Theory of Storage and the Dynamics of Metals Forward Curves

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To be presented at the Vale Conference on Commodities
Getulio Vargas Foundation - Rio de Janeiro
August 16 & 17, 2012
Metals, Energy, Agriculturals : A Multi or Unique Asset Class?

Commodities have displayed over the last 30 years a period of low prices in the 1980s and 1990s, strictly declining if adjusted for inflation, and low volatility.

Low correlations between metals, energy, agriculturals

Then much higher prices prevailed as of 2002 for crude oil, as of 2004 for copper, 2005 for agriculturals. In the case of iron ore, long-term contracts imposed by steelmakers broke down after the concerted action of Vale, Rio Tinto and BHP Billiton.

High correlations appeared, created

By the massive arrival of financial actors buying at the same time several commodities such as copper, gold, crude oil in the form of a commodity index

By the effects of substitution between commodities and competition for the same rare resources, called electricity, water, land
Brazil Equity versus UK Equity

Data from Yahoo Finance via Matlab Datafeed toolbox

Commodity Notes – Correlation 2 - Real World Correlations ©2012 William Smith
US Equity versus the Metals and Minerals Index: ‘Risk on/ Risk off ‘ behaviour recently!

S&P data from Yahoo (ticker ^GSPC) via Matlab Data Source Toolkit
US Equity versus Energy Index

S&P data from Yahoo (ticker ^GSPC) via Matlab Data Source Toolkit
Metal Reserves

 almonds mining techniques, deeper drilling and mining in untapped places such as Greenland, Mongolia and the Arctic should lead to years in mineral reserves, at current production rates, estimated at 590 for iron ore, 136 for copper, 610 for potash; versus 18.9 for gold, 46.2 for crude oil and 82 for metallurgical coal.

 almonds Hotelling in his (1931) paper on *exhaustible* commodities had established that the shadow price of the resource, which is an economic measure of its scarcity, should grow at least at the rate of interest.

 almonds Young (1992) applies Hotelling model to Canadian copper mining firms and finds it poorly depicts the database he analyzes; but the period of analysis ended in 1990 and was the period of price mean-reversion (G. 2005: Is Mean Reversion in Commodity Prices Dead?)

 almonds It is useful to recognize that the possible decline in the quality of the
BDI, Copper and the world economy growth
Dislocation between BDI and Copper Prices

Chart created with NeoTicker EOD © 1998-2007 TickQuest Inc.
Copper versus Crude Oil
Copper Volatility Smile - April 6, 2012
Implied Volatility “Surface”
(bottom axes are price and time to maturity)

5 year 120 call, 10 days volume
(original surface flat 40% volatility)

Merrill Lynch, “Modelling the Implied Volatility Surface”,
Gold 1st Contract (22 Jun 2012)
Theory of Storage
Keynes (1936), Kaldor (1939), Working (1949)

Three fundamentals results:

→ The holder of the physical commodity receives an implicit dividend called convenience yield

→ The volatility of the commodity spot price is high when inventory is low

→ Traditionally, forward curves used to be mostly declining with the maturity (‘normal backwardation’) and sometimes in contango. Today, we even get humps

→ The dynamics of the global forward curve matters, in hedging activities in particular, since one never hedges with the prompt-month
The Forward Curve

→ The set \( \{F^T(t), T > t\} \) is the forward curve prevailing at date \( t \) for a given commodity in a given location.

→ It is the fundamental tool when trading commodities, as spot prices may be unobservable and options not always liquid.

→ It allows to identify the prices forecasted by the market at future dates since real trades did take place at these prices.

