The effects of shale gas on risk premium and volatility in the US gas prices

Fernando Aiube

aiube@puc-rio.br

Pontifical Catholic University of Rio de Janeiro

Petrobras

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Outline

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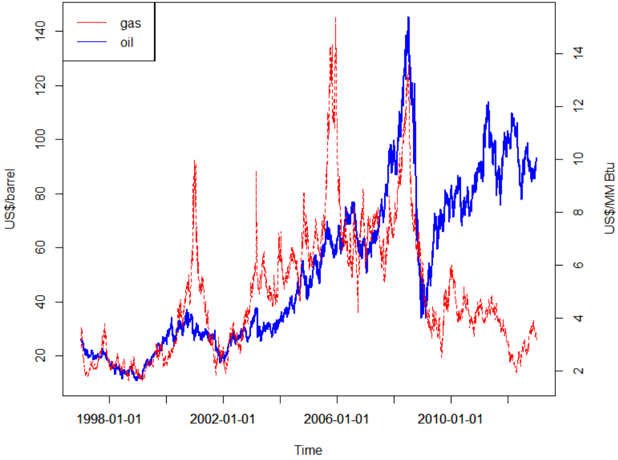
Oil and Gas prices



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EMPIRICAL PROCEDURE

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- Rational expectation, $S_{t+1} = E^P(S_{t+1}|\mathcal{F}_t) + \epsilon_{t+1}$, is used to conduct regressions on $RP_{t,T}$ equation
- $S_T - S_t$ is regressed against the difference $F_{t,T} - S_t$ (basis): in significance case, basis contains information about expected change in spot price: $F_{t,T}$ has power to forecast S_T

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- Motivation: whether there is any connection between the volatility of crude oil and the increased position in commodity-index funds
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Let's consider:

- the partition: $0 = t_0 < t_1 \ldots t_n = T$, with $t_i = i\Delta_n$
- In a high frequency scheme: $n \to \infty$, $\Delta_n \to 0$, with $n\Delta_n = T$
- The solution of the problem is an adaptation of the least squares approach of Bai (1994) for AR models. Following Euler scheme the std residuals are

$$Z_i = \frac{X_{i+1} - X_i - b(X_i)\,\Delta_n}{\sqrt{\Delta_n}\sigma(X_i)}, \qquad i = 1, \ldots, n$$

- Defining $k_0 = [n\tau^\star]$ and $k = [n\tau]$ where $\tau, \tau^\star \in (0,1)$ and $[x]$ is the integer part of real value of x
- The least square estimator of the change point is given by

$$\hat{k}_0 = \arg\min_k \left(\sum_{i=1}^{k} \left(Z_i^2 - \bar{\theta}_1\right)^2 + \sum \left(Z_i^2 - \bar{\theta}_2\right)^2 \right)$$

Change point

where

$$\bar{\theta}_1 = \frac{1}{k}\sum_{i=1}^{k} Z_i^2 \quad \text{and} \quad \bar{\theta}_2 = \frac{1}{n-k}\sum_{i=k+1}^{n} Z_i^2$$

- Once $\hat{k}_0$ is obtained we get

$$\hat{\theta}_1 = \frac{1}{\hat{k}_0}\sum_{i=1}^{\hat{k}_0} Z_i^2 \quad \text{and} \quad \hat{\theta}_2 = \frac{1}{n-\hat{k}_0}\sum_{i=\hat{k}_0+1}^{n} Z_i^2$$

- Under the technical conditions $\hat{\theta}_1$ and $\hat{\theta}_2$ are $\sqrt{n}$-consistent such that

$$\sqrt{n}\begin{pmatrix} \hat{\theta}_1 - \theta_1 \\ \hat{\theta}_2 - \theta_2 \end{pmatrix} \xrightarrow{d} N(0, \Sigma) \quad \text{where} \quad \Sigma = \begin{pmatrix} 2\frac{\theta_0^2}{\tau^\star} & 0 \\ 0 & 2\frac{\theta_0^2}{1-\tau^\star} \end{pmatrix}$$

CHANGE POINT

- The results above hold in high frequency $\Delta_n \to 0$, $n \to \infty$ and $n\Delta = T$
- The drift estimator $b(\cdot)$ is estimated in a non-parametric way
- Let $K \geq 0$ be a kernel function and h_n the bandwidth, then

$$\hat{b}(x) = \frac{\sum_{i=1}^{n} K\left(\frac{X_i - x}{h_n}\right) \frac{X_{i+1} - X_i}{\Delta_n}}{\sum_{i=1}^{n} K\left(\frac{X_i - x}{h_n}\right)}$$

