Incorporating Commodities into a Multi-Asset Class Risk Model

T.J. Blackburn

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Outline of Today's Presentation

- Institutional Participation in Commodities
- Structural Relationships to Other Asset Classes
- Basics of the Everything Everywhere Model
- Approach to Estimating Commodity Contract Factor Exposures
- Empirical Results
- Robustness Checks

Institutional Investment in Commodity Futures

- A meaningful fraction of institutional investors now participate in commodities through holding passive index baskets
  - Numerous commercial commodity indices are now offered as investment products
  - Different indices place different emphasis on various parts of commodity markets (energy, agricultural, precious metals, industrial metals)
  - Stoll and Whaley (2009) estimate institutional investment in US commodity index contracts at $175 Billion, or between 1 and 2% of the capitalization of US equity markets
  - Other institutional investors now hold participation in commodity hedge funds as an alternative to hedge funds investing in securities

Institutional Investment in Physical Gold

- Erb and Harvey (FAJ, 2013) do an extensive study of institutional investment in physical gold
  - They estimate the total supply of physical gold in the world to be worth about $9 Trillion as of the study date
  - About $1.8 Trillion is held by central banks as reserves
  - Another $1.8 Trillion is held by non-bank institutional investors
- They estimate the contemporaneous value of global stock markets at $48 Trillion and the portion of the bond market defined by the Barclay's Global Aggregate as $41 Trillion
  - This implies that the average institutional investor has allocated about 2% of their marketable assets to physical gold
  - Consistent with estimates published by the World Gold Council

Review of Other Selected Literature

- Feldman and Till (2006)
  – Backwardation effects on agricultural commodity returns
- Till and Eagleeye (2006)
  – Historical analysis of commodity volatility and correlation
- Gorton and Rowenhorst (2006)
  – Risk premium in commodities are predictable from inventory effects
- Schneeweis and Kazemi (2008)
  – Momentum effects in commodity prices are structural
- Buyuksahin, Haigh and Robe (2010)
  – Correlation of commodities and equities is not increasing over time
- Black (2009)
  – Increasing commodity prices are not driven by institutional investment
- Kaplan (2010)
  – Long-only commodity index products are return/risk inefficient

A Simple Risk Decomposition

- Consider an institutional investor with $US base currency
  - 52% Allocation to MSCI EAFE
  - 44% Allocation to Barclays Government Aggregate
  - 4% Allocation to Gold
- Example Annualized Volatility Values and Correlations
  - EAFE 12.17% , Barclays 3.25% , Gold 21.47%
  - EAFE/Barclays .23, EAFE/Gold .27, Barclays/Gold .25
- Total Portfolio Volatility = 7.11%,
  - Total variance = 50.54%^{2}
  - Crediting half of covariance to each asset in a pair, 86.26% of total variance is from equities, 8.77% from bonds, 4.97% from gold

Risk Decomposition Comments

- The risk contribution from equities dominates but commodity risk contribution is the same order of magnitude as bonds
- One possible approach to including commodities is to simply include each commodity as it's own additional factor (basically a full covariance matrix)
  - We reject the full covariance approach for three reasons
  - The observed correlation of commodities to each other and other asset classes is very unstable over time. A factor approach will separate persistent from transient effects
  - Adding lots of new factors to the model increases the potential for an ill-conditioned factor covariance matrix, which could impact the quality of forecast for all asset classes

The Problem with Commodity Correlation

- Correlations with other asset classes are very unstable
- For example, let's consider the correlation of the gold and the MSCI EAFE index (in $US)
  - Daily returns for the two years ending 28 October 2013
  - Using GARCH correction for volatility shifts
  - Average correlation was .27
  - Current forecast is .28, but the *upper 90% confidence interval is .82 and the lower 90% confidence interval is -.63*
  - Calculation from V Lab at New York University
  - In a factor model, unstable correlation implies unstable factor exposures even if the model is sound

