expected in the market for light sweet crude oil, the study tries to capture this effect through the inclusion of an inventory variable. And finally, only variables that are nonstationary are included in the long run relationship. The aim is to determine whether a more appropriate specification, one that allows for the theoretical equilibrium, alters the conclusions reached by Antoshin and Samiei (2006).

6.1. Description of data

We investigate the effect of speculation for light sweet crude oil and gold. We analyse light sweet crude oil to enable a comparison of results from the Antoshin and Samiei (2006) estimation with ours. The inclusion of gold in the analysis is due to the importance of the commodity to the South African economy and the lack of supply shortages that could have perverse effects on the long run equilibrium equation. Platinum was excluded from the analysis because of the lack of activity in the one-year futures market.

6.2. Light sweet crude oil

6.2.1. Data characteristics

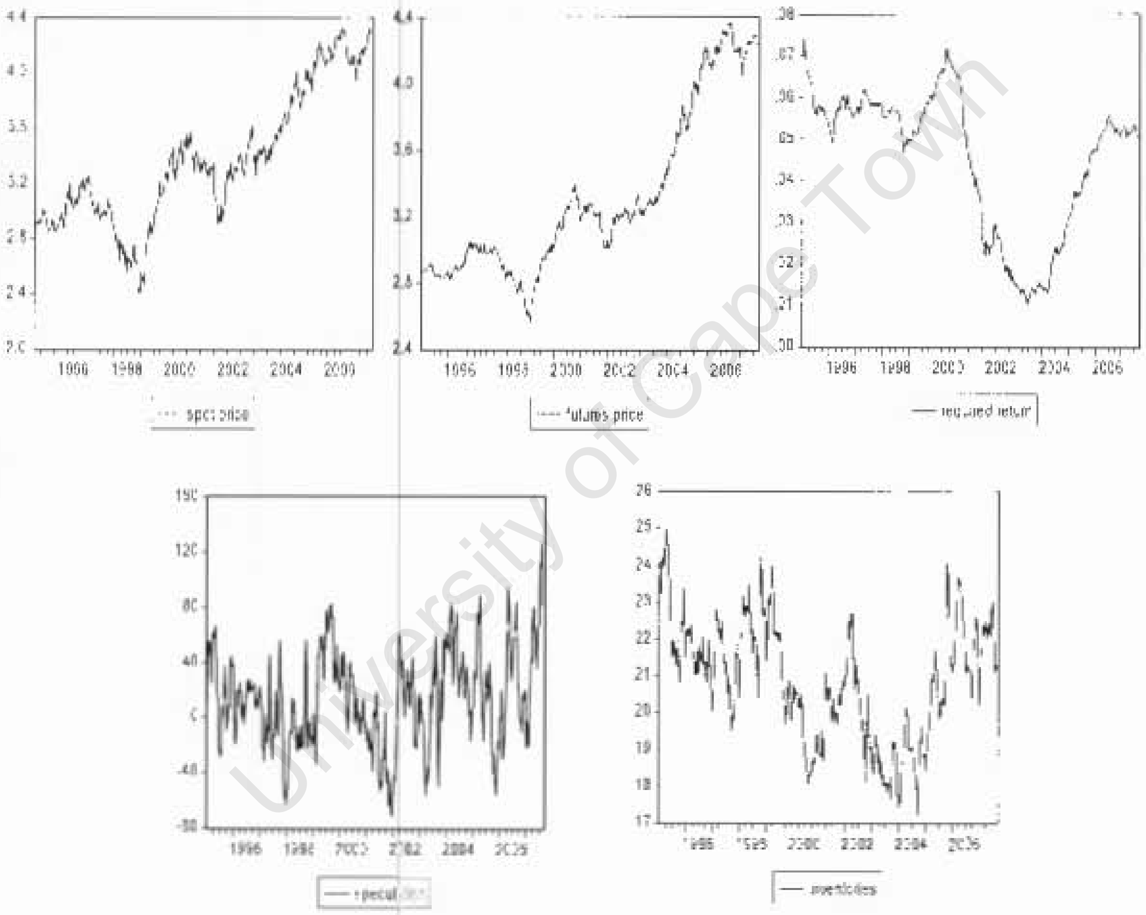
The effect that shortages have on equilibrium prices is captured by the inclusion of an inventory variable in the long run equation. Temporary shortages of inventories will mean that the market will be in contango, while temporary gluts will mean that the market will be in backwardation. We proxy inventory effects by the number of days' supply still available in the US market. Supply constraints impact the equilibrium price and introduce questions about the appropriateness of the arbitrage relationship as an explanation for price movements. Temporary supply shortages might lead to a breakdown in the arbitrage relationship as discussed in section 2.

No lease rate or storage costs for light sweet crude oil is available on a weekly basis and so the required return variable for oil is given by the risk free twelve month rate.

Shown below is the natural log of spot and futures prices, the continuously compounded one year interest rate (the required return), the number of net long non-commercial contracts in millions of contracts and the number of days' supply left in the US.

Data is collected from the first Tuesday of January 1995 to the last Tuesday of August 2007. Unit root tests are performed to determine whether variables are stationary or nonstationary.

Figure 3: Variables influencing the equilibrium price of Light Sweet Crude Oil



Below we show the results of the unit root tests.

Augmented Dickey Fuller Unit Root Test – Light sweet crude oil

	Levels (y)			First difference (Δ y)		
Variable	τ	τ_μ	τ_τ	τ	τ_μ	τ_τ
Log of spot (s_t)	1.245	-0.309	-2.228	-7.043**	-7.166**	-7.220**
Log of futures price (f_t)	1.842	0.277	-1.806	-6.387**	-6.652**	-6.774**
Speculation (n_t)	-4.384**	-5.466**	-5.633**	n/a	n/a	n/a
Required return (k_t)	-0.642	-1.451	1.386	-10.087**	-10.079**	-10.118**
Inventories (q_t)	-0.520	-2.911*	-2.739	-10.204**	-10.201**	-10.247**

*(**) denotes rejection of the hypothesis at the 5%(1%) level

The log of spot and the log of the futures price, the interest rate and the inventory variables are all I(1). The number of net long non-commercial positions is I(0) and so we must conclude that speculation cannot cause, and cannot be caused by, spot and futures prices[5].

6.2.2. Estimation

The nonstationary prices, required return and inventories variables are included in the long run equation. The effect of speculation is included in the short run component of the VECM only as speculation is stationary.

The following VECM for oil is estimated.

$$\Delta y_t = \alpha(\beta' y_{t-1} + \mu) + \sum_{i=1}^{L_1 - 1} \Gamma \Delta y_t + \gamma + \sum_{i=0}^{L_2} n_t + \epsilon \quad (6)$$

Where $y_t = \begin{pmatrix} s_t \\ f_t \\ r_t \\ q_t \end{pmatrix}$,

s_t is the natural logarithm of the spot price, f_t is the natural logarithm of the futures price, r_t is the continuously compounded risk free interest rate, q_t is the number of days' supply left in the US, μ captures the cost incurred in setting up the arbitrage portfolio, and n_t is the number of millions

5 The univariate characteristics of the speculations variable in the oil market precludes the inclusion of this variable in the long run equilibrium equation for oil. In this study the effect of speculation is only included in the short run.

of net long non-commercial contracts.

From the simple VAR estimation, we include the number of lags as indicated by the Akaike Information Criterion (L_1 = 3). We test for cointegration with an intercept term but no linear trend[6]. The intercept term captures the cost of creating the arbitrage portfolio.

Unrestricted Cointegration Rank Test (Trace Statistic)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value
None	0.044174	50.67994*	47.21	54.46
At most 1	0.021564	21.17783	29.68	35.65
At most 2	0.006089	6.942791	15.41	20.04
At most 3	0.004515	2.954762	3.76	6.65

*(**) denotes rejection of the hypothesis at the 5%(1%) level
Trace test indicates 1 cointegrating equation(s) at the 5% level

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5 Percent Critical Value	1 Percent Critical Value
None	0.044174	29.50211*	27.07	32.24
At most 1	0.021564	14.23504	20.97	25.52
At most 2	0.006089	3.988028	14.07	18.63
At most 3	0.004515	2.954762	3.76	6.65

*(**) denotes rejection of the hypothesis at the 5%(1%) level
Max-eigenvalue test indicates 1 cointegrating equation(s) at the 5% level

Both the maximum eigenvalue and trace statistic do not reject the hypothesis, at the 5% level of significance, that at least one cointegrating relationship does exist.