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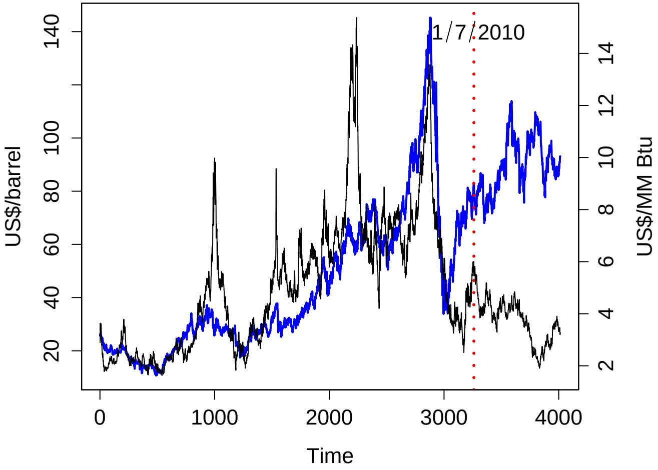

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(II) A highly publicized study was released by American Clean Skies Foundation quantifying for the first time the impact of the unconventional supply growth

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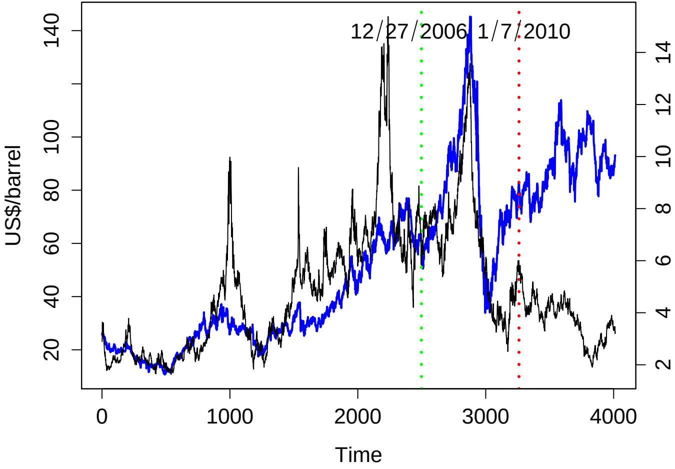

IMPLIED-RISK PREMIUM

- Considering liquid contracts we chose 7 future series traded on NYMEX from 03/26/1997 to 10/03/2012
- Calibration of the two periods using the KF and the maximization of likelihood

TABLE : Implied risk premium (US$/MM Btu)

	$\mathbb{F}_1$	$\mathbb{F}_5$	$\mathbb{F}_{10}$	$\mathbb{F}_{15}$	$\mathbb{F}_{20}$	$\mathbb{F}_{25}$	$\mathbb{F}_{30}$
First period	0.1974	1.4522	3.1054	4.1002	5.1993	6.9243	7.2030
Second period	-0.0050	-0.0438	-0.1017	-0.1567	-0.2143	-0.2966	-0.3400

TABLE : Relation RP to spot price

	$\mathbb{F}_1$	$\mathbb{F}_5$	$\mathbb{F}_{10}$	$\mathbb{F}_{15}$	$\mathbb{F}_{20}$	$\mathbb{F}_{25}$	$\mathbb{F}_{30}$
First period	0.0428	0.3192	0.6896	0.9157	1.1641	1.5521	1.6156
Second period	-0.0014	-0.0119	-0.0279	-0.0432	-0.0592	-0.0821	-0.0942

COMMENTS AND RESULTS ON IMPLIED RP

- The first period Jan-97 to Dec-06 is in normal backwardation (producers hedge: go short)
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MODELS SET UP

The ARMA (r,s) for the unseasoned conditional mean z_t is given by

$$\Phi(L) z_t = \Theta(L) \epsilon_t \qquad z_t = y_t - \sum_{i=1}^{4} S_i D_i$$

$\Phi(L) = 1 - \ldots - \phi_r L^r$, $\Theta(L) = 1 + \ldots + \theta_s L^s$
The GARCH(p,q) for conditional variance σ_t^2 is given by

$$\sigma_t^2 = \omega + \alpha(L) \epsilon_t^2 + \beta(L) \sigma_t^2$$

$$\omega > 0, \quad \alpha(L) = \alpha_1 L + \ldots + \alpha_q L^q, \quad \beta(L) = \beta_1 L + \ldots + \beta_p L^p$$

