Causes and Implications of Shifts in Financial Participation in Commodity Markets

Lavan Mahadeva

Oxford Institute for Energy Studies
CRU International

Workshop on the Financialization of Commodities, Bank of Canada, Ottawa, 21.03.14
The financial participation of those who have no capacity to store oil in international energy markets has increased tremendously in the 2000s ([Domanski and Heath, 2007]). Eg. Hedge Funds, Index Investors, CLNs

A mostly empirical economic literature has sprung up linking greater financialization participation to changes in behaviour of oil prices (see [Fattouh et al., 2012] for a survey).

When can shifts in financial participation be associated with suboptimal pricing, costly volatility or bubbles?

Anticipations of supply and demand shifts (with a convenience yield) are competing explanations of correlated movements in participation, spreads and inventory.
Testing the Financialization Hypothesis

- Financial futures volume and the volume of physical trade in oil need not be cointegrated, with no adverse consequences for welfare.
- Financial futures volume and spreads can be jointly determined by expectations of fundamentals.
- Question is *Can changes in the incentives and constraints of purely financial players affect prices and, thus, the welfare of spot purchasers?*
- We build a (semi-)structural model (macro-finance) to answer this question.
- We match the model to the data before 2003 (pre-financialization).
- We experiment with structural financialization changes (lower risk aversion and lower wealth for financial speculators), and also lower net supply and high net supply volatility.
- We see if structural financial changes predict higher and more volatile prices and a worse outcome for consumers.
We see if the predictions of the model match what data tells us happened after 2003.

We see if the model predictions for supply and demand do a better job in explaining facts.
Speculators

- Physical speculators: buy oil on the spot market and store it. They can sell it forward or wait and sell it next period. They also hold a risk-free asset. Two periods.
- The choice of how much to hedge is a powerful lever.
- There is a convenience yield to holding oil and a re-distributive cost/margin to futures transactions.
- We solve for their decision as a portfolio maximization with utility — depends on distribution of prices.
- Financial speculators: contract to buy oil on the futures market, and sell it at delivery. They hold shares and a risk-free asset.
- Their financial gamble is a bet.
- We solve for their decision as a portfolio maximization with utility (risk aversion).
Physical Speculators

\[ U_{r,1} = \mathbb{E}_0 \left[ \frac{(W_{r,1})^{1-\tau_r}}{1-\tau_r} \right] \]  
(1)

and

\[ W_{r,1} = W_{r,0} \left( (1 - \alpha_{r1,0} - \alpha_{r2,0}) \left( 1 + r_f \right) + \alpha_{r1,0} \frac{P_1 C_{q1,1}}{P_0} + \alpha_{r2,0} \frac{F_{01} C_{q2,1}}{P_0} \right) \]  
(2)

where

- \( P_s \) is the price of oil in period \( s \) (\( s = 0, 1 \))
- \( F_{01} \) is the price of oil contracted at time 0 to be delivered at time 1.
- Wealth in period \( s \) is denoted by \( W_{r,s} \).
- \( \alpha_{r1,0} + \alpha_{r2,0} \) is the share of wealth in physical oil
- \( \frac{\alpha_{r2,0}}{\alpha_{r1,0} + \alpha_{r2,0}} \) is the share of oil sold forward.
- also bonds earning a risk-free rate of \( r_f \).
In log terms, we write $C_{q1,1}$ and $C_{q2,1}$ as:

$$c_{q1,1} = \varrho_1 \text{prob}(P_1 > P^*) + \bar{c}_{q1}$$

and

$$c_{q2,1} = \varrho_2 \text{prob}(P_1 > P^*) + \bar{c}_{q1} - c_{g,1}$$

(3)

where

- $\text{prob}(P_1 > P^*) = \text{prob}(p_1 > p^*) = 1 - \phi\left(\frac{p^* - \mathbb{E}_0[p_1]}{\text{Var}_0[p_1]^{0.5}}\right)$, given standard normal cumulative distribution $\phi(.)$.
- $\varrho_1$ and $\varrho_2$ are the elasticities of the convenience yield.
- A stochastic proportionate transaction gain for writing short futures contracts equal to the log of the cost paid by those going long ($c_{g,1}$).
The financial speculators’ problem is to maximise the objective