6.2.3. Expectations of long run equilibrium coefficients

The long run relationship between the spot price, the futures price and the required return is given by $s_0 = f_0 - k$ (Eq. 2). The coefficients on the spot and futures prices are expected to be equal and opposite in sign, while the required return is expected to be equal to the coefficient on the spot price. Normalising the coefficient on the spot price to 1, we expect a coefficient of -1 and 1 on the futures price and the required return, respectively. Inventory is an alternative source of supply, as such the coefficient is expected to reflect that higher inventory levels is associated with lower spot prices.

6 The equilibrium equation as derived in section 3 (Eq. 2) does not include a trend.

Given that $y_t = \begin{pmatrix} s_t \\ f_t \\ r_t \\ q_t \end{pmatrix}$, we expect $\beta = \begin{pmatrix} +1 \\ -1 \\ +1 \\ \geq 0 \end{pmatrix}$.

Ideally the required return in the long run equation for oil would include the unit cost of storage and a lease rate. Weekly storage costs and lease rates, however, are not readily available. This lack of data results in the required return specified in the long run model for oil being equal to the risk free rate. It is not implausible that the unit cost of storage would be relatively constant, say at a cost of c. The theoretically correct discount rate ($1+r+c$) is less than the modelled required return ($1-r$) for all ($c>0$) and so the coefficient on the required return which excludes storage costs will be biased downward.

The one-year futures price is constructed by stitching together a number of consecutive futures contracts that are approximately one year from maturity. The New York Mercantile Exchange (NYMEX) lists twelve contracts for oil, every month a contract expires, so that the length of time between the spot price and maturity of the one year futures contract can vary between eleven and twelve months. The time mismatch between the futures contract, the spot price and the required return (which is always a twelve month rate) introduces systematic structure in the residuals when estimating the long run equation. Furthermore, the mismatch between the time to maturity of the futures contract and the interest rate variable has consequences for the coefficient values of the long run equation. The coefficients on the futures price are expected to be biased downward, below unity, while the coefficient on the required return variable will again be biased downward.

6.2.4. Long run estimation results

From the results of the unrestricted VECM, as can be seen below, all the variables are as expected and highly significant with the exception of the risk free rate. The estimates are for the VECM estimated over the full sample.

Vector Error Correction Estimates – Long run equilibrium for light sweet crude oil

	Spot price s_t	Futures price f_t	Required return k_t	Inventory q_t
Long run equilibrium (β)	1.000 n/a	-0.918** (0.004)	-3.727** (1.465)	2.249** (0.329)
Speed of adjustment coefficients (α)	-0.022 (0.012)	-0.007 (0.007)	3.82E-04 (2.60E-04)	-0.025** (0.005)

*(**) denotes rejection of the hypothesis at the 5%(1%) level
Standard errors are reported in parenthesis

The coefficient on the spot price has been normalised to unity, and as expected the coefficient on the futures prices is close to unity although biased lower by the maturity mismatch discussed earlier. The inventory variable's coefficient is negative as expected - the more inventories are available in the market, the lower the spot price of oil. The coefficient on the risk free rate is completely contrary to the expected value. The expected value of the coefficient is positive one. However it was expected to be biased downwards as a result of the exclusion of storage costs from the long run equation and the maturity mismatch.

Figure 4-5, below, shows the evolution of the long run coefficients and the 90% confidence levels. Following the Antoshin and Samiei (2006) methodology, a rolling VECM is estimated. In each regression the number of lags in the VAR is selected according to the Akaike Information Criterion and one cointegrating vector is specified. A window length of 7 years is used to smooth out the volatility observed in the estimates of Antoshin and Samiei (2006).

As a result of the unexpected coefficient on the risk free rate, coupled with the knowledge of the bias introduced through the lack of weekly unit storage costs, the coefficient on the futures price is restricted to the theoretically expected value of negative one. It is hoped that the coefficient on the risk free rate will be closer to its expected value as a result of this restriction.

Figure 4: Coefficient on the risk free rate in the equilibrium equation

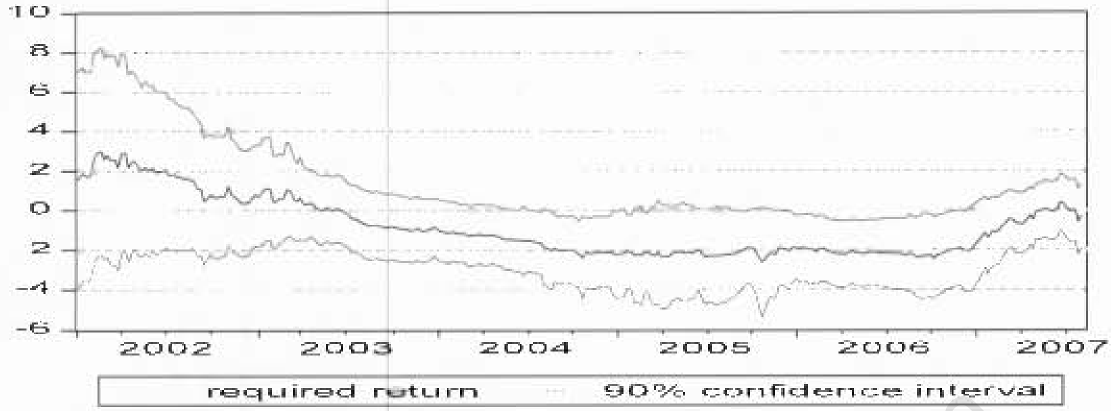
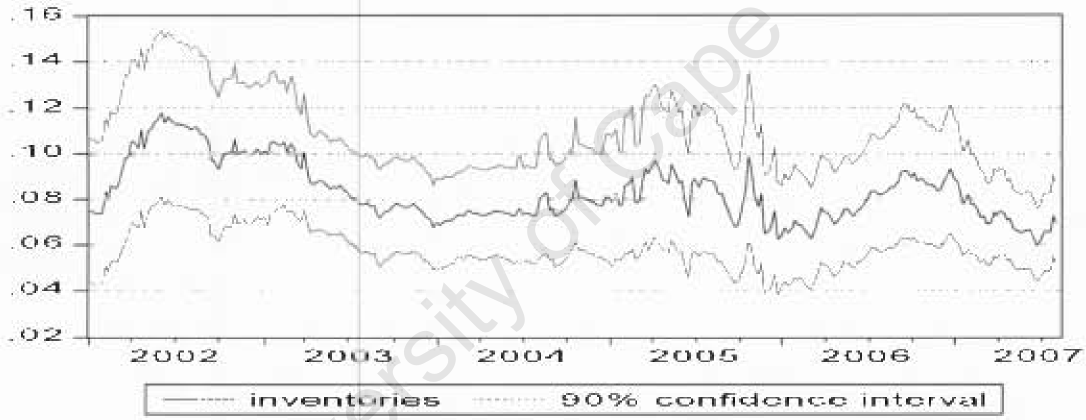


Figure 5: Coefficient on the inventory variable in the equilibrium equation



The charts are indicative of a stable long run relationship between the variables . The coefficient on the risk free rate remains negative, but is not statistically significant in any of the estimation periods. The coefficient on the inventories variable is stable and significant throughout. However, by restricting the coefficient on the future price to negative one, the inventory coefficient has become much smaller than the value estimated over the full sample.

The stability of the coefficients in the long run equation is noticeably different from the volatile coefficients estimated by Antoshin and Samiei, see Figure 1.

Figures 6-9 below show the evolution of the speed of adjustment coefficients.