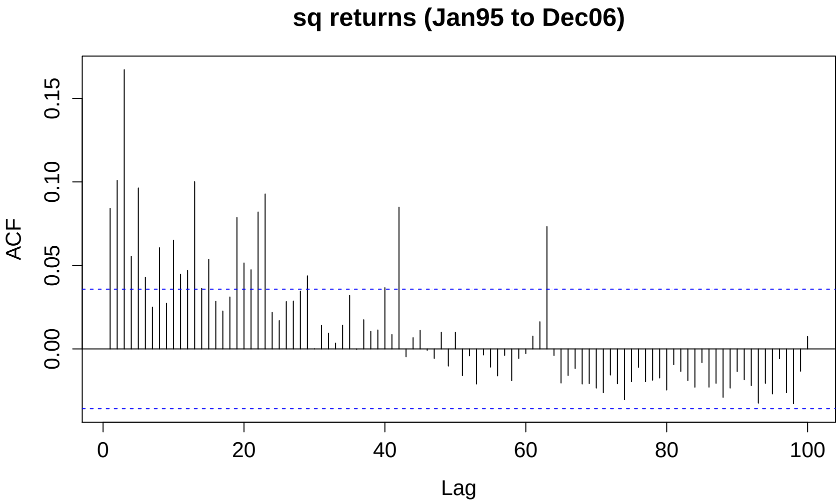
MODELS SET UP

The FIAPARCH(p,d,q) for σ_t is written as

$$\sigma_t^{\delta} = \omega \left[1 - \beta(L)\right]^{-1} + \left[1 - \left[1 - \beta(L)\right]^{-1} \varphi(L)(1 - L)^{d}\right] (|\epsilon_t| - \gamma\epsilon_t)^{\delta}$$

$$\delta > 0, \quad 0 \leq d \leq 1, \quad \varphi(L) = 1 - \alpha(L) - \beta(L)$$

