THE VOLATILITY OUTLOOK FOR COMMODITIES

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THE ECONOMICS AND ECONOMETRICS OF COMMODITY PRICES
AUGUST 2012 IN RIO
Asset prices change over time as new information becomes available.
Both public and private information will move asset prices through trades.
Volatility is therefore a measure of the information flow.
Volatility is important for many economic decisions such as portfolio construction on the demand side and plant and equipment investments on the supply side.
Investors with short time horizons will be interested in short term volatility and its implications for the risk of portfolios of assets.

Investors with long horizons such as commodity suppliers will be interested in much longer horizon measures of risk.

The difference between short term risk and long term risk is an additional risk - “The risk that the risk will change”
The commodity market has moved swiftly from a marketplace linking suppliers and end-users to a market which also includes a full range of investors who are speculating, hedging and taking complex positions.

What are the statistical consequences?

Commodity producers must choose investments based on long run measures of risk and reward.

In this presentation I will try to assess the long run risk in these markets.
The most widely used set of commodities prices is the GSCI data base which was originally constructed by Goldman Sachs and is now managed by Standard and Poors.

I will use their approximation to spot commodity price returns which is generally the daily movement in the price of near term futures. The index and its components are designed to be investible.
Using daily data from 2000 to July 23, 2012, annualized measures of volatility are constructed for 22 different commodities. These are roughly divided into agricultural, industrial and energy products.
VOLATILITY BY ASSET CLASS (1996-2003)
COMMODITY VOLS SINCE 2000

VOL
TAIL RISK MEASURE: ANNUAL 1% VAR?

- What annual return from today will be worse than the actual return 99 out of 100 times?
- What is the 1% quantile for the annual percentage change in the price of an asset?

- Assuming constant volatility and a normal distribution, it just depends upon the volatility as long as the mean return ex ante is zero. Here is the result as well as the actual 1% quantile of annual returns for each series since 2000.
PREDICTIVE DISTRIBUTION OF ASSET PRICE INCREASES
A 1% CHANCE
1% Annual VaR Assuming Normality and Constant Risk

Normal 1% VaR
1% ANNUAL VAR AND 1% REALIZED QUANTILE (OF ALL 252 DAY RETURNS, WHAT IS 1% QUANTILE)
Like most financial assets, volatilities change over time.

Vlab.stern.nyu.edu is website at the Volatility Institute that estimates and updates volatility forecasts every day for several thousand assets. It includes these and other GSCI assets.
VOLATILITY OF COPPER, NICKEL, ALUMINUM AND VIX - AUG 6, 2012
GOLD SILVER PLATINUM AND VIX

Annualized Volatility

Gold Spot - GJR-GARCH Vol Prediction
S&P GSCI Silver Index - GJR-GARCH Vol Prediction
S&P GSCI Platinum Index - GJR-GARCH Vol Prediction
VIX Vol

Gold Spot Return
Gold Spot Price

Jan '08  Jul '08  Jan '09  Jul '09  Jan '10  Jul '10  Jan '11  Jul '11  Jan '12  Jul '12

V-Lab (2012)

90%  80%  70%  60%  50%  40%  30%  20%  10%  0%  20%  15%  10%  5%  0%  -5%  -10%  -15%
GAS models proposed by Creal, Koopman and Lucas postulate different dynamics for volatilities from fat tailed distributions.

Because there are so many extremes, the volatility model should be less responsive to them.

By differentiating the likelihood function, a new functional form is derived. We can think of this as updating the volatility estimate from one observation to the next using a score step.
The updating equation which replaces the GARCH has the form

\[ h_{t+1} = \omega + A \left( \frac{r_t^2}{c + r_t^2 / h_t} \right) + Bh_t \]

The parameters A, B and c are functions of the degrees of freedom of the t-distribution.

Clearly returns that are surprisingly large will have a smaller weight than in a GARCH specification.
What is the forecast for the future?
One day ahead forecast is natural from GARCH
For longer horizons, the models mean revert.
One year horizon is between one day and long run average.
We would like a forward looking measure of VaR that takes into account the possibility that the risk will change and that the shocks will not be normal.

LRRISK calculated in VLAB does this computation every day.

