Simulation-Based Analysis of the Efficiency of the NYMEX Natural Gas Futures Market

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Introduction

- Movassagh and Modjtahedi (2005, Journal of Futures Markets) tested the efficient market hypothesis for the NYMEX natural gas futures market. They found,
  - Futures prices are downward biased with bias increasing with the time to maturity of the contracts for 1990-2003.
- We illustrate:
  1. Conventional tests of futures price bias are subject to two sources of biases: (i) econometric issues due to features unique to natural gas price data, (ii) sample selection bias (the market is studied more frequently after unusual events).
  2. The test statistics obtained with the NYMEX data lie within their Monte Carlo distributions deduced from the calibration of the one-factor mean-reversion model of Schwartz (1991).

$\Rightarrow$ No evidence for the bias in the NYMEX natural gas futures prices.

Common tests for futures price bias

- Two regressions,

  (1) ${}_tF_t - {}_tF_{t-k} = \alpha + e_{k,t}$

  (2) ${}_tF_t = \alpha + \beta\, {}_tF_{t-k} + e_{k,t}$

  where

  ${}_tF_t$ = spot (nearby futures) price for delivery at month *t,*

  ${}_tF_{t-k}$ = futures price traded at $t - k$ for delivery at month *t,*

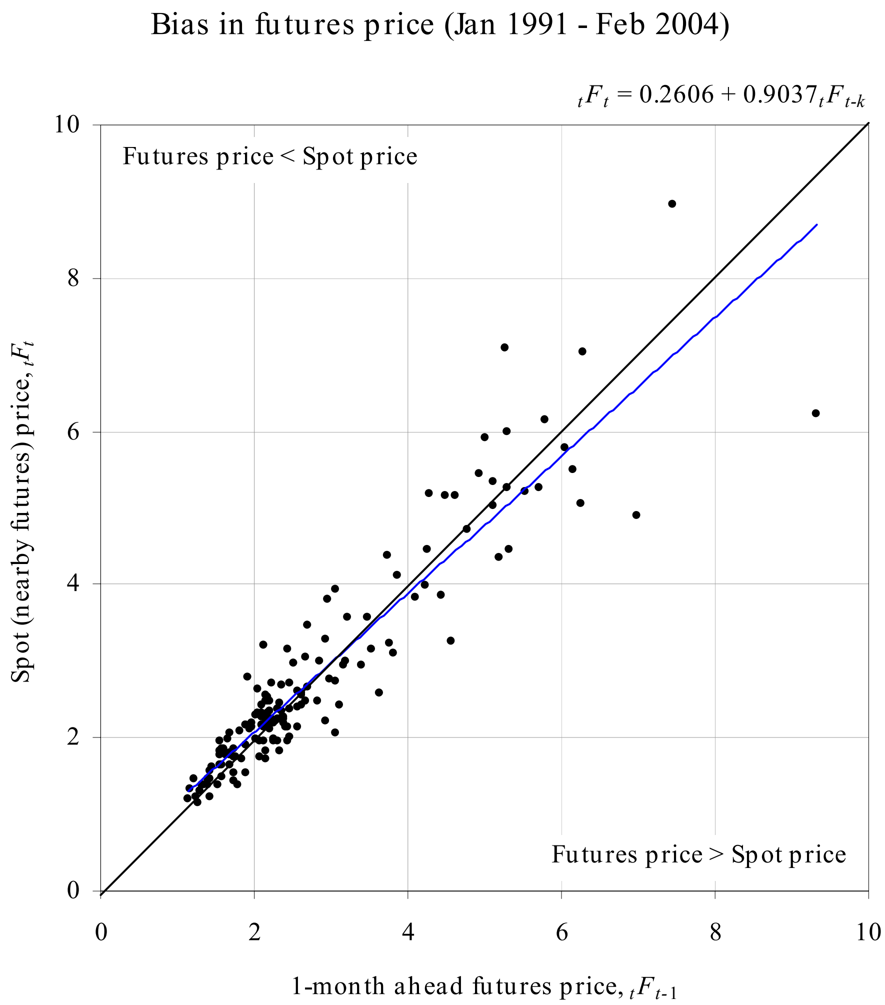
  $E[e_{k,t}] = 0$

- The null hypothesis of unbiased futures price is tested by,

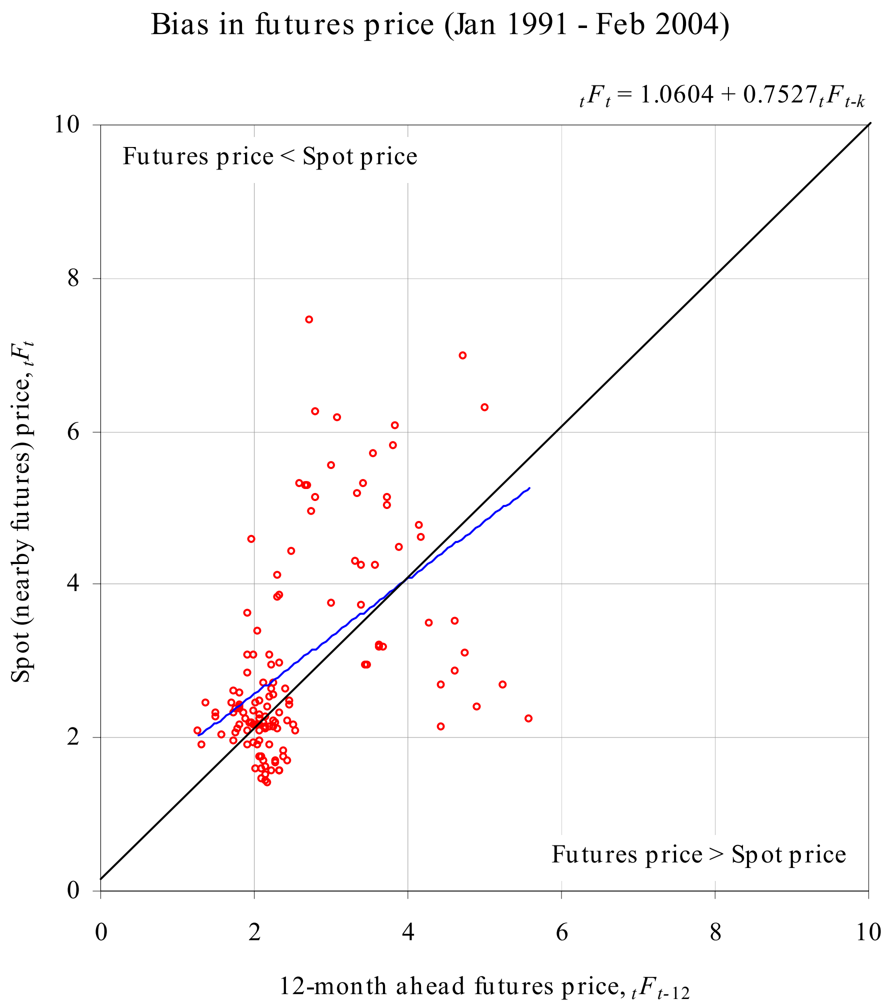