ACF - LONG MEMORY

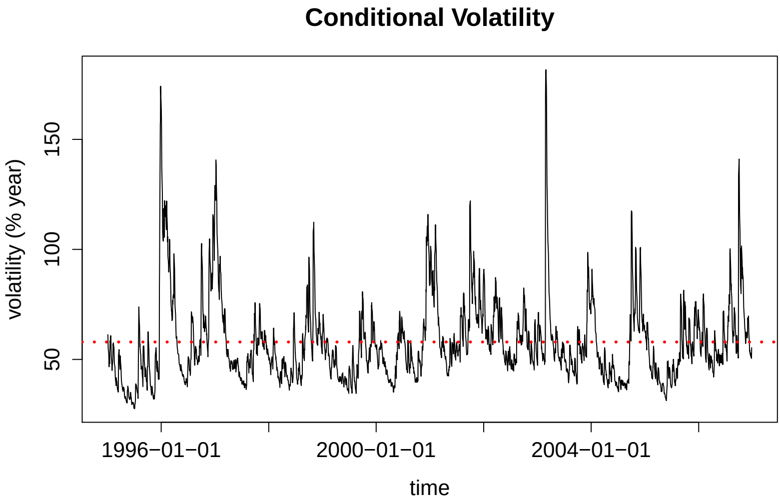


ESTIMATION RESULTS

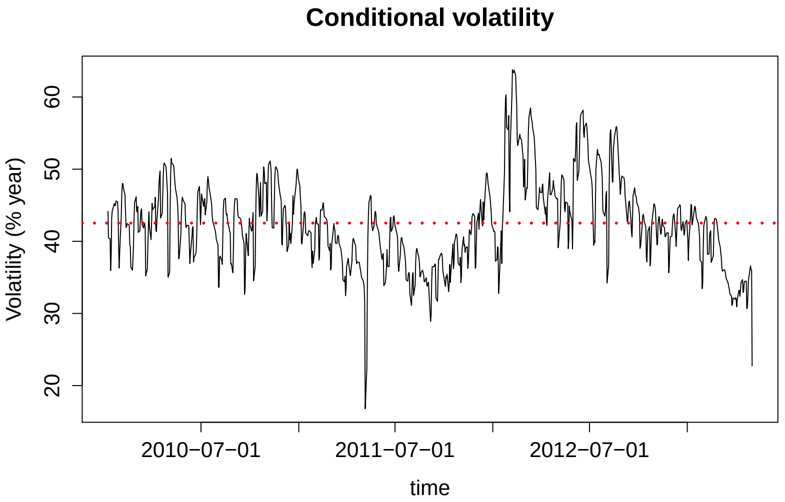
TABLE : Main results of the estimation

Parameter	First period		Second period	
	Value	p-value	Value	p-value
d	0.39500	0.0000	0.30331	0.0395
γ	-0.24830	0.0011	0.76682	0.3012
δ	1.87100	0.0000	1.59497	0.0019
$\bar{\sigma}_{fiaparch}$	57.92	–	42.52	–
$\bar{\sigma}_{fiaparchJun04}$	58.01	–	–	–

CONDITIONAL VOL - 1ST PERIOD



CONDITIONAL VOL - 2ND PERIOD



VOLATILITIES

Volatility (% year)	First period	Second period
$\bar{\sigma}_{fiaparch}$	57.92	42.52
$\sigma_{historical}$	62.41	43.31
$\sigma_{chpoint}$	59.07	46.09

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CONCLUSION

- The results obtained with Schwartz and Smith's model for the RP are in accordance with those in empirical research for the period before the low price regime
- Using a Gaussian model it is easy to obtain insights on the nature of RPs involved in futures prices. More complex models to capture the spiky nature of prices of natural gas will impose time consuming techniques on the estimation (Cartea and Williams (2007))

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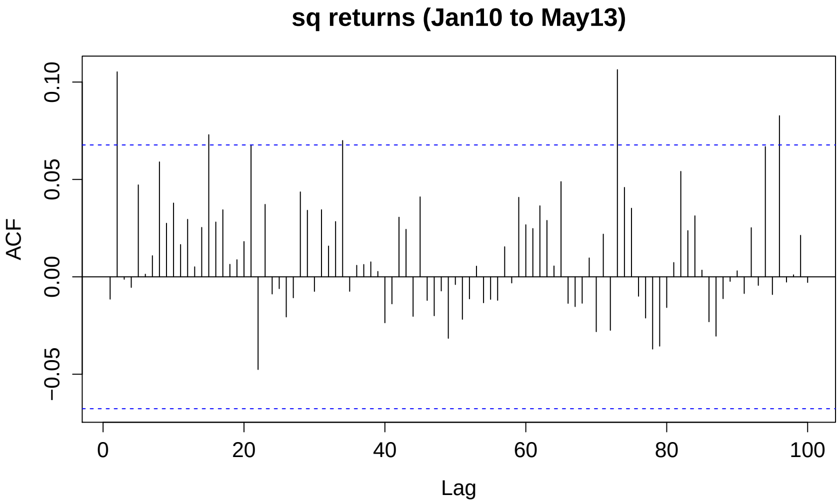