Using an estimated volatility model and the empirical distribution of shocks, it simulates 10,000 sample paths of commodity prices. The 1% and 5% quantiles at both a month and a year are reported.
COPPER: ONE YEAR AHEAD 1% VAR

S&P GSCI Copper Spot Index - Long Term GJR-GARCH Forecast - 365 Day - 1st Percentile

S&P GSCI Copper Spot Index Return
S&P GSCI Copper Spot Index Price

V-Lab (2012)
SILVER: ANNUAL 1% VAR

V-Lab (2012)

S&P GSCI Silver Index - Long Term GJR-GARCH Forecast - 365 Day - 1st Percentile

S&P GSCI Silver Index Return
S&P GSCI Silver Index Price
GOLD: ANNUAL 1% VAR

S&P GSCI Gold Spot Index - Long Term GJR-GARCH Forecast - 365 Day - 1st Percentile

S&P GSCI Gold Spot Index Return
S&P GSCI Gold Spot Index Price
Some commodities are more closely connected to the global economy and consequently, they will find their long run VaR depends upon the probability of global decline.

We can ask a related question, how much will commodity prices fall if the macroeconomy falls dramatically?

Or, how much will commodity prices fall if global stock prices fall.
WHAT IS THE CONSEQUENCE?
We will define and seek to measure the following joint tail risk measures.

**Marginal Expected Shortfall (MES)**

\[
MES_t = E_t \left( y_{t+1} \mid x_{t+1} < c \right)
\]

**Long Run Marginal Expected Shortfall (LRMES)**

\[
LRMES_t = E_t \left( \sum_{i=t+1}^{T} y_i \middle| \sum_{i=t+1}^{T} x_i < c \right)
\]
Estimate the model

\[ y_t = \alpha + \beta x_t + \epsilon_t \]

Where \( y \) is the logarithmic return on a commodity price and \( x \) is the logarithmic return on an equity index.

If beta is time invariant and epsilon has conditional mean zero, then MES and LRMES can be computed from the Expected Shortfall of \( x \).

But is beta really constant?

Is epsilon serially uncorrelated?
This is a new method for estimating betas that are not constant over time and is particularly useful for financial data. See Engle(2012).

It has been used to determine the expected capital that a financial institution will need to raise if there is another financial crisis and here we will use this to estimate the fall in commodity prices if there is another global financial crisis.

It has also been used in Bali and Engle(2010,2012) to test the CAPM and ICAPM and in Engle(2012) to examine Fama French betas over time.
ROLLING REGRESSION

INTERACTING VARIABLES WITH TRENDS, SPLINES OR OTHER OBSERVABLES

TIME VARYING PARAMETER MODELS BASED ON KALMAN FILTER

STRUCTURAL BREAK AND REGIME SWITCHING MODELS

EACH OF THESE SPECIFIES CLASSES OF PARAMETER EVOLUTION THAT MAY NOT BE CONSISTENT WITH ECONOMIC THINKING OR DATA.
THE BASIC IDEA

- IF \( (y_t, x_t), \ t = 1, ..., T \) is a collection of \( k+1 \) random variables that are distributed as

\[
\begin{bmatrix}
  y_t \\
  x_t
\end{bmatrix}
| F_{t-1} \sim N(\mu_t, H_t) = N\left(\begin{pmatrix}
  \mu_{y,t} \\
  \mu_{x,t}
\end{pmatrix},
  \begin{pmatrix}
    H_{yy,t} & H_{yx,t} \\
    H_{xy,t} & H_{xx,t}
  \end{pmatrix}\right)
\]

- Then

\[
y_t \bigg| x_t, F_{t-1} \sim N\left(\mu_{y,t} + H_{yx,t} H_{xx,t}^{-1} \left(x_t - \mu_{x,t}\right), H_{yy,t} - H_{yx,t} H_{xx,t}^{-1} H_{xy,t}\right)
\]

- Hence:

\[
\beta_t = H_{xx,t}^{-1} H_{xy,t}
\]
We require an estimate of the conditional covariance matrix and possibly the conditional means in order to express the betas.

In regressions such as one factor or multi-factor beta models or money manager style models or risk factor models, the means are small and the covariances are important and can be easily estimated.

In one factor models this has been used since Bollerslev, Engle and Wooldridge (1988) as \( \beta_t = \frac{h_{yx,t}}{h_{xx,t}} \)
Econometricians have developed a wide range of approaches to estimating large covariance matrices. These include:

- Multivariate GARCH models such as VEC and BEKK
- Constant Conditional Correlation models
- Dynamic Conditional Correlation models
- Dynamic Equicorrelation models
- Multivariate Stochastic Volatility Models
- Many many more

Exponential Smoothing with prespecified smoothing parameter.
For none of these methods will beta ever appear constant.