Structural Relationships to Other Asset Classes

- Many public companies either produce or consume large amounts of commodities that are widely traded
  - Operating companies are active in hedging commodity and currency exposures so investor exposures are difficult to assess
  - Bartram (2006), Bartram and Aretz (2010), Bartram, Burns and Helwege (2013)
- Exhaustible commodities (e.g. oil, gold) are directly linked to fixed income markets through Hotelling's Rule (1931)
  - Leaving a resource in the ground is an investment decision in itself
  - The price of "in-ground" commodities should grow at the risk adjusted interest rate so clearly linked to fixed income volatility
  - Limits the ability of governments or companies to control prices by adjusting availability of supply from reserves
  - diBartolomeo (1993)

Northfield Everything Everywhere Model

- Global, multi-asset class risk model introduced in 2001
  - 90 factors in total, combination of specified exogenous and statistical factors *for equities from our equity models*
  - Multiple geographic regions, economic sectors
  - Observed yield curves for major markets, implied yield curves for small bond markets
  - Links fixed income credit risk to equity market risks via contingent claims model from Merton (1974)
  - "On demand" data creation for derivatives
- Currently provides factor representation of more than six million individual securities, currencies and commodities
  - Annual horizon (update monthly), 10 Day horizon (updated daily)
- Extensions to non-traded asset classes including real estate, infrastructure and private equity

Commodities Previous Approach

- Previously commodity contracts were processed through our procedure for estimating risk of an asset in the absence of fundamental knowledge
  – Same procedure for estimating risk for a hedge fund with no position transparency, http://www.northinfo.com/Documents/508.pdf

- Generally produced good estimates of absolute volatility but factor exposures for commodity contracts were very unstable over time
  – Consistent with correlations between commodities and other asset classes being very unstable as previously stated

Commodities in 3rd Generation Global Model

- Three stage estimation procedure
- First stage: Subdivide the universe of commodities into four groups.
- Agricultural, Energy, Precious Metals, Industrial Metals
- Strike a balance between variance explained by each of next two steps

Commodities New Procedure – 2nd Stage

- Second stage: Using return times series history create four Principal Component Analysis (PCA) factor models
  - Orthogonal linear transformation to uncorrelated factor returns
  - Factors not required to have independent meaning
  - May however be found to have meaning after the fact
  - Separates ‘signal’ from random ‘noise’
  - Eigenvalue decomposition of covariance matrix
- Each commodity has it own exposures for the two (usually) strongest principal components defined for it’s cluster
- PCA analysis updated monthly, rolling 60 month estimation

PCA Example

- Suppose each commodity driven by exposure to market factor plus idiosyncratic part

$$r_i = \beta_i m + \varepsilon_i$$

- Then $C_{ij} = \beta_i \beta_j \sigma_m + \sigma_\varepsilon \delta_{ij}$
- $\lambda_1 = (\Sigma_i \beta_i^2)\sigma_m + \sigma_\varepsilon \sim N\sigma_m + \sigma_\varepsilon$, $\lambda_j = \sigma_\varepsilon$
- Total variance = $\Sigma_i \lambda_i = N\sigma_m + N\sigma_\varepsilon$
- Market factor will be responsible for half the total variance, each idiosyncratic part for 1/2N of total variance

Commodities New Procedure- 3rd Stage

- Third Stage: Restate the PCA factor exposures into factor set defined by the 3rd Gen. Global model.
- Each commodity PCA factor is treated as a new security
- Factor loading are established by regressions of the PCA factor return time series against apparently relevant factors
  - Unlike equities, commodities do not have well-defined membership in regions or sectors
  - Only those factors included which have intuitive relationship to each commodity group or very strong statistical significance (energy commodities should have an obvious relationship to oil prices)

Commodities New Procedure

- Combine PCA and factor regression
- Algebraic restatement of commodity exposures to their group's PCA factor into the model factors is per diBartolomeo (2012)
- *Potentially test and adjust for interactions* between second stage PCA factors and third stage residuals
- Adjust specific variances to account for kurtosis and serial correlation per Parkinson (1980)

Example: Precious Metals – As of 6/09

	PC1	PC2	PC3	PC4	PC5
TOCOM-PALLADIUM CONTINUOUS	0.58	0.45	-0.22	0.11	0.63
CMX-GOLD 100 OZ CONTINUOUS	0.17	-0.43	0.32	-0.73	0.39
NYM-PALLADIUM CONTINUOUS	0.53	0.30	-0.07	-0.43	-0.66
NYM-PLATINUM CONTINUOUS	0.39	-0.08	0.80	0.44	-0.10
CMX-SILVER 5000 OZ CONTINUOUS	0.44	-0.71	-0.46	0.27	-0.10
Proportion of Variance	0.76	0.17	0.04	0.02	0.01