\[ U_{s,1} = \mathbb{E}_0 \left[ \frac{\left( W_{s,1} \right)^{1-\tau_s}}{1 - \tau_s} \right] \]  

subject to a budget constraint,

\[ W_{s,1} = W_{s,0} \left( (1 - \alpha_{s2,0}) (1 + r_f) + \alpha_{s1,0} \frac{P_1 C_{g,1}}{F_0^1} + \alpha_{s2,0} R_{e,1} \right) \]

where wealth in period 1 denoted by \( W_{s,1} \), \( \alpha_{s2,0} \) is the share of wealth held in risky equity as opposed to riskless bonds and \( \alpha_{s1,0} \) is the value of the futures commitment in terms of period 0 wealth. \( \alpha_{s1,0} \) is not a share, as a futures position is essentially a bet rather than an investment.
The solution to the financial speculators’ problem of maximizing 4 subject to 5 by choice of $\alpha_{s1,0}$ and $\alpha_{s2,0}$ is approximately given by:

$$\frac{1}{(1 + \alpha_{s1,0})} \alpha_{s,0}^T = \frac{1}{1 + \tau_s}$$

$$(\mathbb{E}_0[r_{ss,1}] - r_f \nu + \frac{1}{2} \text{diag}(\mathbf{Var}_0[r_{ss,1}]) + \frac{1}{2} \text{diag}([\mathbb{E}_0[r_{ss,1}] - r_f \nu][\mathbb{E}_0[r_{ss,1}] - r_f \nu]^T))$$

$$\times (\mathbf{Var}_0[r_{ss,1}] + [\mathbb{E}_0[r_{ss,1}] - r_f \nu][\mathbb{E}_0[r_{ss,1}] - r_f \nu]^T)^{-1}$$

(6)
**Consumers**

- Final consumers: buy oil each period and take the demand for other goods as given.
- Model is solved by equating supply and demand each period, with carryover between the two.
- All three prices are endogenous as is carry over, volumes etc.
Consumers’ welfare

The objective of final consumers is to maximize their utility from consumption over both periods

\[ U(C_{c,0}) + \beta \mathbb{E}_0 U(C_{c,1}) \]  

(7)

where \( \beta \) is the discount rate and it is assumed that each period’s utility is of the power form,

\[ U(z) = \frac{(z)^{1-\chi} - 1}{1 - \chi} \]  

(8)

and that total consumption \( C_{c,s} \) is a CES aggregate of the consumption of purchases of spot oil \( (X_s) \) and other items \( (Y_s) \),

\[ C_{c,s} = \lambda_s \left[ \Gamma_s \left( X_s \right)^\omega + (Y_s)^\omega \right]^{\omega-1} \]  

(9)

with \( \lambda_s \equiv \left( \frac{1}{1+\Gamma_s^{\frac{1}{\omega}}} \right)^{\omega-1} \) for \( s = 1, 2 \).
Spreads I

\[ E_t[P_{t+1}] \]

Expected Spot Price - Spot Price
“Expected rise”

Expected Spot Price – Futures Price
“The Risk Premium”

Spot Price-Futures Price
“The inverse basis” or “the convenience yield”

Lavan Mahadeva OIES and CRU
Basis and the Roll Return ([Domanski and Heath, 2007])

Second, these authors also provide evidence that, historically, the return on a diversified basket of long commodity futures has been comparable with the return on other asset classes with similar risk features, such as equities.

Several authors have emphasized the importance of the so-called roll return from a long position in commodity futures as a component of total returns (Erb and Harvey (2005), Feldman and Till (2006)). Indeed, roll returns are an important explanation for why the average return on commodity futures has exceeded the average return from holding spot commodities (Gorton and Rouwenhorst (2004)). Investors earn a positive roll return if they can roll over a futures contract that is close to expiry into a new contract at a lower price. This occurs when the spot price (to which the price of the original futures contract converges over time) is higher than the price of the new futures contract, i.e. in a backwardated market.