  $\alpha = 0$ in (1)

  $\alpha = 0$ and $\beta = 1$ in (2).

Graphical representations of the second regression



Graphical representations (cont.)



Issues in estimating (1) and (2): I – Econometric Issues

- For both (1) and (2), $e_{k,t}$ is serially correlated and heteroskedastic.

$\Rightarrow$ Heteroskedasticity and autocorrelation consistent (HAC) covariance matrix such as the one suggested by Newey and West (1987).

- ${}_tF_{t-k}$ in the right-hand side of (2) is correlated with the past forecast errors ($\approx$ 0.30, due to serial correlation in the underlying market shocks, storage), causing bias in the OLS estimates of α and β.

$\Rightarrow$ Two methods are used to estimate (2):

1. If ${}_tF_{t-k}$ and ${}_tF_t$ are stationary, the OLS estimates are biased while consistent (bias diminishes with sample size).
2. If ${}_tF_{t-k}$ and ${}_tF_t$ are non-stationary and cointegrated, Dynamic OLS (DOLS) of Stock and Watson (1993) is more efficient than (static) OLS.

Econometric Issues – cont.

BUT, there are some issues in these methods:

- Consistency of NW standard errors and OLS estimates of α and β in (2) means that the bias diminishes with the sample size.

$\Rightarrow$ Is the sample size of 150+ sufficient to say the bias is negligible?

- It is difficult to test if the price series are non-stationary when they are highly persistent. We don't have a good tool to determine whether to estimate (2) by OLS or DOLS.