Figure 6: Speed of adjustment coefficient on spot prices

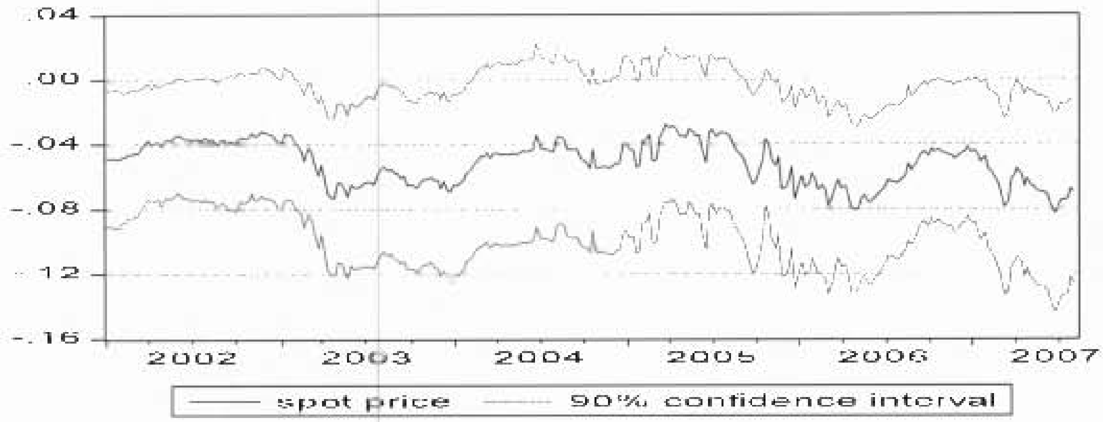


Figure 7: Speed of adjustment coefficient on futures prices

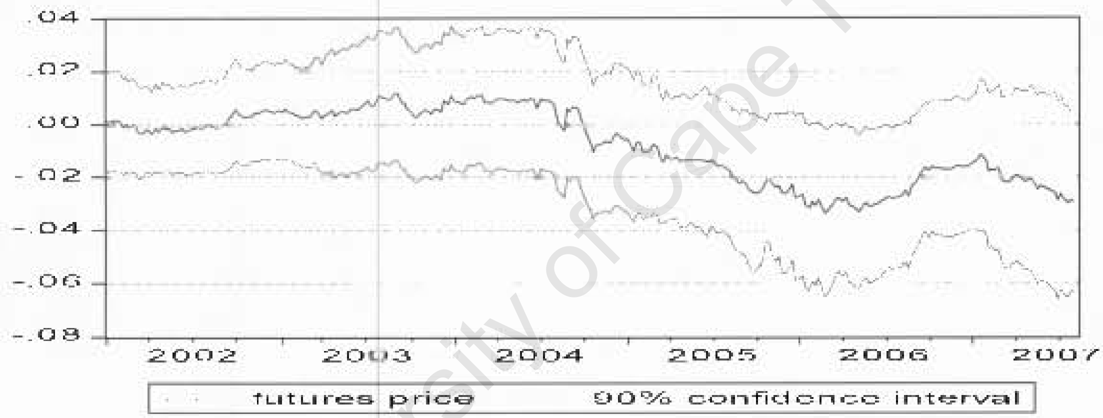


Figure 8: Speed of adjustment coefficient on required returns

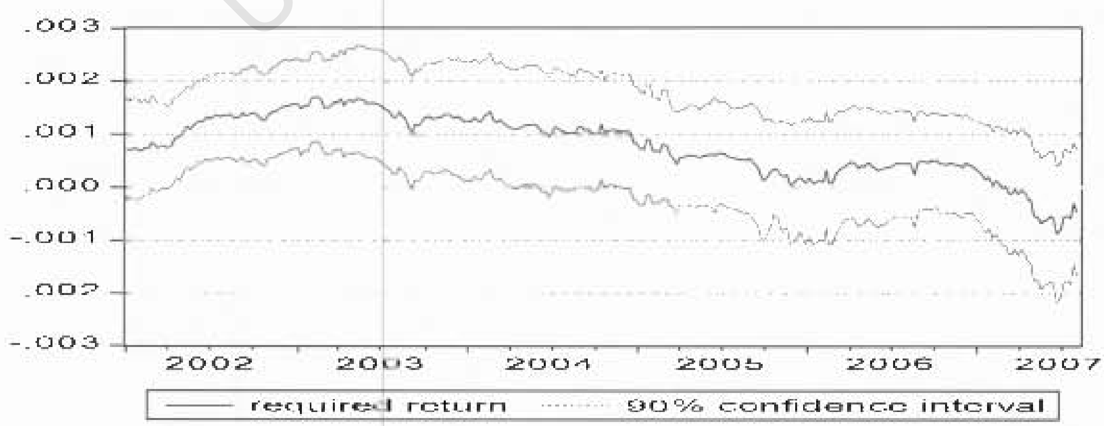
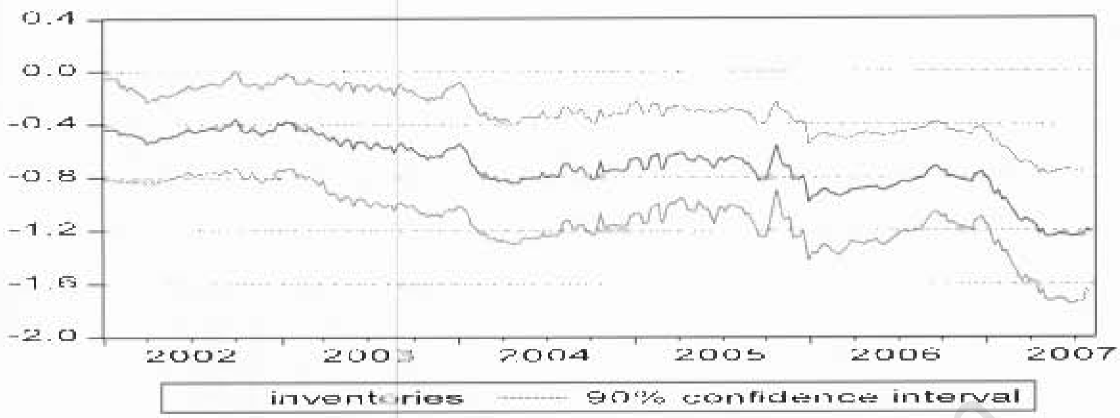


Figure 9: Speed of adjustment coefficient on inventories



The coefficients on spot and futures price in the long run equation is restricted to be one and negative one, respectively. The stability of the coefficients are noticeable and differ vastly in this stability from the adjustment coefficients estimated by Antoshin and Samiei (2006). Only the inventories variable is statistically significant throughout the estimation period. The coefficients on spot prices, futures prices and the required return are not statistically different from zero for most of the estimation period. Spot and futures prices and required returns are exogenous. Inventory levels adjust to bring the system back to equilibrium.

6.2.5. Short run effects of speculation on the spot and futures price of oil

Antoshin and Samiei (2006) included net long non-commercial positions in the long run equation, despite the unit root tests indicating that the series is stationary. When one includes speculation in the short run equations instead, one cannot reject that speculation has an influence on the price of crude oil. The short run dynamics show that both the spot and the futures price of oil respond to speculation. Only coefficients on net long non commercial positions significant at the 5% level is reported.

Vector Error Correction Estimates – Short run effect of speculation

	Δf_t	Δs_t
n_t	7.91E-04**	1.47E-03**
	(6.3E-05)	(1.2E-03)
n_{t-1}	-3.79E-04**	-5.34E-04**
	(9.7E-05)	(1.8E-04)
n_{t-2}	-4.05E-04**	-7.70E-04**
	(9.8E-05)	(1.8E-04)

* (**) denotes rejection of the hypotheses at the 5% (1%) level

Standard errors are given in parenthesis

The table above shows the effect of speculation on the changes in the spot and futures price of oil. In both instances speculation drives prices higher, followed by a number of weeks of correcting the over valuation that follows.