- First component overall market
- Second component difference between palladium vs. gold + silver
- Together these comprise 93% of variance in sample
- Remaining components probably noise – not included

Example: Precious Metals – As of 6/09

- Regression onto model factors:
- PC1 ~ 1.8 (GLOBAL MARKET) + 2.4 (NON-ENERGY MINERALS SECTOR) + 2.8 (INTEREST RATE SENSITIVE SECTOR) + 0.04 (OIL) + 0.40 (WORLD GOVT BOND INDEX) + ε
- PC2 ~ 0.92(NON-ENERGY MINERALS SECTOR) -0.32(ENERGY MINERALS SECTOR) + 1.9(WORLD GOVT BOND INDEX) + ε

Empirical Test Design

- Estimate the model as of December 31 of each year from 1996 to 2011
- Form thousands of equal weighted portfolios of commodity contracts
  - Number of members from 3 to 25
  - Some portfolios draw members from just one category (e.g. energy), some draw from all categories
  - Forecast portfolio returns for each month of the subsequent year based on known EE factor returns
- Calculate the correlation of forecast returns with actual realized returns out of sample for each portfolio
  - Also calculate the dispersion in portfolio correlation across portfolios in the test for the same sample period

Empirical Test Results

- Agricultural commodities had the weakest but still significant results
  - Across years the average correlations between forecasts and outcomes ranged from .15 (T=2.89) for 3 contract portfolios to .22 (T = 3.24) for 15 contracts
  - In 4 out of 18 years, the average correlation is zero or negative (wrong sign) for 15 contract portfolios

- Energy commodities had the best results
  - This is natural since oil prices are a factor in the EE model
  - Across years, the average correlations for 2 contract portfolios averaged .71 (T= 19.22) and .79 (T= 27.61) for 4 contract portfolios

More Test Results

- The two metals groups were in the middle
  - For precious metals: Across years, the average correlation of 2 member portfolios was .38 (T=4.19) and .38 (T=3.65) for 4 member portfolios. Correlation across portfolios was negative in 3 years
  - For industrial metals: Across years, the average correlation of 3 member portfolios was .47 (T=7.79) and .51 (T=8.51) for 4 members portfolios
- For portfolios that drew members from the full universe of contracts, the results are very strong
  - Across years, the average correlation of 3 member portfolios was .41 (T=12.45), .53 (T=12.85) for 10 member portfolio and .59 (T=11.16) for 25 member (index like) portfolios
  - For 25 member portfolios the average correlation is .70 over the last ten years. For commodity indices that are heavily weighted toward energy (i.e. GSCI) the results are stronger

Commodities - Robustness Checks

- Company sector factor definitions
  - Tested both the regular sector factor return histories and revised histories based on separating producing companies from consuming companies for each type of commodity
  - Distinction was based on membership in equity portfolios used in ETFs designed to mimic commodity returns
  - Results were slightly worse for “purified” sectors but differences were not statistically significant
- Rigorous treatment of possibly spurious PCA factors
  - Miller (2006)
  - Bouchard, Laloux, Cizeau and Potters (2000) estimates a rule for the number of “apparently significant” eigenvectors in matrices known to be random

A Last Check

- We can convert the factor representation of a commodity contracts (or portfolios) and other assets (e.g. S&P 500) to the numerically equivalent full covariance matrix
  - http://www.northinfo.com/Documents/58.pdf
- We can now conveniently compare the forecasts from the Northfield model to forecasts from various time series models using the V Lab website from NYU
- Dan checked a bunch of items and have not found any cases where forecast differences were statistically significant at the 90% level

Conclusions

- Effectively incorporating commodities in a multi-asset class risk model is a complex task.
- Volatility properties of commodities are relatively well behaved over time, but correlations are very unstable
- We chose to relate commodities to existing model factors
  - We believe our process reasonably separates transient effects (noise) from effects which are likely to be persistent
  - Preserves the structure of the existing models which have been proven effective for larger asset classes
  - Utilizes intuitive relationships between commodities and equity behavior of related companies.
  - Perhaps include weather factors in the future?