$\Rightarrow$ Does the futures price follow unit-root? If not, DOLS can create bias larger than OLS (Elliott, 1998).

$\Rightarrow$ Is the bias greater for OLS or for DOLS, specially for natural gas?

Approach – Simulation Design

1. Estimate a one-factor mean-reversion model using the NYMEX data,

$$p_t = a_0 + a_1 t + a_2 \sin\left(\tfrac{2\pi t}{12}\right) + a_3 \cos\left(\tfrac{2\pi t}{12}\right) + a_4 \sin\left(\tfrac{2\pi t}{6}\right) + a_5 \cos\left(\tfrac{2\pi t}{6}\right) + X_t$$

$$X_t = \rho X_{t-1} + u_t \qquad u_t \sim \mathrm{N}(0, \sigma^2)$$

2. Generate simulated spot price from the estimated price dynamics model and unbiased futures price as the best possible, unbiased forecast,

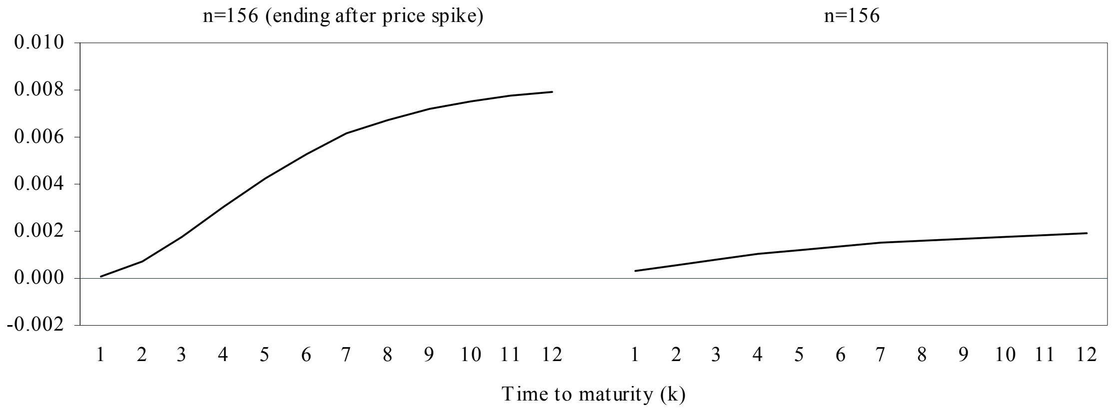
$$_t f_{t-k} = \mathrm{E}_{t-k}[p_t] = f(t) + \rho^k X_{t-k}$$

3. Estimate (1) and (2) using the simulated data in two styles of samples:
   - N = 156 months – observation period randomly selected,
   - N = 156 months – observation period truncated two months after a major price spike.

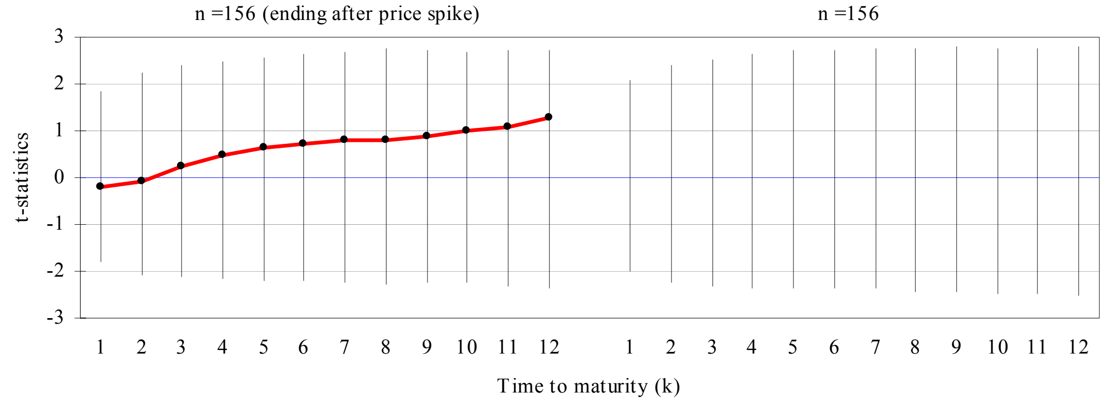
4. Repeat 1,000 times to deduce the Monte Carlo distributions and contrast with the empirical estimates.