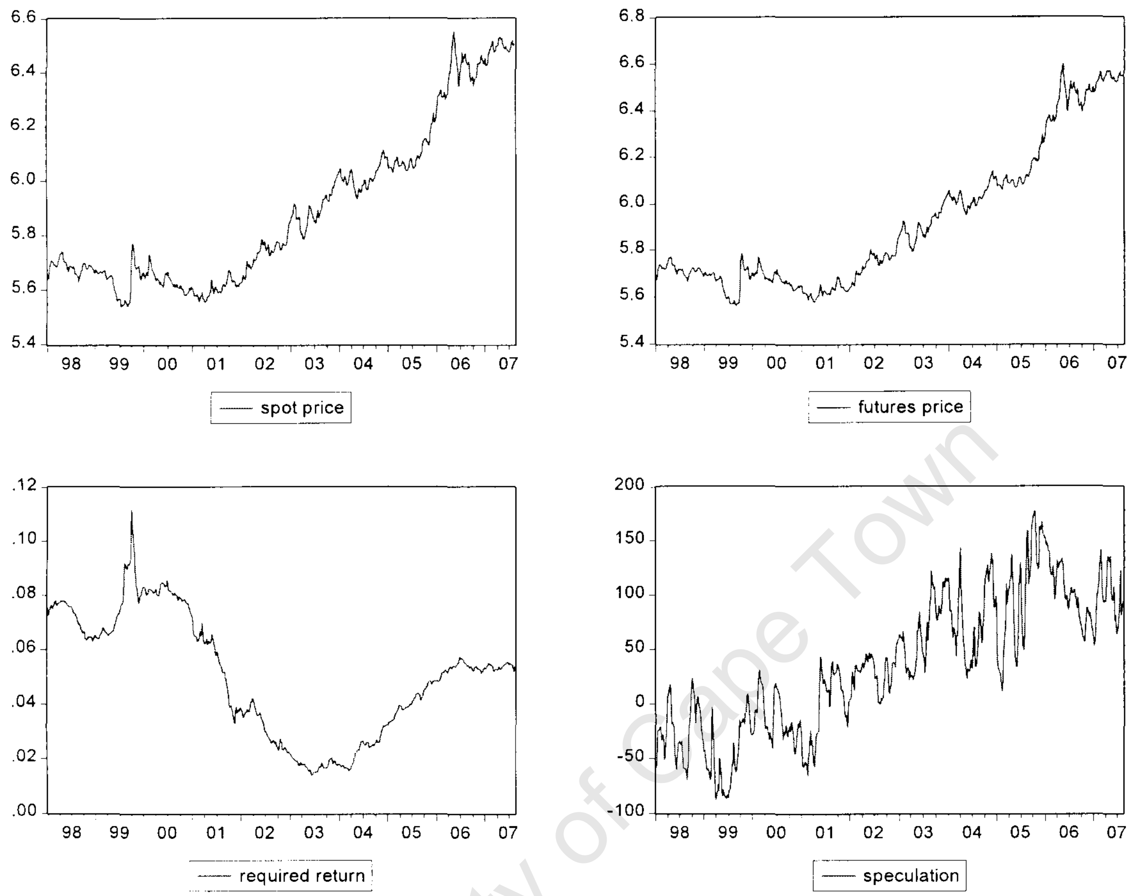
These results are different from those presented by Antoshin and Samiei (2006), see figure 2. The concurrent week's level of more or less speculation is associated with higher or lower prices. This effect is then corrected in the weeks that follow. These results show that it is the level of net long non-commercial contracts that is important in the price changes for light sweet crude oil and, not as per the previous study's estimates, the changes in number of net long positions. The charts in Appendix 1 indicate the pervasive and constant influence that speculation has on the change in prices.

6.3. Gold

6.3.1. Data characteristics

The amount of gold mined is a very small proportion of the world's stock of gold (Skousen, 2001). Any arbitrage trader can trade away disequilibria by borrowing gold from various institutions. The rate at which you can borrow the gold is known as the lease rate. The lease rate of gold is only available from 13 January 1998 and so we estimate the VECM from then to the end of August 2007. The required return for creating the arbitrage portfolio is equal to the one year lease rate plus the one year risk free rate. We show below the natural log of spot and futures prices, the continuously compounded required return and the number of net long non-commercial contracts.

Figure 10: Variables influencing the equilibrium price of Gold



We show the results of the unit root tests for spot and futures prices, the required return and the number of net long non-commercial contracts in millions of contracts below.

Augmented Dickey Fuller Unit Root Test - Gold

	Levels (y)			First difference (Δ y)		
Variable	τ	τ_μ	τ_τ	τ	τ_μ	τ_τ
Log of spot (s_t)	2.395	1.319	-1.776	-5.148**	-9.465**	-9.600**
Log of futures price (f_t)	2.388	1.355	-1.671	-4.988**	-5.361**	-9.521**
Required return (k_t	-1.087	-1.460	-0.902	-6.451**	-6.469**	-6.592**
Speculation (n_t)	-1.195	-1.799	-6.167**	-9.900**	-9.922**	-9.916**

*(**) denotes rejection of the hypothesis at the 5%(1%) level

The log of spot, the log of the futures price and the required return are all I(1). The number of net long non-commercial positions is also I(1). The I(1) characteristics of the speculation variable means that it is possible that speculation can have an effect on the equilibrium price of gold. Note the contrast with oil, where by the I(0) nature of speculation it followed that speculation could not cause (or be caused by) spot and futures prices.

6.3.2. Estimation

The nonstationary prices, required return and speculation variables are included in the long run equation. The effect of speculation is included in the long run specification of the VECM as speculation is nonstationary in the gold market.

$$\Delta y_t = \alpha(\beta' y_{t-1} + \mu) + \sum_{t=1}^{L_1 - 1} \Gamma \Delta y_t + \gamma + \epsilon \qquad (7)$$

Where $y_t = \begin{pmatrix} s_t \\ f_t \\ k_t \\ n_t \end{pmatrix}$

s_t is the natural logarithm of the spot price, f_t is the natural logarithm of the futures price, k_t is the continuously compounded required return – which includes the risk free rate and the lease rate, n_t is the number of millions of net long non-commercial contracts.

From the simple VAR estimation, the number of lags to include (using the Akaike Information Criterion) L_1 is ten. We test for cointegration specifying ten lags and an intercept term, but no linear trend. Both the maximum eigenvalue and trace statistic do not reject the hypothesis, at the 5% or 1% level of significance, that at least one cointegrating relationship does exist. The results are tabled below.

Unrestricted Cointegration Rank Test (Trace Statistic)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value
None	0.092651	72.35873**	47.21	54.46
At most 1	0.038530	24.61956	29.68	35.65
At most 2	0.009935	5.327199	15.41	20.04
At most 3	0.000865	0.424915	3.76	6.65

*(**) denotes rejection of the hypothesis at the 5%(1%) level
Trace test indicates 1 cointegrating equation(s) at both 5% and 1% levels

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5 Percent Critical Value	1 Percent Critical Value
None	0.092651	47.73917**	27.07	32.24
At most 1	0.038530	19.29236	20.97	25.52
At most 2	0.009935	4.902285	14.07	18.63
At most 3	0.000865	0.424915	3.76	6.65

*(**) denotes rejection of the hypothesis at the 5%(1%) level
Max-eigenvalue test indicates 1 cointegrating equation(s) at both 5% and 1% levels

6.3.3. Expectations of long run equilibrium coefficients

NYMEX lists contracts for gold that mature in Feb, April, June, August, October and December. As there are only six contracts per year, the time between the spot price and the one year futures price could vary between ten and twelve months. This mismatch (as with oil) will introduce systematic structure in the residuals of the long run equation.

However, as with oil the coefficients on the futures and returns variables are expected to be biased downward, below unity. This is as a result of the maturity mismatch between the required returns and the futures contract. The net long non-commercial positions (the proxy for speculation) ought to be statistically insignificant if speculation in the long run has no effect on prices.

It is expected that $\beta=\begin{pmatrix}+1\\-1\\+1\\0\end{pmatrix}$ given that $y_t=\begin{pmatrix}s_t\\f_t\\k_t\\n_t\end{pmatrix}$.

6.3.4. Long run estimation results

All the variables are highly significant and it can be seen that the long run coefficients, with the exception of speculation, are as expected. The theoretical equilibrium relationship between the required return, futures price and the spot price is supported by the empirical evidence. The significance of the speculations variable in the long run equilibrium equation suggest that speculation does affect equilibrium prices in the long run. Estimates of long run relationships over the full sample is shown below. The coefficient on spot price is normalised to -1 to provide sensible loading matrix coefficients.

Vector Error Correction Estimates – Long run effects of speculation in the market for Gold

	Spot price s_t	Futures price f_t	Required return k_t	Speculation n_t
Long run equilibrium (β)	-1.000	1.009**	-0.774**	-32.0E-05**
	n/a	(0.008)	(0.072)	(5.20E-05)
Speed of adjustment coefficients (α)	-0.380**	-0.412**	0.007	105.100
	(0.099)	(0.099)	(0.008)	(81.462)

*(**) denotes rejection of the hypothesis at the 5%(1%) level

Standard errors are given in parenthesis

As expected the required return coefficient is biased to below unity. The futures price coefficient, which had also been expected to be biased to below unity, is slightly higher than expected and at the 5% confidence limits not statistically different from one. The elasticity of the spot price, futures price and the required return to speculation (millions of net long non-commercial contracts) is 0.189%, 0.188% and 0.002%, respectively. The number of net long non-commercial contracts is associated with lower spot and futures prices. This analysis does not investigate the reasons for this, but the author suggests that this might be a valuable avenue for future research.