In the one regressor case this requires the ratio of \( \frac{h_{yx,t}}{h_{xx,t}} \) to be constant.

This is a non-nested hypothesis.
NON-NESTED HYPOTHESIS TESTS

- Model Selection based on information criteria
  - Two possible outcomes
- Artificial Nesting
  - Four possible outcomes
- Testing equal closeness- Quong Vuong
  - Three possible outcomes
Select the model with the highest value of penalized log likelihood. Choice of penalty is a finite sample consideration- all are consistent.
Create a model that nests both hypotheses.
Test the nesting parameters
Four possible outcomes
- Reject f
- Reject g
- Reject both
- Reject neither
Consider the model:

\[ y_t = \beta' x_t + (\gamma \circ \beta_t)' x_t + v_t \]

- If gamma is zero, the parameters are constant.
- If beta is zero, the parameters are time varying.
- If both are non-zero, the nested model may be entertained.
Stress testing financial institutions

How much capital would an institution need to raise if there is another financial crisis like the last? Call this SRISK.

If many banks need to raise capital during a financial crisis, then they cannot make loans - the decline in GDP is a consequence as well as a cause of the bank stress.

Assuming financial institutions need an equity capital cushion proportional to total liabilities, the stress test examines the drop in firm market cap from a drop in global equity values. *Beta!!*
BETA: BANCO DO BRASIL
### Systemic Risk Rankings for 2012-08-10
(MES is equity loss for a 2% daily market decline)

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<thead>
<tr>
<th>Institution</th>
<th>SRISK%</th>
<th>RNK</th>
<th>SRISK ($ m)</th>
<th>MES</th>
<th>Beta</th>
<th>Cor</th>
<th>Vol</th>
<th>Lvg</th>
<th>MV</th>
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<td>3.68</td>
<td>1.43</td>
<td>0.67</td>
<td>26.2</td>
<td>23.18</td>
<td>38,902.1</td>
</tr>
</tbody>
</table>
Estimate regression of commodity returns on SP 500 returns. There is substantial autocorrelation and heteroskedasticity in residuals.

This may be due to time zone issues with the commodity prices or it may have to do with illiquidity of the markets. The latter is more likely as there is autocorrelation in each individual series.

Estimate regression with lagged SP returns as well with GARCH residuals. This is the fixed parameter model.
DCB MODEL

- Condition on $t-2$:

$$
\begin{pmatrix}
R_{i,t} \\
R_{m,t} \\
R_{m,t-1}
\end{pmatrix} 
| F_{t-2} \sim N(0, H_t)
$$

- The equation:

$$
R_{i,t} = \beta_{i,t} R_{m,t} + \gamma_{i,t} R_{m,t-1} + u_{i,t}
$$

- Here $u$ can be GARCH and can have MA(1). In fact, it must have MA(1) if $R_i$ is to be a Martingale difference.
BETANEST FOR METALS

Graph showing the volatility of aluminum, copper, and nickel from 2000 to 2012.
GAMMAS FOR METALS

GAMMANEST_ALUMINUM
GAMMANEST_COPPER
GAMMANEST_NICKEL
BETAS FOR PRECIOUS METALS

![Graph showing betas for precious metals over time]

- BETANEST_GOLD
- BETANEST_PLATINUM
- BETANEST_SILVER
GAMMAS PRECIOUS METALS

![Graph showing volatility in precious metals](chart)

- **GAMMANEST_GOLD**
- **GAMMANEST_PLATINUM**
- **GAMMANEST_SILVER**
BETA: AGRICULTURAL COMMODITIES
Approximation is based upon last parameter values continuing and upon Pareto tails in returns.

It is based on the expected shortfall of the market which is defined as

\[ ESM_t = E_t \left( R_m \mid R_m < -.02 \right) \]

\[ LRMES = \exp \left( -20 \times (\beta + \gamma) \times ESM \right) - 1 \]
LRMES FROM 7/25/12
LRMES FOR METALS
CONCLUSIONS AND FINDINGS

- The one year VaR changes over time as the volatility changes.
- The equity beta on most commodities have risen dramatically since the financial crisis.
- The long run risk to be expected in commodity prices in response to a global market decline has increased.
- The Long Run Expected Shortfall if there is another global economic crisis like the last one ranges from less that 10% to 50%.