Results – Bias in α and Monte Carlo confidence intervals in (1)

- Coefficient estimate of α

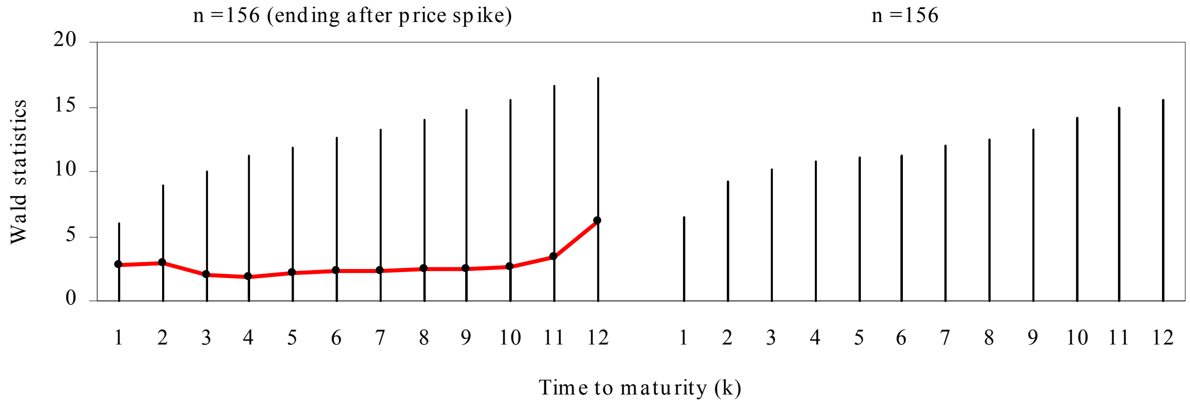


- Confidence intervals of NW HAC t-statistics

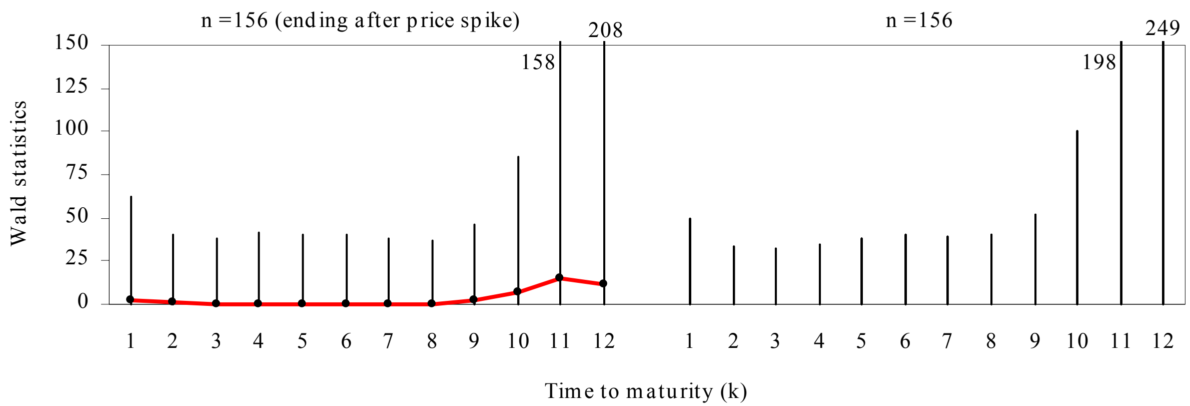


Results – Critical values of Wald-statistics for $\alpha = 0$ and $\beta = 1$

- OLS



- DOLS



Conclusions

- The conventional unit-root tests implies that the NYMEX natural gas futures prices are non-stationarity, suggesting the use of DOLS.
- For the available sample size, both OLS and DOLS yield the biased estimates of (2), with bias greater for DOLS than for OLS.
- For the available sample size, NW HAC standard errors are too small.
- Truncating the sample period shortly after price spikes implies downward bias in the futures price with bias increasing with time to maturity of the contracts.

⇒ All these lead to conclude that the futures price is biased.

- Issues are attributable to the properties of natural gas price series.
- Using Monte Carlo critical value consistent with the features observed with the NYMEX data, instead of theoretical value, implies no significant bias in the futures prices for 1/1991-12/2003.