The adjustment coefficients indicate that speculation and required returns are exogenous. The adjustment coefficients on the price variables are statistically significant and negative.

Figures 11-13 show the evolution of the long run coefficients and the 90% confidence levels during the estimation period is shown. Following the methodology of Antoshin and Samiei (2006), a rolling VECM is estimated. In each regression the number of lags in the VAR is selected according to the Akaike Information Criterion and one cointegrating vector is specified. A window length of 7 years is used. The coefficient on the spot price has been restricted to -1. In each regression the number of lags in the VAR is selected according to the Akaike Information Criterion and one cointegrating vector is specified. The figures are indicative of a stable long run relationship between variables prior to 2006. The coefficients are consistent with the expected theoretical values.

Figure 11: Coefficient on the futures price in the equilibrium equation

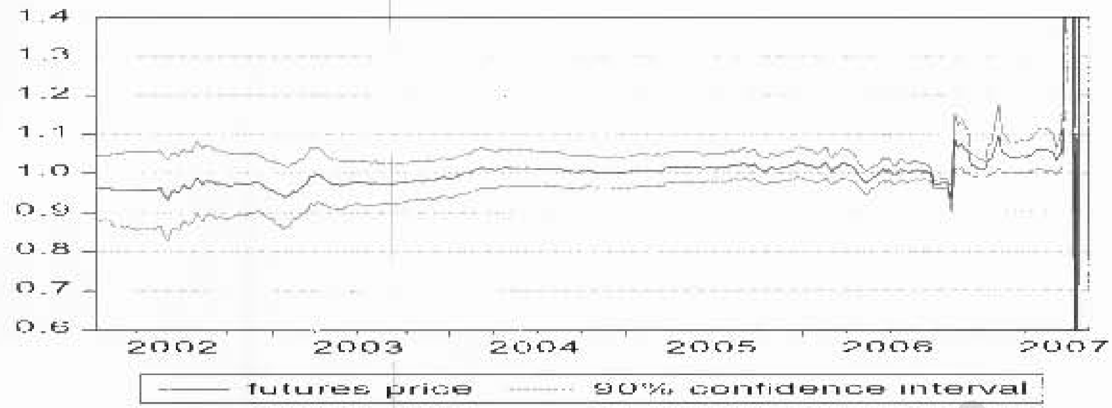


Figure 12: Coefficient on the required return in the equilibrium equation

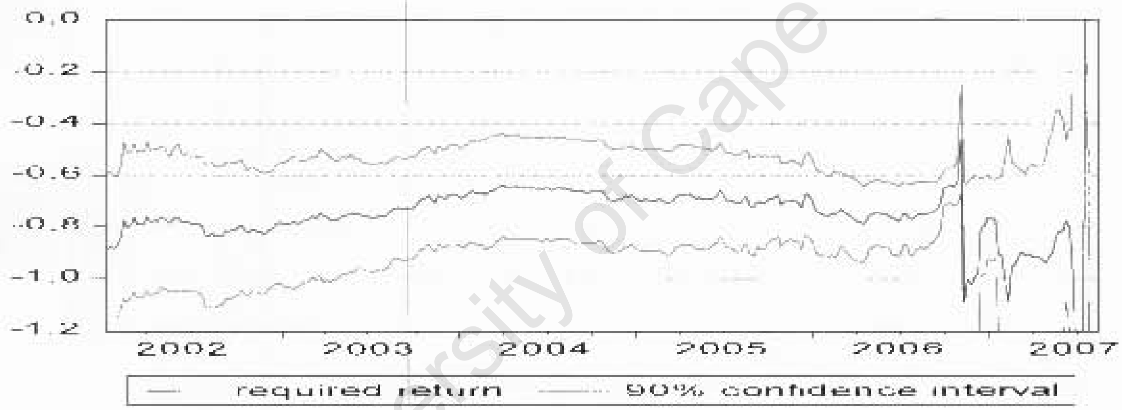
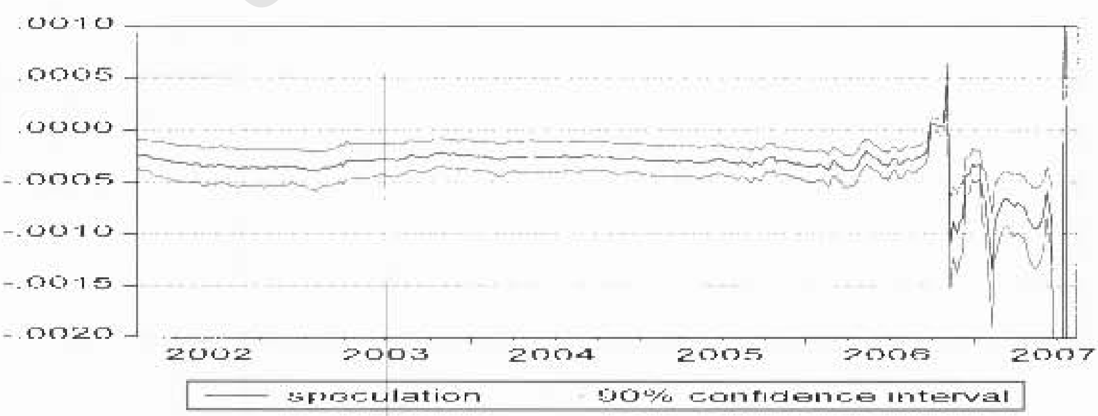


Figure 13: Coefficient on net long non-commercial positions in the equilibrium equation



Figures 14-17 show the evolution of the adjustment coefficients over time. Again it is noticeable how stable these relationships have been prior to 2006. Neither the required return nor the speculative positions coefficients are ever statistically significant at the 90% confidence level. Both spot and futures price coefficients are statistically significant throughout the estimation period.

