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NOTE:

The following Presentation represents *Work in Progress* for discussion at the EMEE2010 workshop. It therefore must not be referred to without the consent of the author(s).

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EMEE 2010
On the Dynamics of Gasoline-Crude Crack Spreads

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Motivation: Lets Read Some Aristotle

Story about Thales the Milesian (chapter XI of Politics)

He knew by his skill in the stars while it was yet winter that there would be a great harvest of olives in the coming year; so, having a little money, he gave deposits for the use of all the olive-presses in Chios and Miletus, which he hired at a low price because no one bid against him. When the harvest-time came, and many were wanted all at once and of a sudden, he let them out at any rate which he pleased, and made a quantity of money.

Conclusion

1) Philosophers can easily be rich if they like, but their ambition is of another sort (Aristotle).
2) Understanding of spreads is important

Frictions Leading to Dynamics Spreads

1. Capacity related costs and capacity constraints
2. Production adjustment costs
3. Costly inventories
4. ?

At this version of the paper we only focus on the first mechanism!

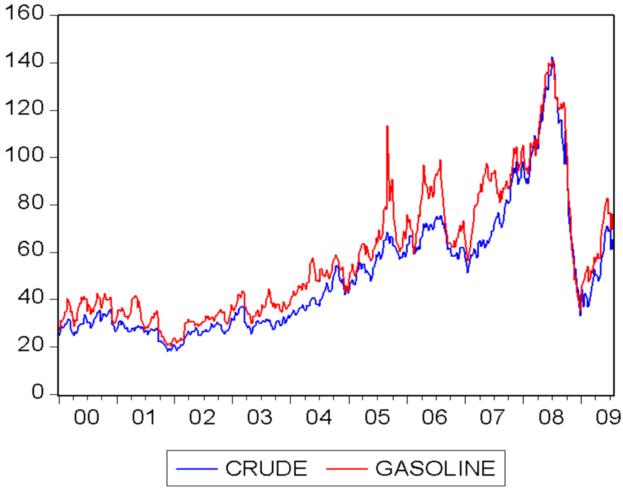
Why the Study of Spreads is Important?

1. Optimal hedging under input/output uncertainty
2. Vertical investments
3. Valuation (Do analysts care?)
4. ...

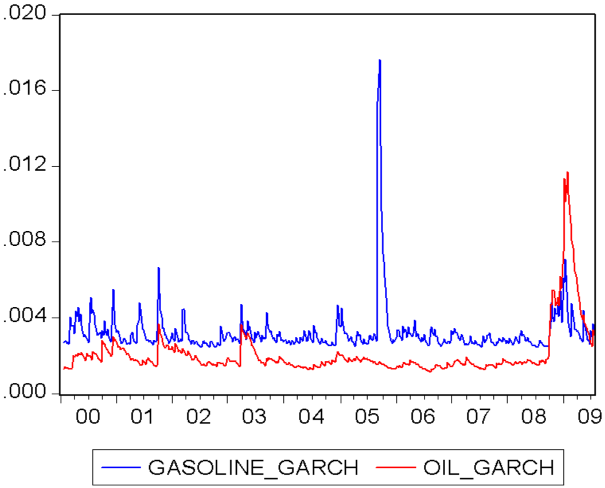
Review of Literature

- IO: cost pass through (effect of Katrina in the case of gasoline)
- Volatility spill–over (mostly empirical)
- Asymmetric response of gasoline retail prices to changes in oil price
- Delay in gasoline price response: Inventories and adjustment costs
- Spread options pricing: Exogenous stochastic processes