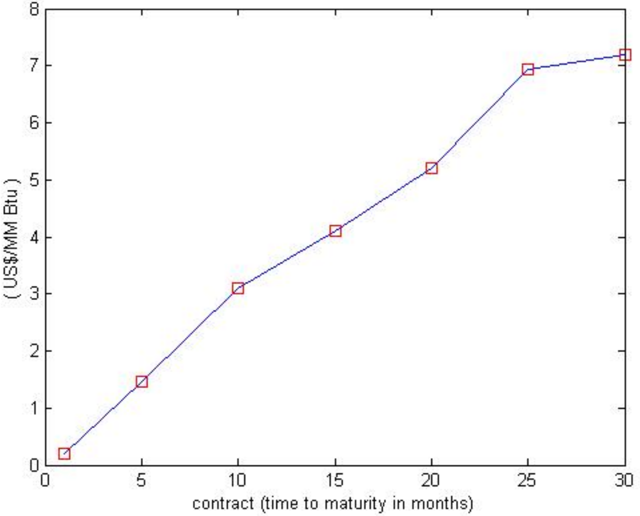
ESTIMATION RESULTS

TABLE : Estimation results for both periods

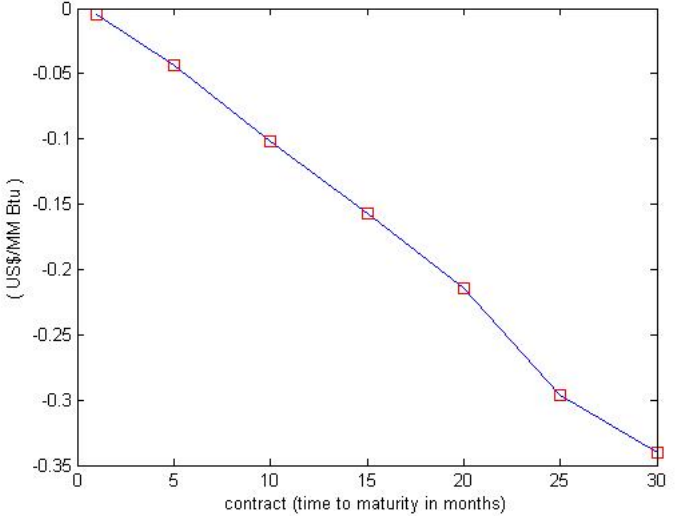
Parameter	first period MLE value	first period Std error	second period MLE value	second period Std error
κ	1.5324***	0.0180	1.2170***	0.0213
σ_χ	0.6123***	0.0113	0.3502***	0.0149
μ_ξ	0.1682***	0.0476	−0.1086	0.0796
σ_ξ	0.1490***	0.0044	0.1460***	0.0065
ρ	0.1826***	0.0405	0.4327***	0.0464
λ_χ	0.6885***	0.0337	−0.0068	0.0160
$\mu_\xi^\star$	−0.0555***	0.0011	0.0291***	0.0016
α_1	0.0714***	0.0004	0.0412***	0.0004
β_1	0.0291***	0.0009	0.0001	0.0015
α_2	0.0283***	0.0004	0.0200***	0.0004
β_2	−0.0028**	0.0011	0.0039***	0.0014

Note: asterisks *, **, *** denote 10%, 5% and 1% significance level, respectively.

RP IN THE FIRST PERIOD



RP IN THE SECOND PERIOD



Studies using Schwartz and Smith's model

- Manoliu and Tompaidis (2002) analyzed US natural gas market
- Sørensen (2002) studied the seasonality in agricultural commodities
- Lucia and Schwartz (2002) and Villaplana (2004) analyzed the electricity markets
- Bernard, Khalaf, Kichian and McMahon (2008) investigated oil prices focusing on the forecasting out-of-sample
- Aiube, Baidya e Tito (2008) extended the model including jumps in the specification
- Kolos and Ronn (2008) studied the market price of risk
- Cartea and Williams (2007) investigated the market price of risk in UK natural gas market

SCHWARTZ AND SMITH'S MODEL UNDER P-MEASURE

$$\begin{aligned} \ln(S_t) &= f(t) + \chi_t + \xi_t \\ d\chi_t &= -\kappa\chi_t dt + \sigma_\chi dB_{\chi_t} \\ d\xi_t &= \mu_\xi dt + \sigma_\xi dB_{\xi_t} \end{aligned}$$

$$f(t) = \alpha_1 cos\left[2\pi\left(t + \beta_1\right)\right] + \alpha_2 cos\left[4\pi\left(t + \beta_2\right)\right].$$

ESTIMATION RESULTS

Parameter	First period		Second period	
	Value	p-value	Value	p-value
S_1	-0.00002	0.9871	-0.00273	0.0905
S_2	0.00151	0.0774	0.001263	0.5211
S_3	-0.00071	0.5714	-0.00269	0.0863
S_4	0.00147	0.3786	-0.00036	0.8513
ω	0.001753	0.1493	0.002695	0.5613
d	0.39500	0.0000	0.30331	0.0395
α	0.20268	0.0843	0.3550	0.0252
β	0.52606	0.011	0.69131	0.0000
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δ	1.87100	0.0000	1.59497	0.0019
ν	5.71661	0.0000	11.84982	0.0098
$\bar{\sigma}$	57.92	–	42.52	–
$\bar{\sigma}_{Jun04}$	58.01	–	–	–

LONG MEMORY

$$(1-L)^d = \sum_{j=0}^{\infty} \vartheta_j L^j = \sum_{j=0}^{\infty} \binom{d}{j} (-L)^j \, .$$