Roll returns can be considerable. For example, in the crude oil market, the roll yield from purchasing three-month futures was about 14% per annum over 2003–04 (Graph 2). However, roll returns became negative when the price of the futures contract rose above the spot price, i.e. the market moved into contango, in 2005. Essentially, the profitability of strategies aimed at generating positive roll returns depends on the persistence of the factors that cause markets to backwardate, including low levels of commodity stocks available for short selling and positive returns received by owners from holding the physical commodity (the so-called convenience yield).

The presence of investors with a shorter-term focus, such as hedge funds, has increased considerably during the past three years. The number of hedge funds has grown significantly, with many focusing on short-term trading strategies. However, the profitability of such strategies is uncertain and depends on the persistence of the factors that cause markets to backwardate.

It is important to note that these calculations are all in US dollars and therefore the correlation between commodity prices and exchange rate movements is not a consideration. To the extent that commodity prices are in US dollars and other assets in the portfolio under consideration are not, currency hedging may be important for obtaining diversification benefits.

---

**Graph 2**

Crude oil prices and roll returns

- **Spot price minus three-month futures price (lhs)**
- **Roll return (rhs)**

1. In US dollars per barrel.
2. Annual returns from rolling over consecutive three-month futures at maturity in excess of spot price returns.

Sources: Bloomberg; BIS calculations.
## Summary of Behaviour Changes I

Table: Pre- and Post-Financialization.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial Partn Stocks</td>
<td>Probably higher</td>
<td>Higher</td>
<td>Difficult to estimate Rel. to flow capac.?</td>
</tr>
<tr>
<td>Real Oil Price</td>
<td>15.2</td>
<td>36.4</td>
<td>Jan. 1986 $s</td>
</tr>
<tr>
<td>Std Devn of Oil Price</td>
<td>31.3 pp</td>
<td>34.4p</td>
<td>Annual Arith.</td>
</tr>
<tr>
<td>Real Inverted Basis</td>
<td>9.4%</td>
<td>1.9%</td>
<td>Avge Annual Arith. Retn.</td>
</tr>
<tr>
<td>Real Oil Price Apptn</td>
<td>Ex-post lower</td>
<td></td>
<td>Difficult to estimate</td>
</tr>
<tr>
<td>Risk Premium</td>
<td>Probably lower</td>
<td></td>
<td>See [Plante and Thies, 2012]</td>
</tr>
</tbody>
</table>
Generalized from [Conroy and Rendleman, 1983]. Farmers choose to sell their crop forward to protect from exogenous price ($P$) and output volatility $Y$. There is no storage, no intertemporal production smoothing: future output and price are stochastic and exogenous. Financial speculators receive an exogenous stochastic investment return $R$ from other assets and can bet on futures.

\[
\begin{align*}
F^1_0 - \mathbb{E}_0[P_1] &= -\frac{2\sigma^2_P}{W^r/\tau^r + W^s/\tau^s} \left[ \left( \mu_Y + \beta_Y \mathbb{E}_0[P_1] \right) + \beta_R \mathbb{E}_0[P_1] + 4 \frac{\text{Cov}_0[P_1, P_1 Y_1]}{\sigma^2_P} \right]. \\
\end{align*}
\]

(10)

$\tau^s$ is risk aversion of financial speculators and $W^s$ is their wealth. $\mu_Y$ is average farm output, $\mu^R$ is average return on other financial assets. Equation 10 suggests that without storage, the relationship between financial layer changes and the risk premium is complex, ambiguous in sign and time-varying.

- If $\beta_{\ln Y \text{ on } \ln P}$ is -1, then revenues are certain and there is less need to hedge. If $\beta_{\ln Y \text{ on } \ln P}$ is 0 or positive, then revenues are very uncertain and there is a great need to hedge.
Similarly if there is a greater covariance of financial assets and commodity prices, then financial speculators will want to short futures. Skew also can matter.
Spot Term Structure Response to Financialization

Consider an inverted spot market clearing relationship at time 0: 
\[ P_0 = f(\Gamma_0, Q_0) \] 
where \( Q_0 \) is the change in inventory and \( \Gamma_0 \) is supply and demand fundamentals. Let \( \%\delta X|_f \) indicates the percentage change in \( X \) as a consequence of a shift in the financial layer.