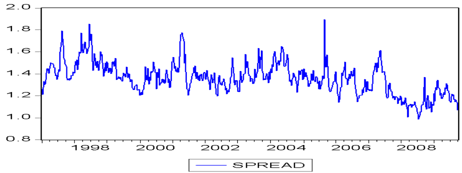
Weekly Price of Crude and Gasoline

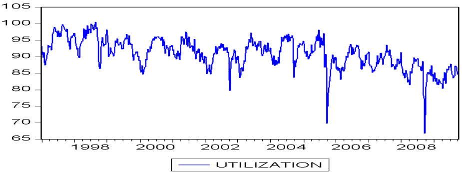


Garch Series for Crude and Gasoline



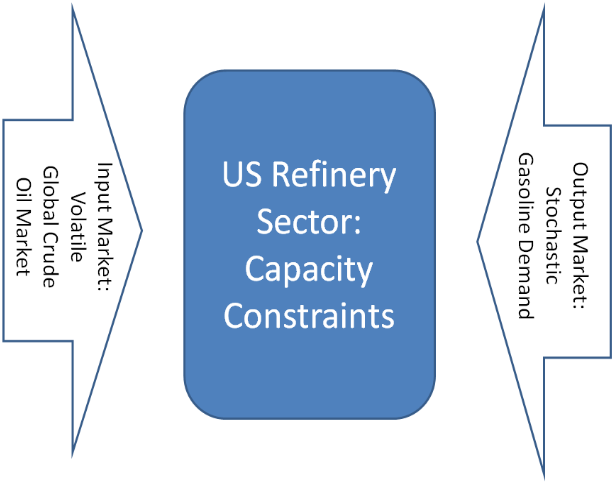
Spread and Capacity Utilization





$$R^2 = 0.26$$

Overview of the Model



(Crack) Spreads=Output Price - Input Price

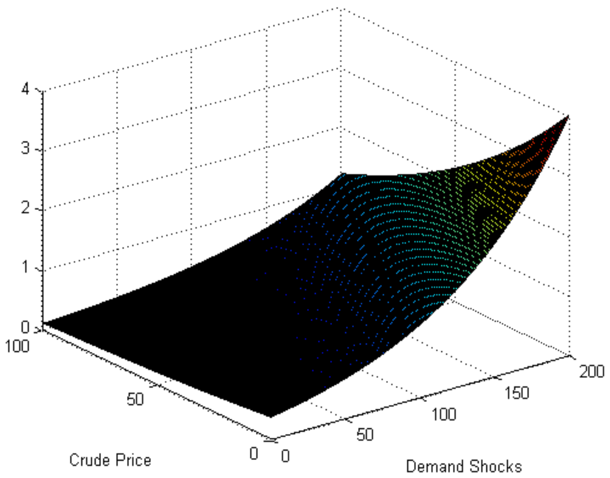
Elements of the Model

- International input market (Q_{NUS})
- Closed product economy (no import/export of gasoline)
- Linear demand function: $P_G = X - bq$
- X: Mean-reverting seasonal demand process
- $TC = (P_C + P_I)q + K(q)$
- K(q): Capacity related costs
- To get a closed form: $K(q) = \frac{\phi q^2}{\bar{q}}$

Simultaneous Determination of Input and Output Price for Competitive Industry

$$CS = \begin{cases} \frac{(\frac{2\phi}{\overline{q}}+\alpha)X+(b+\alpha)P_I-(\alpha^2+\frac{2\alpha\phi}{\overline{q}})Q_{NUS}}{b+2\alpha+\frac{2\phi}{\overline{q}}} & \text{if } q^* \leq \overline{q} \\ X-(b+\alpha)\overline{Q}_{US}-\alpha Q_{NUS} & \text{Otherwise} \end{cases}$$

Input/Output Shocks and Spreads



$$K(q) = e^{\frac{\phi q}{q^*}}$$

Results

Proposition

Higher demand or crude price volatility increases the expected spreads. The effect is stronger when the mean demand is higher

Proposition

If global crude oil price depends on US refinery demand, the difference between crack spread of monopoly and competitive market is ambiguous. If crude oil price is exogenous, crack spreads are always higher in monopoly market.

Results

Proposition

If demand and input prices are uncorrelated, a low input (crude) price increases spreads. If they are positively correlated the effect is ambiguous.

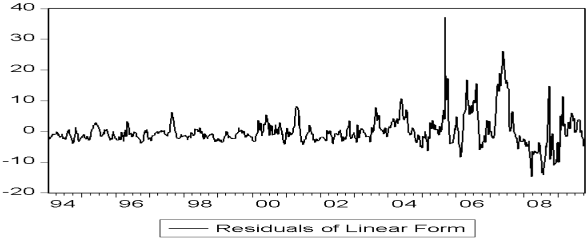
Proposition

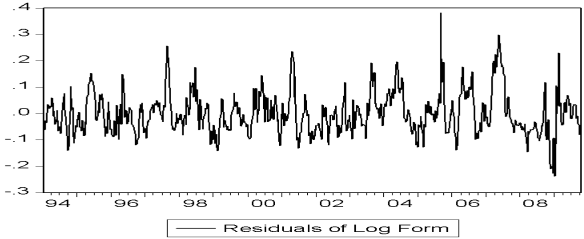
The correlation between input and output prices depends on the level of output demand and input price. When output demand is low and input price is high, prices are highly correlated. When output demand is strong or input price is very low the correlation drops significantly.

Estimation: Overview

- Goal: Understand the dynamics of demand process
- Limitations: Lack of inventories, adjustment costs, linear demand effect
- Data:
  1. Weekly spot prices of gasoline and crude (1990/11/02 to 2010/04/23, 1017 observation)
  2. Weekly production and capacity utilization of gasoline
  3. Weekly futures prices (24 months) of both commodity (2005/10/07 and 2009/09/25, 218 observation)

Residuals from a VEC Model





Estimation: Kalman Filter

A method to extract information about unobservable state variables

- Observables: Z=Spot and futures price of crude and gasoline
- Unobservable (latent) variable: Demand parameter

$$
\begin{aligned}
& X_{t+1} = c_X + HX_t + \epsilon_1 \\
& Z_t = FX_t + d + \epsilon_2 \\
& c_X = \mu_X \overline{X}, H = (1 - \mu_X) \\
& F = m_2 \\
& \mathbb{E}(\epsilon_1) = 0 \\
& \mathbb{E}(\epsilon_2) = 0 \\
& \sigma_T = \mathbb{E}(\epsilon_1^2) \\
& \sigma_M = \mathbb{E}(\epsilon_2^2) \\
& < \epsilon_1, \epsilon_2 >= 0;
\end{aligned} \tag{1}
$$