→ The shape of the forward curve is a crucial piece of financial information to be compared to all the other sources!
Crude Oil in Backwardation in September 2007
Spot-Forward Relationship for a Storable Commodity

Under no arbitrage

\[ f^T(t) = S(t) \left[ 1 + \frac{r}{T-t} + \frac{c}{T-t} - y_1(T-t) \right] \]

If we define a convenience yield net of cost of storage

\[ f^T(t) = S(t)[1 + (r - y)(T - t)] \]

Or in continuous time, at a fixed date \( t \) (today), for a given maturity \( T \)

\[ f^T(t) = S(t)e^{(r-y)(T-t)} \]
Copper Forward Curve - 27 May 2008: Backwardation
A hump in the Oil Forward Curve (bid/ask) - March 2006
Copper Forward Curve, Oct 2009

Copper Forward Curve
Iron Ore Futures Curve

62% Fe CFR China (TSI) Swap Futures, 14 Aug 2012

China import Iron Ore Fines 62% FE spot (CFR Tianjin port), US Dollars per Metric Ton

http://www.indexmundi.com/commodities/?commodity=iron-ore&months=60

Iron Ore – Evolution of Spot Price
Working (1949) proposed to use the spread of the forward curve (long term forward – short term forward) as a proxy for inventory: when the spread is negative, inventory is low.

Fama and French (1988) use LME Future prices over the period 1972 to 1983 to test five base metals (copper, aluminium, copper, lead, tin and zinc) and find that the variance of spot prices declines with high inventories. In the case of gold, forward curve spreads provided little forecast for price volatility.

Ng and Pirrong (1994) analyze four base metals over the period 1986 to 1992 and find persistence of the property that both spot and forward variance declines with inventory in the case of metals.

G - Nguyen (2005) reconstruct a world inventory of soybeans over several years and directly exhibit a quasi-perfect inverse relationship between inventory and spot price volatility.
→ G- Ohana (2009)
  . Examine at US crude oil and natural gas markets
  . Show that indeed the spread of the forward curve is a good proxy for inventory
  . Exhibit that the correlation between the spread of the forward curve and low inventory is particular significant during periods of scarcity

→ G – Smith (2012)
  . Reconstruct inventory for copper, lead, iron, tin from the addition of the LME and SHFE data
  . Validate the use of the spread of the forward curves as a measure of inventory
  . Display directly an affine relationship between inverse inventory and spot price volatility
Copper Inventory – 1985 to 2011
Why Should Different Commodities Be Correlated?

**Economic Effects**

**Dollar Effect**
- Dollar → Commodities

- “Give me $100 of commodity exposure”

**‘ETF’ Effect**

**Macroeconomic Effect**
- “China growth slows”

Correlation (A,B) > 0
Why Should Different Commodities Be Correlated?

Resource Competition

Water for Agriculture or Mining or Oil & Gas
“Fracking”

Shipping for Metal ore or Agriculturals

Land for Residential Land or Agriculture or Mining

Offshore Experts for Windfarms or Offshore Oil

Correlation \((A,B) > 0\)
Agriculture Index versus Base Metals Index

Commodity Notes – Correlation 2 - Real World Correlations

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Why Should Different Commodities Be Correlated?

A is needed to produce B

Aluminium Ore (Bauxite) → Lots of Electricity → Aluminium

Correlation (A,B) > 0
Why Should Different Commodities Be Correlated?

Substitution: A or B

Oil

Natural Gas

Power Station

Correlation (A,B) > 0

Electricity
Corn and Wheat Prices - 2000 to 2011

Corn vs Wheat

- Wheat, No. 2 Hard (Kansas) Cts/BU
- Corn No. 2 Yellow Cents/Bushel
World Fertilizer Index – 2000 to 2011
Why Should Different Commodities Be Correlated?

Alternative Output: A can produce B or C

Sugar Cane → Correlation (B, C) > 0 due to competition → Sugar → or → Ethanol as Biofuel
Sugar versus Crude Oil

Why Should Different Commodities Be Correlated?

Co-Production: A and B produced together

Zinc

Lead

Correlation (A,B) > 0 since supplies of both occur at the same time.
COMEX Gold Prices - 2002 to 2010
Gold Prices since 1975
Gold 1st Contract (22 Jun 2012)
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