Figure 14: Speed of adjustment coefficient on spot prices

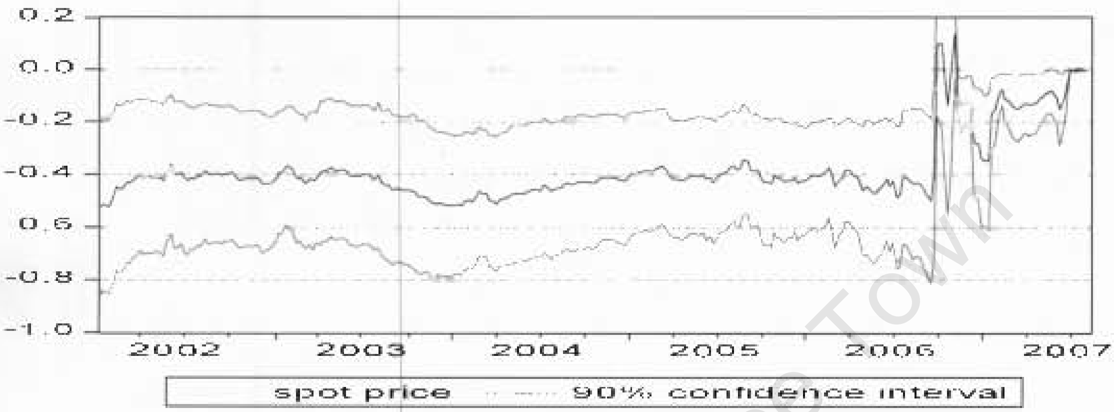


Figure 15: Speed of adjustment coefficient on futures prices

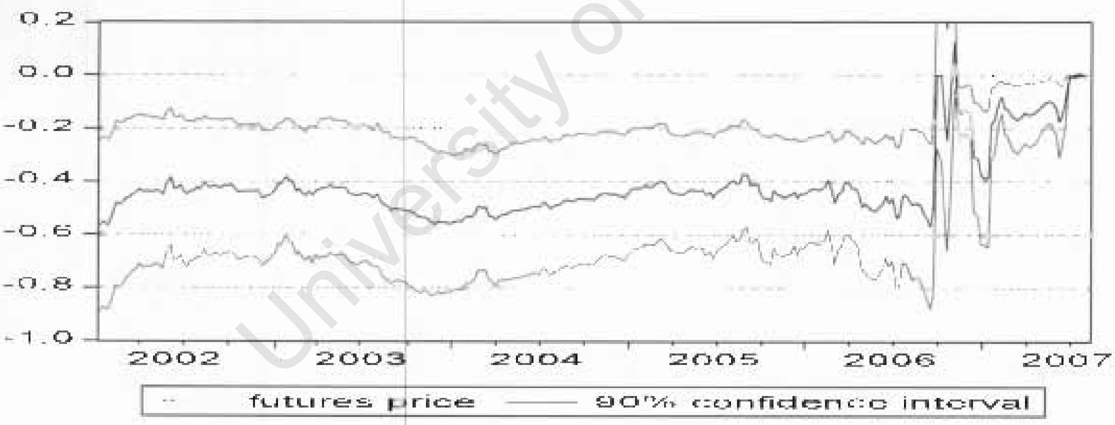


Figure 16: Speed of adjustment coefficient on required return

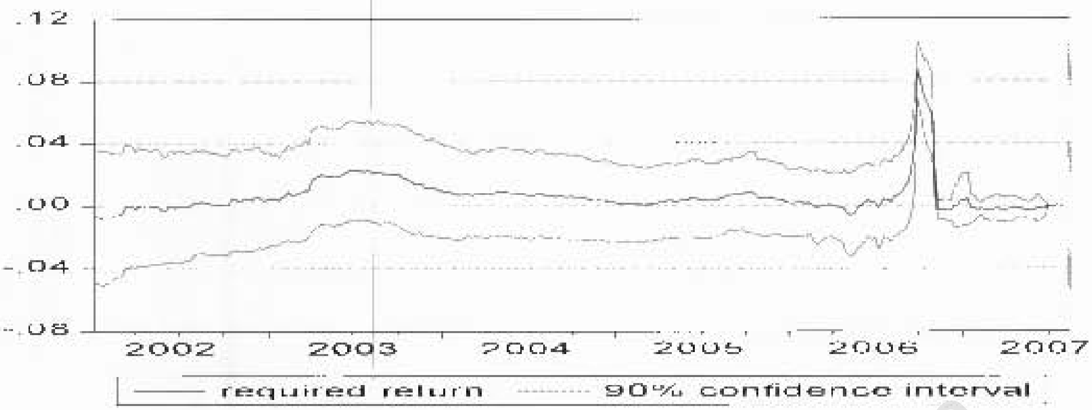
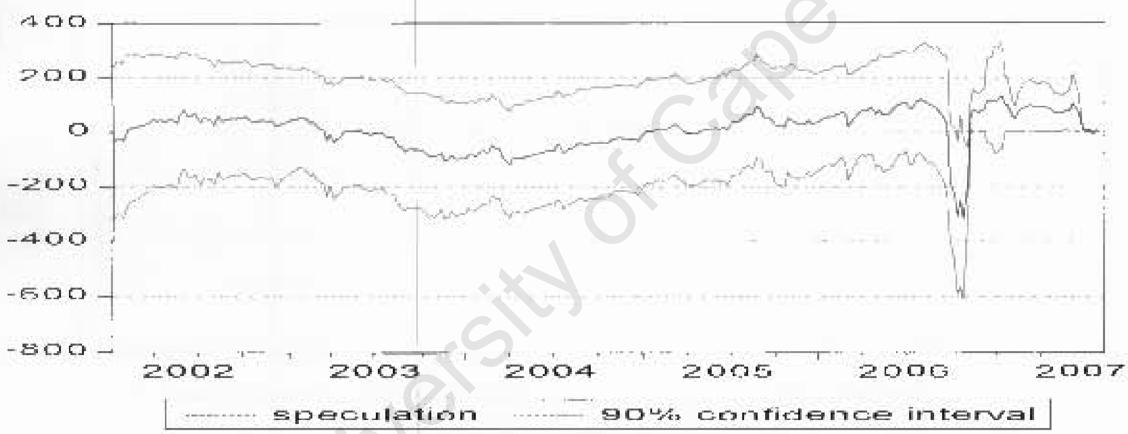


Figure 17: Speed of adjustment coefficient on net long non-commercial positions



6.3.5. Short run effects of speculation on the spot and futures price of gold

The short run dynamics show that both the spot and the futures price of gold respond to the previous week's change in the spot and future price, but that speculation is not responsive to these changes. In both instances speculation has a statistically significant effect on prices with a two week lag. As with the long run equation, the effect of more net long non-commercial contracts on prices is negative. Only significant coefficients (at the 5% level) on prices and speculation are reported.

Vector Error Correction Estimates – Short run effects of speculation

	Δf_t	Δs_t	Δn_t
Δf_{t-1}	-1.057**	-0.774**	-242.852
	(0.376)	(0.378)	(309.756)
Δf_{t-7}	-0.852**	-0.788**	-88.981
	(0.345)	(0.347)	(284.033)
Δf_{t-8}	0.703**	0.453**	214.276
	(0.347)	(0.347)	(285.417)
Δs_{t-1}	1.247**	0.954**	300.140
	(0.377)	(0.379)	(310.785)
Δs_{t-7}	0.726**	0.655**	79.529**
	(0.353)	(0.352)	(288.188)
Δs_{t-8}	-0.705**	-0.474**	-232.783**
	(0.350)	(0.352)	(288.399)
Δn_{t-2}	-23.4E-05**	-22.5E-05**	-0.069
	(7.1E-05)	(7.1E-05)	(0.058)
Δn_{t-3}	-0.000	-8.72E-05	-0.154**
	(7.2E-05)	(7.2E-05)	(0.059)

*(**) denotes rejection of the hypothesis at the 5%(1%) level

Standard errors are given in parenthesis

The coefficient on speculation (one week lagged) in the spot and futures price equation is never statistically significant. It can be concluded that speculation does not affect the spot and futures prices of gold one week later. The effect of speculation on the spot and futures price with a two week lag, however, shows the number of net long non-commercial positions have had a statistically significant and negative impact on both spot and futures prices. The evolution of the short run effects of speculation over time is shown in Appendix 1.

7. Conclusion

Antoshin and Samiei (2006) investigated the effect of speculation on commodity prices using a VECM. They included in their analysis the number of net long non-commercial positions and the spot and futures prices of the commodities they investigated.

In the market for oil the analysis in this paper found the number of net long non-commercial contracts, the proxy for speculation, to be stationary. Given the stationarity of the speculations variable it cannot be included in the long run equation. A stationary variable cannot in the long run explain the level of a nonstationary variable – in this case either spot or futures prices. Therefore this dissertation concurs with the results from the earlier study regarding long run causality. Speculation in the long run does not influence the level of spot and futures prices in the market for oil. However, the stationarity of the speculations variable also means that speculation cannot be caused by spot and futures prices. The speed of adjustment coefficients indicate that equilibrium in the oil market is not achieved through adjustments in prices, but through adjustments in inventories.

In contrast to the earlier study, speculation was included only in the short run equations and was found to have a statistically significant effect on the two price variables. In any week the level of net long non-commercial contracts is associated with changes in prices. More net long contracts is associated with positive change in the price variables. The over valuation that follows the increased speculation is then corrected in the weeks that follow, as can be seen by the consistently negative and significant coefficients on the one and two weeks lagged speculations variable.

The study also analyses the effect of speculation on the price of gold. The level of net long non-commercial contracts was found to be nonstationary and so was included in the long run equilibrium equation. The coefficient on speculation in the cointegrating equation was highly significant and, contrary to expectations, negative. This analysis does not investigate the possible reasons for this, but suggest that it would be a useful avenue for future research. The speed of adjustment coefficient on net long non-commercial contracts was not statistically significant, indicating that although speculation forms part of the long run equilibrium it is not the way in which equilibrium is achieved. In the market for gold, it is spot and futures prices that adjust to bring the market back to equilibrium.

In the short run equations, counter intuitively the effect of an increase in speculation appears to reduce the price of gold. Again, the coefficient on speculation (with a two week lag) was statistically significant and negative in both the spot price and futures price equation. A coefficient plot of the rolling regressions confirmed that this was true for all the periods that were estimated.

In both markets investigated, oil and gold, speculation has a pervasive and relatively stable effect on prices. In the instance of oil, speculation only has an effect in the short run, while the long run equilibrium price of oil is independent of the effects of speculation. In the gold market, however, speculation influences prices in both the short run and long run. This study also finds that, in both the short run and long run, speculation in the gold market does not respond to prices.

