Dependence of commodity spot-futures markets: Helping investors turn profits

Sana BEN KEBAIWER
PhD Student
Growth rate of commodity futures open interest
Source: CFTC Data

<table>
<thead>
<tr>
<th>Commodities</th>
<th>1990</th>
<th>2000</th>
<th>2016</th>
<th>Growth rate 90-00</th>
<th>Growth rate 00-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude oil</td>
<td>272.262</td>
<td>464.369</td>
<td>1.678.012</td>
<td>71%</td>
<td>261%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>8.180</td>
<td>333.874</td>
<td>991.540</td>
<td>3982%</td>
<td>197%</td>
</tr>
<tr>
<td>Wheat</td>
<td>283.154</td>
<td>683.987</td>
<td>2.013.454</td>
<td>142%</td>
<td>194%</td>
</tr>
<tr>
<td>Corn</td>
<td>1.094.145</td>
<td>2.172.482</td>
<td>6.665.012</td>
<td>99%</td>
<td>207%</td>
</tr>
<tr>
<td>Soybean</td>
<td>557.624</td>
<td>830.915</td>
<td>3.447.435</td>
<td>49%</td>
<td>315%</td>
</tr>
<tr>
<td>Cotton</td>
<td>38.149</td>
<td>62.079</td>
<td>185.401</td>
<td>63%</td>
<td>199%</td>
</tr>
<tr>
<td>Copper</td>
<td>33.535</td>
<td>73.423</td>
<td>170.499</td>
<td>119%</td>
<td>132%</td>
</tr>
<tr>
<td>Gold</td>
<td>117.763</td>
<td>142.078</td>
<td>418.942</td>
<td>21%</td>
<td>195%</td>
</tr>
</tbody>
</table>

Open interest doubles for: corn
3 times for cotton
4 times for crude oil
1.4 times for wheat
6.5 times for soybean
9 times for gold

The growth in open interest futures positions is significantly followed by an increase in the financial investors participants in the futures market.
MOTIVATION

NON COMMERCIAL POSITIONS
Commodity Boom

Since 2005, trading of commodity futures has risen more than any other sector of the global derivatives market.

**AGRICULTURE**
- From 500 thousand contracts to 1,500 thousand contracts

**ENERGY**
- From 700 thousand contracts to 3 million contracts

**PRECIOUS METALS**
- From 100 thousand contracts to 4.6 million

Source: CME
the onset of the subprime crisis between 2007 and 2008 has further reinforced the enthusiasm for commodities.

**FIRST**

**SECOND**

Commodity futures returns offer the same mean return as US equity return but with negative correlations between commodity and stock and bond markets => decrease risk.

**THIRD**

Diversification
the co-movement between international equity market increased dramatically
Headging against risk and inflation,Gorton and Rouwenhorst (2006), Erb and Harvey (2006), Bhardwaj et al. (2015)

**FORTH**

Growing use by the financial investors especially, to hedge in periods of crises:
=> Financialization of Commodity market
Synchronized with changes in prices
Futures Contracts Fonctions

• Transmit information to all economic agents: producers, hedgers, policy makers, and speculators (Chun and Lee, 2015)
  • Have the power of predicting spot prices (Working, 1953).

⇒ In this paper, I focus on the second function of the futures contract, especially in non-stable periods, as investors and policymakers are more sensitive to price predictability during such periods.

⇒ I investigate whether the futures contract market is connected to the spot market in positive and negative crises periods, thus helping to predict future prices.
A vast literature explored the link between COMMODITIES futures and spot prices: results were different from one author to another; it does not exist an evidence about the results, and the methodologies were varied.

**Previous Studies**

- Futures have the power to lead spot markets
  - French (1986), working (1953), Bopp and Stizer (1987), Shwarz and Szakmary (1994)

- Futures transfer risks
  - Garbade and Silber (1983)

- Commodity markets are sometimes inefficient
  - Beck (1994)

- Efficient on the long run but not in the short run

- Different methodologies
  - Linear and non linear: Bekiros and Dilks (2008), Arouri et al (2013)
The literature assumes that a high correlation exists between futures and spot prices for the majority of the commodities. That is why futures prices are considered as a major predictor for spot prices. In the same time, other studies do not confirm this evidence.

However, this never means that the two markets have the same behavior and the same reactions in periods of booms and busts. I will focus on tail dependence and the existence of symmetric and asymmetric dependence between the two markets in crash periods.