Then

\[ P_0 = f(R_0, Q_0) \text{ and } \mathbb{E}_0[P_1] = \mathbb{E}_0g(R_1, Q_0) \]

with

\[ \frac{\partial f(.)}{\partial Q_0} \approx -\frac{\partial g(.)}{\partial Q_0} > 0 \]

\[ \Rightarrow \%\delta \mathbb{E}_0[P_1]|_f \approx -\%\delta P_0|_f \]

(11)

as \( \Gamma_0 \) and \( \Gamma_1 \) are independent of Financialization.

- Equal and opposite proportionate reaction in spot prices.
- Final consumers’ losses from a higher future spot price offset by a lower current spot price (or vice versa).
- Even if consumers cannot temporally shift, welfare losses limited (better off than market manipulation w/o frictions).
Spot Term Structure Response to Financialization: Multiperiod Model

Now the spot market clearing relationship at time $t$ would be

$ST_t - ST_{t-1} = (P_t^{elas_s} \cdot \Gamma_{s,t} - P_t^{elas_d} \cdot \Gamma_{d,t})$

where $ST_t - ST_{t-1}$ is the change in inventory, $elas_d$ is the elasticity of demand, $\Gamma_{d,t}$ is the demand fundamentals and $elas_s$ and $\Gamma_{s,t}$ are the equivalent for supply. Rolling this forward, we have

$\left( P_t^{elas} \cdot \Gamma_{s,t} - P_t^{elas_d} \cdot \Gamma_{d,t} \right) = ST_t - ST_{t-1}$

$\Rightarrow ST_{t-1} = \sum_{k=t}^{\infty} \left( P_k^{elas_s} \cdot \Gamma_{s,k} - P_k^{elas_d} \cdot \Gamma_{d,k} \right)$  \hspace{1cm} (12)

As $\Gamma_{s,k}$, $\Gamma_{d,k}$ and $ST_{t-1}$ ($k = t, \ldots, \infty$) are unchanged for a pure change in the financial layer, then a change in prices at one point in the term structure will have to be matched by a near equally proportionate change in the opposite direction at another point.
Risk Premium & Inverse Basis reaction to Financialization shifts

\[
\% \delta E_0[P_1]|_f - \% \delta F_0^1|_f \approx \% \delta P_0|_f - \% \delta F_0^1|_f + \% \delta E_0[P_1]|_f - \% \delta P_0|_f \quad (13)
\]
\[
\Rightarrow \% \delta E_0[P_1]|_f - \% \delta F_0^1|_f + (\% \delta F_0^1|_f - \% \delta P_0|_f) \approx -2\% \delta P_0|_f
\]

- Large differential reaction in risk premium and inverse basis needed to explain large rise in spot price.
Results — Price levels

Current and Futures Price (% Change)

- Risk aversion fall (2 to 1.5)
- Wealth + 25%
- 5% more net supply
- Supply volatility +15%

Lavan Mahadeva OIES and CRU
Results — summary

Without pure speculation

-20
-15
-10
-5
0
5
10
15
Response of financial Participation with Pure
Speculation (%)

change from base
following
financialisation
shift

- Risk aversion fall (2 to 1.5)
- Wealth + 25%
- 5% more net supply
- Supply volatility +15%

Lavan Mahadeva OIES and CRU
So far, futures trade is about risk-sharing.

Earlier [Hirshleifer, 1977] and now [Sismek, 2012] have demonstrated that trade in a financial instrument can combine both a risk-sharing and a pure speculation motive when there are persistent belief disagreements.

Rational traders will not trade in a complete market even if they have private information.

[Shalen, 1993] demonstrated that a widening dispersion of beliefs leads to a rise in volume and unconditional volatility in futures markets.

[Söderlind, 2009] neatly demonstrates that this depends on risk aversion being not too high: beliefs generate volatility as well as trade opportunities.

Naturally worth exploring for commodities, where there are huge belief disagreements about important unobservables: the convenience yield and future technology trends.
Hence

\[ E_0'[p_1] = E_0[p_1] - \epsilon \quad \text{and} \quad E_0^s[p_1] = E_0[p_1] + \epsilon, \text{ where } \epsilon = 0.2 \]  \hspace{1cm} (14)

and solve for the portfolio shares which reflect these disagreements. All other expressions in the model remain as they were.