The dissertation applied a different specification of the long run spot-futures parity relationship than that used by Antoshin Samiei (2006). The results obtained differ from those of the original study as has been shown. The earlier study concluded that prices influence speculation rather than the other way around. This dissertation supports the common view that speculation influences prices and that prices do not always reflect only demand and supply fundamentals, but also a demand for speculative holdings predicated on the expected short run change in the value of the commodities.

8. Appendix 1

8.1. *Short run effect of speculation*

8.1.1. Light sweet crude oil

Figure 18: Effect of speculation on spot prices

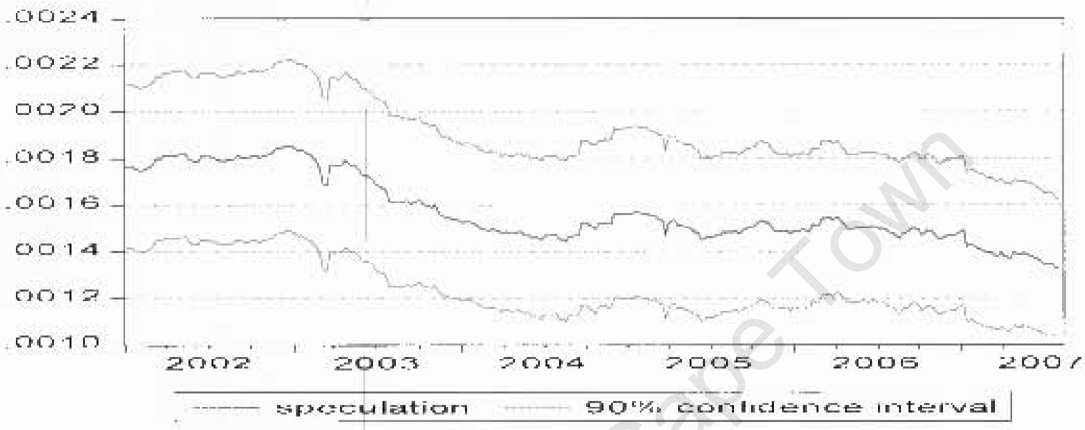


Figure 19: Effect of speculation on futures prices

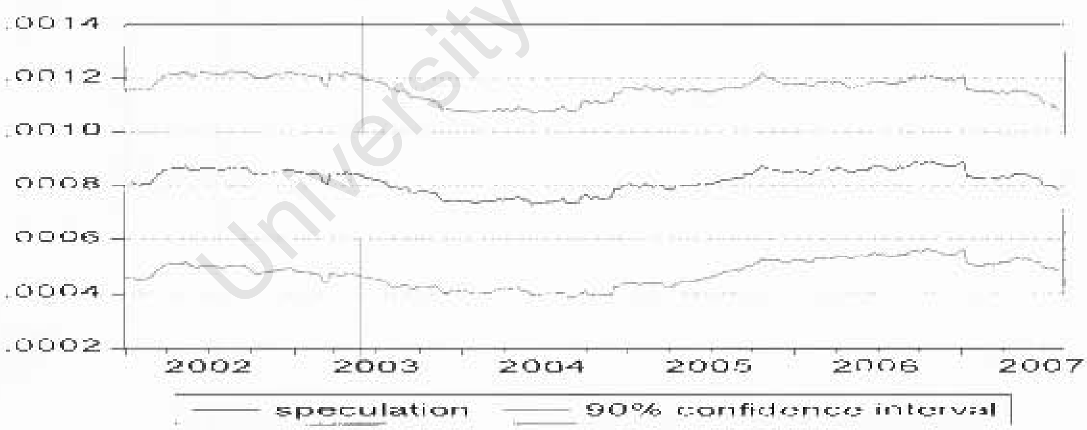


Figure 20: Effect of speculation (one week lagged) on spot prices