What is the relationship between spot and futures markets when both are in a very good condition? What is their relationship when both markets are in a very bad condition? Finally, how do they differ in good and bad conditions? This paper designs a 4 Copula approaches to answer the above questions.
**MOTIVATION**

**COPULA APPROACH**

- Correlation proposed by Pearson may be too restrictive to measure the dependency
- Linear correlation can pose a huge problem because, in some cases, it exist a potential asymmetry and non-linearity
- Previous methodologies are not able to identify asymmetries in asymptotic tail dependence

**ADVANTAGES**

- Copula is flexible
- Copulas is a more widespread approach that overcomes the disadvantages and weakness of the previous methodologies

  - The dependence of extreme events, which are highly present in the commodity markets
  - Copula is invariant under strong increasing or decreasing transformations
  - We can model each variable separately and in the same time measure the dependence between these same variables
METHODOLOGY: COPULA

NORMAL (SYMMETRIC)

Elliptical Copula

\[ \lambda_L = \lambda_U = 2 \left( -\sqrt{y + 1} \right) + 1 \]

GUMBEL (ASSYMMETRIC)

More efficient when dealing with dependence in upper tail

\[ \lambda_{UC} = 2 - 2^{-\theta} \]
\[ \lambda_{LC} = 0 \]

FRANK (SYMMETRIC)

Archimedean Copula

\[ \lambda_{UP} = \lambda_{LP} = 0 \]

CLAYTON (ASSYMMETRIC)

More powerful in dealing with dependence in negative or lower tail

\[ \lambda_{UC} = 0 \]
\[ \lambda_{LC} = \frac{1}{2\theta} \]
DATA

Energetic and non-energetic commodities are a desirable asset classes for international portfolio diversification

=> Strong alternative investment instrument to hedge against risks in equity markets.

From each category of commodity: the top actively trading commodities

The nearest maturity of the futures contract because they are the most liquid and the most active contracts

Daily data: 1997 to 2016

Energy=Crude oil, Natural Gas, Precious Metals= Gold, Platinum, Agriculture=Soybean, Wheat, and soft agriculture= Cotton, Sugar
### Energy

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Normal Copula</th>
<th>Clayton Copula</th>
<th>Gumbel Copula</th>
<th>Frank Copula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude oil</td>
<td>0.887103 (0.002345)</td>
<td>3.41118 (0.06071)</td>
<td>3.49114 (0.04383)</td>
<td>14.0689 (0.2077)</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.3285 (0.0125)</td>
<td>0.37865 (0.02232)</td>
<td>1.25637 (0.01375)</td>
<td>2.1234 (0.0924)</td>
</tr>
</tbody>
</table>

### Precious Metals

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Normal Copula</th>
<th>Clayton Copula</th>
<th>Gumbel Copula</th>
<th>Frank Copula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>0.9854678 (0.000298)</td>
<td>25.0696 (0.3712)</td>
<td>18.8854 (0.2627)</td>
<td>78.161 (1.127)</td>
</tr>
<tr>
<td>Platinum</td>
<td>0.9740385 (0.000538)</td>
<td>20.2828 (0.2958)</td>
<td>13.81675 (0.1886)</td>
<td>64.8953 (0.9121)</td>
</tr>
</tbody>
</table>

### Agriculture

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Normal Copula</th>
<th>Clayton Copula</th>
<th>Gumbel Copula</th>
<th>Frank Copula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean</td>
<td>0.64977 (0.007136)</td>
<td>1.11609 (0.03066)</td>
<td>1.79035 (0.02127)</td>
<td>5.0452 (0.1077)</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.949673 (0.001046)</td>
<td>8.9235 (0.1343)</td>
<td>6.55604 (0.08551)</td>
<td>29.5938 (0.4129)</td>
</tr>
</tbody>
</table>

### Soft Commodities

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Normal Copula</th>
<th>Clayton Copula</th>
<th>Gumbel Copula</th>
<th>Frank Copula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>0.664739 (0.006845)</td>
<td>1.22554 (0.03163)</td>
<td>1.80706 (0.02145)</td>
<td>5.2625 (0.1091)</td>
</tr>
<tr>
<td>Sugar</td>
<td>0.681461 (0.006518)</td>
<td>1.28196 (0.03215)</td>
<td>1.82948 (0.0164)</td>
<td>5.3399 (0.1092)</td>
</tr>
</tbody>
</table>
Contour Plots

Crude oil:

Gold:

Wheat:

Sugar:

Natural Gas:

Platinum:

Soybean:

Cotton
Results

According to maximum likelihood indices, Clayton Copula is the best to model the dependence between the majorities of commodities spot and futures returns.