- In the new baseline the real value of futures contract is larger (20%) larger: this is pure speculation.
Results — without pure speculation

Without pure speculation

Lavan Mahadeva OIES and CRU
Results — with pure speculation

-20 | -15 | -10 | -5 | 0 | 5 | 10 | 15
Response of financial Participation with Pure Speculation (%)

Wealth + 25%
5% more net supply
Supply volatility +15%

Risk aversion fall (2 to 1.5)

change from base following financialisation shift

Lavan Mahadeva OIES and CRU
Financial Layer Changes and Commodity Prices: History

- Tulipmania
- Grain and Sugar in the Seven Years War
- US Agriculture in the 1920's Depression
- Amaranth and Gas Futures
Grain and Sugar in the Seven Years War
([Schnabel and Shin, 2001])

Figure 4.3: Berlin grain prices, April 1763 = 100. “Cleaned” prices are adjusted for exchange rate.

Far from being perfect, there certainly also existed spill-overs into neighboring countries. Thus, the distressed sales by large players in Berlin in April 1763 elicited unwelcome price shocks for players in Hamburg and Amsterdam. The more highly leveraged players had to liquidate their positions too, thereby exacerbating the price declines. The parallels with the LTCM crisis in 1998 are very clear. In the summer of 1998, the forced unwinding of large leveraged portfolios by LTCM and other copycat funds caused adverse price moves, which in turn forced further unwinding that amplified these adverse price moves. When traders have short horizons due to bankruptcy constraints, liquidity problems quickly translate into solvency problems. This is one of the major insights from our stylized model presented above.

We must exercise some caution in interpreting the price data from Berlin due to the fluctuations in the value of the currency that arose from debasement and major currency reforms that were introduced as a consequence. Figure 4.4 plots the Berlin exchange rate in terms of the number of “Reichsthaler preussisch Kurant” (i.e., the circulating Prussian Reichsthaler) per unit of circulating currency in Amsterdam and Hamburg—that is, Amsterdam and Hamburg “Kurant”. Thus, higher numbers in figure 4.4 denote

31 In absolute terms, the price of Berlin grain barely exceeded the Amsterdam price at the peak of bubble in the spring of 1763, but in the pre-crisis period (1761-1762) it was much lower than in Amsterdam. Hamburg prices were generally closer to Berlin prices than to Amsterdam prices.

32
Berlin grain price rises in August 1761 and falls by 75% between May and August 1763 following the signing of a peace agreement in February. Eventually holders of grain and sugar “were forced to sell their trading goods in public auctions, thus strongly depressing prices... Since May complaints are heard concerning these auctions and hurried sales that damaged the market.”

- Correlations between prices increased, especially those heavily traded by merchant bankers.
- Grain price fall coincides with bankruptcies in Hamburg
- Evidence on low capital and liquidity of key banks involved
- Grain prices rose in Prussia’s most difficult period
What can create sharp changes in the wealth available in the investment of commodities?

- Too few investors (liquidity risk) ⇒ concentration/position limits
- Highly leveraged investors (funding risk) ⇒ microprudential policy
- Many investors but with interlocking liability structure ⇒ macroprudential policy
- Marked to market margins, risk-averse market making which is not perfectly elastic, execution order is not perfectly sequential [Bernardo and Welch, 2004], clearing rules and collateral liquidation mechanism [?] ⇒ market microstructure frictions during crisis
Underlying shifts in Financialization (as either a huge rise in financial speculators wealth or a fall in their risk aversion) cannot explain the scale of recent movements in oil prices. Greater financial wealth or lower risk aversion have (if anything) beneficial effects on consumer welfare (as they lower volatility and raise stocks). Even if we allow for pure speculation, and volatility in financing costs for commodity speculation. Supply and demand forces matter more in lowering basis and can even explain the movements in participation. This may be different in the presence of poorly designed financial system, which leads to large proportionate fluctuations in net wealth. . . . suggesting there is role for policy with clear objectives and institutional design.
References

Liquidity and Financial Market Runs. 

Pricing commodities when both price and output are uncertain. 

Financial investors and commodity markets. 