Parameter Estimation under Physical Measure

Unknow parameter: $\theta = [m_1, m_2, d, X, \mu_X, X_0]$

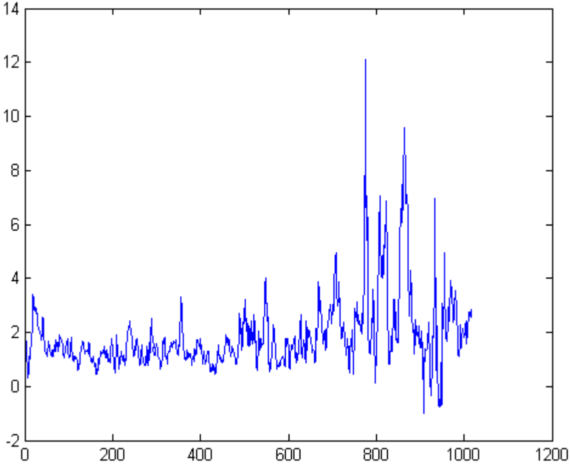
Specification 1) Price relationship:
$P_G = m_1 P_C + m_2 X + \epsilon$, $P_I = \alpha P_C \Rightarrow m_1 = (1 + \alpha + \pi) P_C$

m_1	m_2	d	μ	$\overline{X}$	X_0
1	3.55	-0.58	0.09	1.86	1.95

Specification 2) Supply Relationship: $P_G = d + m_1 Q + m_2 X + \epsilon$

m_1	m_2	d	μ	$\overline{X}$	X_0
9.01	4.79	-0.07	0.00	12.90	6.30

Estimated Demand Process (1990-2010)



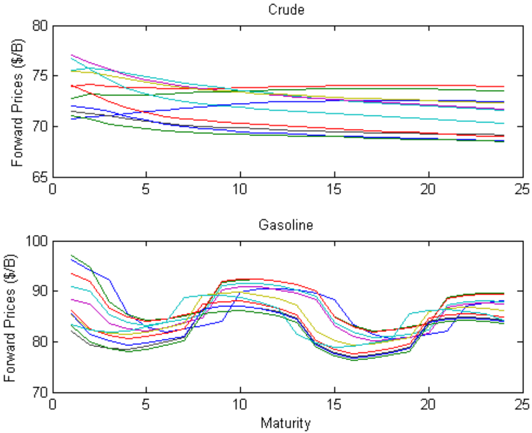
$$\sigma_X = 1.7$$

Joint Estimation of Demand Dynamics under P and Q

- X evolves under physical measure over time
- X evolves under Martingale measure over maturity
- Term-structure of (latent) demand process

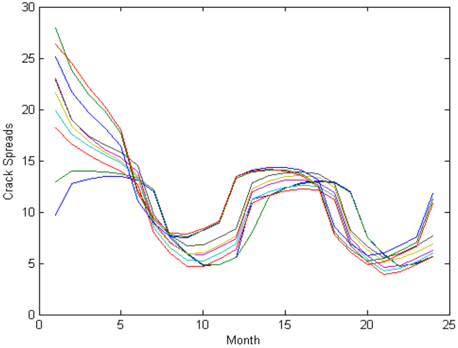
$$E^{Q}_{t,T}(P_G) = d + m_1 E^{Q}_{t,T}(P_C) + m_2 E^{Q}_{t,T}(X)$$

Seasonality in Gasoline Futures



Vector of seasonality factors

Gasoline–Crude Spread Futures Curves



Observed seasonality and mean–reversion

Joint Estimation of Demand Dynamics under P and Q

- $Y_t = M_1 Z + M_1(d_t + X),\ Y_t = [F_{Gas}(t, T)]$ and $Z = [F_{Crude}(t, T)]$
- $d_t = [Cons + Q(T)(\overline{X}_Q(1 - e^{-\mu_Q(T-t)}))]$
- $X = [Q(T)X_t e^{-\mu_Q(T-t)}]$
- $X_{t+1} = X_t e^{-\mu} + (1 - e^{-\mu})\overline{X}$
- Unknow parameter: $\theta = [m_1, m_2, d, X, \mu_X, X_Q, \mu_Q, X_0, Q(T)]$
- $T \in \{1, ..., 24\}$

Joint Estimation of Demand Dynamics under P and Q: Results

m_1	m_2	Cons	μ_Q	$\overline{X}_Q$	μ_X	$\overline{X}$	X_1
1.03	3.50	4.82	0.03	-0.29	0.05	0.71	2.89

Table: Dynamics under P and Q

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.10	1.05	1.12	1.19	1.43	1.22	1.13	1.16	0.90	1.21	1.64	1.11

Table: Monthly Factors

Future Steps

1. Further insights for hedging
2. More precise calibration
3. Valuation: refinery as a sequence of options
4. Dynamic model including adjustment costs
5. Capacity building problem

Thank you!