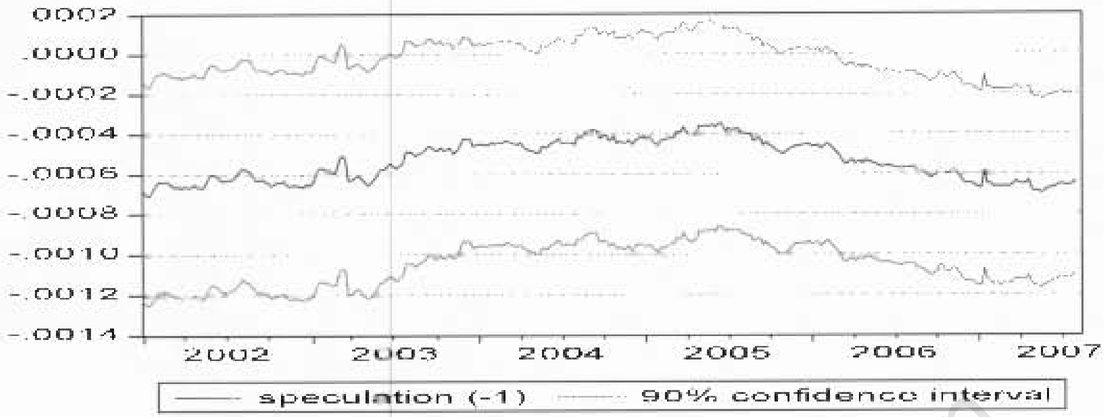


Figure 21: Effect of speculation (one week lagged) on futures prices

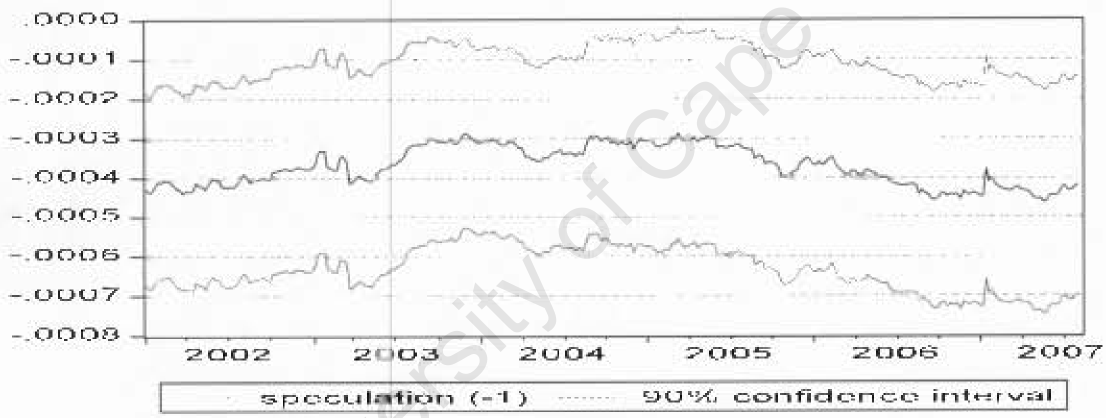


Figure 22: Effect of speculation (two weeks lagged) on spot prices

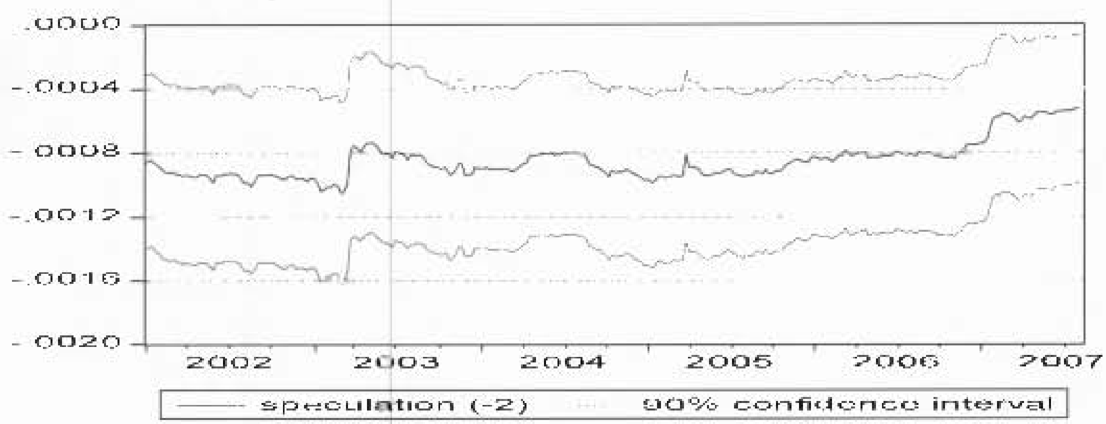
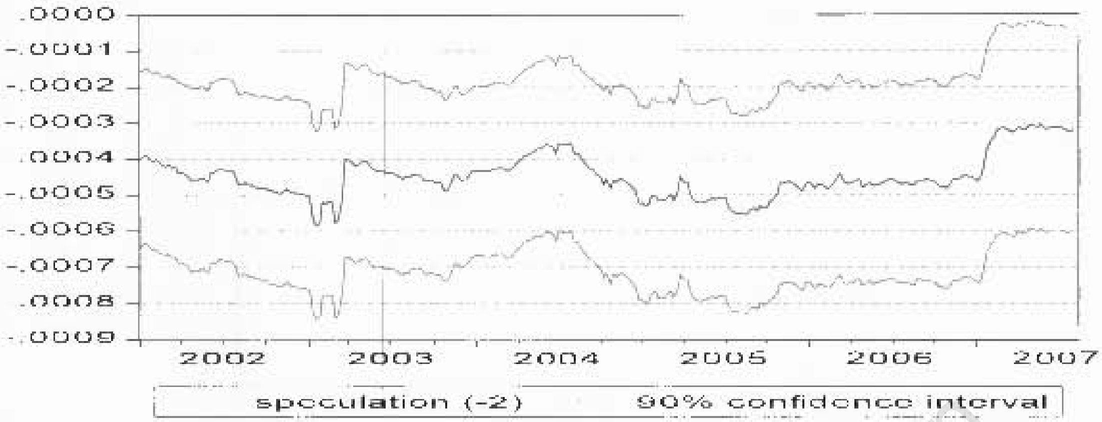


Figure 23: Effect of speculation (two weeks lagged) on futures prices



8.1.2. Gold

Figure 24: Effect of speculation (one week lagged) on spot prices

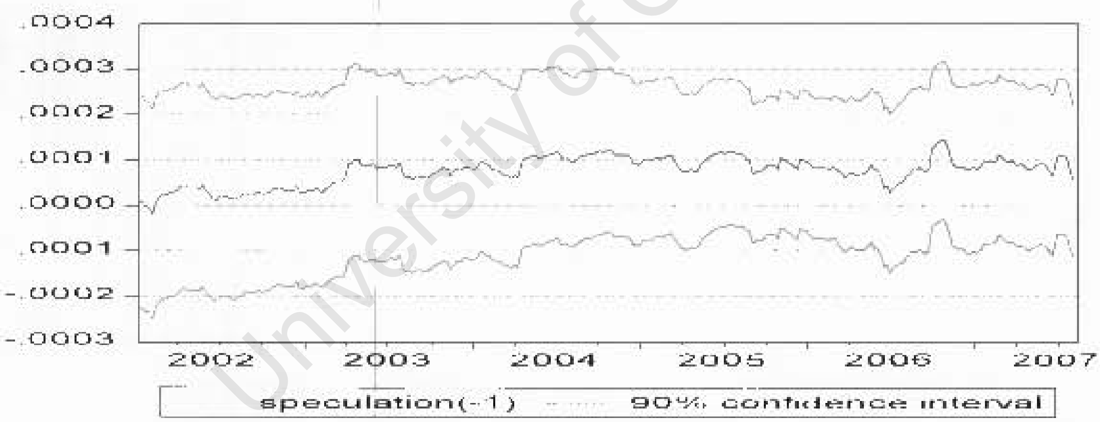


Figure 25: Effect of speculation (two weeks lagged) on spot prices

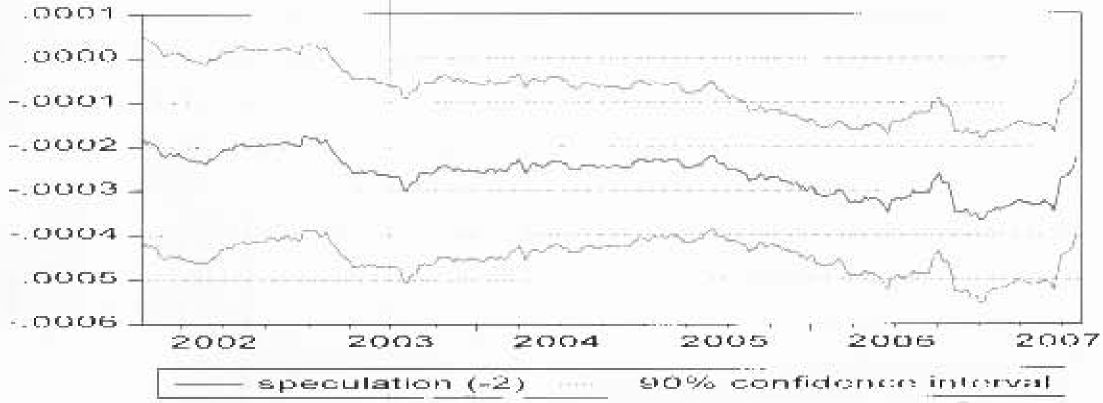


Figure 26: Effect of speculation (one week lagged) on futures prices

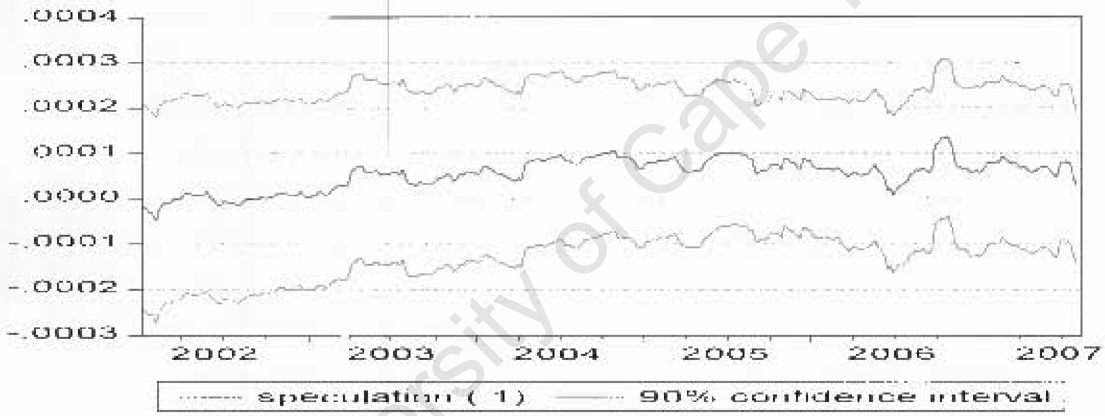
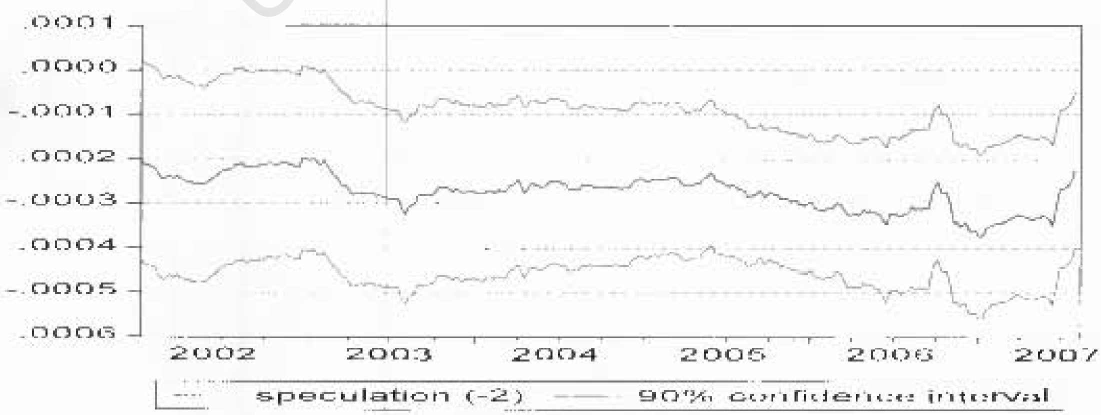


Figure 27: Effect of speculation (two weeks lagged) on futures prices



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