The role of speculation in oil markets: What have we learned so far? 

Stochastic convenience yield implied from commodity futures and interest rates. 
References II

Commodity futures investing: method to the madness.

Foreshadowing LTCM: The Crisis of 1763.
Sonderforschungsbereich 504 Publications 02-46, Sonderforschungsbereich 504, Universität Mannheim & Sonderforschungsbereich 504, University of Mannheim.

Volume, volatility, and the dispersion of beliefs.

Speculation and risk sharing with new financial assets.
Working Paper 17506, NBER.

Why disagreement may not matter (much) for asset prices.
Explaining the CTFC data

Direction of arrow indicates to whom oil is being sold to for future delivery. The CTFC net long data is the red minus the pink arrow (number of barrels). This can vastly exceed the number of barrels which are actually changing hands, as they can be settled eg. by taking the opposite position on another futures contract on the same settlement date. The difference in futures prices is then a profit or loss.
Spreads and Players

E_t[P_{t+1}] 

Physical Speculators (hedged) 

Consumers/Producers (unhedged) 

Physical Speculators (unhedged) 

Financial Speculators 

P_t 

[F_{t+1}^t] 

Physical Speculators (hedged)
The Convenience Yield

In logs

\[
\frac{p_0 - f_1^0}{f_1^0 - p_0 + cy_t - c_t} = r_t
\]

Futures price  Spot price  Convenience yield  storage costs

opportunity cost

\[
\text{total return on hedged physical oil}
\]

But as \( cy_t = f\left(\frac{\text{Inventory}}{\text{Demand}}\right) \)

\[
\Rightarrow p_0 - f_1^0 + r_t + c_t = f\left(\frac{\text{Inventory}}{\text{Demand}}\right)
\]
Results — Financial participation

Financial speculator's futures position (% change)

- Risk aversion fall (2 to 1.5)
- Wealth + 25%
- 5% more net supply
- Supply volatility +15%

Lavan Mahadeva OIES and CRU
Results — Price levels

Current and Futures Price (% Change)

- Risk aversion fall (2 to 1.5)
- Wealth + 25%
- 5% more net supply
- Supply volatility +15%

Lavan Mahadeva OIES and CRU
Results — Carry over

Lavan Mahadeva OIES and CRU
Results — Spreads

The inverse basis (pp change in ratio)

Risk aversion fall (2 to 1.5)  Wealth + 25%  5% more net supply  Supply volatility +15%

Lavan Mahadeva OIES and CRU
Results — Price uncertainty

- Risk aversion fall (2 to 1.5)
- Wealth + 25%
- 5% more net supply
- Supply volatility +15%

Lavan Mahadeva OIES and CRU
Results — Welfare

% Extra Compensation Consumers Need

- Risk aversion fall (2 to 1.5)
- Wealth + 25%
- 5% more net supply
- Supply volatility +15%

Lavan Mahadeva OIES and CRU
Results — Welfare exposure

% Extra Sensitivity of Consumer Welfare to Oil Prices (change in elasticity- baseline is 0.35)

-0.02
0.00
0.02
0.04
0.06
0.08
0.10
0.12

Risk aversion fall (2 to 1.5)
Wealth + 25%
5% more net supply
Supply volatility +15%

Lavan Mahadeva OIES and CRU
Results — without pure speculation

Without pure speculation

Response of financial Participation with Pure Speculation (%)

Risk aversion fall (2 to 1.5)
Wealth + 25%
5% more net supply
Supply volatility +15%

change from base following financialisation shift

Current Spot Price Level (%) with

Welfare (pp) with

Lavan Mahadeva OIES and CRU
Results — with pure speculation

-20
-15
-10
-5
0
5
10
15

Response of financial Participation with Pure Speculation (%)

With pure speculation

Risk aversion fall (2 to 1.5)
Wealth + 25%
5% more net supply
Supply volatility +15%
change from base following financialisation shift

Lavan Mahadeva OIES and CRU
The diagram shows how mispricing in underlying assets in one part of the financial system can create mispricing in commodity spreads in principle. This can be due to inadequacies in microprudential; macroprudential and/or collateral policies.

Key question: Are some commodity spreads more sensitive than others to shocks in the financial system? Why?