- **DEPENDENCY**
  All the copula dependency parameters are significant for all the commodities.
  All the commodities spot and futures prices are highly dependent in calm periods.

- **ASSYMMETRY**
  Clayton Copula is the most appropriate: almost all the dependencies are asymmetric.

- **TAIL DEPENDENCE**
  Tail dependencies are different according to the type of the commodity.
Crude Oil
Asymmetric Dependency
High tail
Dependency remain strong during positive and negative crashes

Natural Gas
Asymmetric Dependency
Upper tail with increasing shape
Lower tail converge to 0
Lower dependency during negative crashes

Gold
Symmetric Dependency
High Upper and Lower tail
Very Storable commodities
Frank and normal copula: sharps at (0.0) and (1.1).

Platinum
Symmetric dependency
High Upper and Lower Tail
Storable commodity
Economic news has similar effect
Wheat
Asymmetric
High upper tail
Storable in weak quantities

Soybean
Quite symmetric
dependency
Low dependency in crash periods
Spot and futures converge with lags
Behavior of inventory holders

Sugar
Symmetric dependency
Low dependency in crash periods
Storable for long periods
Low frequency of shocks

Cotton
Symmetric dependency
High tail dependency
High storable commodity
Storable for long periods
<table>
<thead>
<tr>
<th>Copula Families</th>
<th>Gumbel parameter</th>
<th>Gumbel Upper tail</th>
<th>Clayton parameter</th>
<th>Clayton Lower tail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commodities</td>
<td>$\theta_G$</td>
<td>$\lambda_U$</td>
<td>$\theta_c$</td>
<td>$\lambda_L$</td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude oil</td>
<td>3.491</td>
<td>0.793</td>
<td>3.411</td>
<td>0.829</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>1.256</td>
<td>0.496</td>
<td>0.978</td>
<td>0</td>
</tr>
<tr>
<td>Precious Metals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gold</td>
<td>18.885</td>
<td>0.962</td>
<td>25.069</td>
<td>0.973</td>
</tr>
<tr>
<td>Platinum</td>
<td>13.816</td>
<td>0.948</td>
<td>20.282</td>
<td>0.967</td>
</tr>
<tr>
<td>Agriculture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>1.79</td>
<td>0.664</td>
<td>1.116</td>
<td>0.108</td>
</tr>
<tr>
<td>Wheat</td>
<td>6.556</td>
<td>0.591</td>
<td>8.9235</td>
<td>0.923</td>
</tr>
<tr>
<td>Soft commodities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td>1.807</td>
<td>0.707</td>
<td>1.225</td>
<td>0.665</td>
</tr>
<tr>
<td>Sugar</td>
<td>1.829</td>
<td>0.495</td>
<td>1.281</td>
<td>0.664</td>
</tr>
</tbody>
</table>
The goodness fit test

<table>
<thead>
<tr>
<th>Copula families</th>
<th>Normal Copula</th>
<th>Clayton Copula</th>
<th>Gumbel Copula</th>
<th>Frank Copula</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>param</td>
<td>p-value</td>
<td>param</td>
<td>p-value</td>
</tr>
<tr>
<td>Commodities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude oil</td>
<td>0.92058</td>
<td>0.00495</td>
<td>5.83</td>
<td>0.00495</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.34427</td>
<td>0.1139</td>
<td>0.57647</td>
<td>0.00495</td>
</tr>
<tr>
<td>Precious Metals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gold</td>
<td>0.99676</td>
<td>0.00495</td>
<td>37.019</td>
<td>0.00495</td>
</tr>
<tr>
<td>Platinum</td>
<td>0.99493</td>
<td>0.00495</td>
<td>29.177</td>
<td>0.00495</td>
</tr>
<tr>
<td>Agriculture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>0.65596</td>
<td>0.00495</td>
<td>1.6729</td>
<td>0.00495</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.97817</td>
<td>0.00495</td>
<td>13.007</td>
<td>0.00495</td>
</tr>
<tr>
<td>Soft commodities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton</td>
<td>0.6729</td>
<td>0.01485</td>
<td>1.7729</td>
<td>0.00495</td>
</tr>
<tr>
<td>Sugar</td>
<td>.68029</td>
<td>0.00495</td>
<td>1.8189</td>
<td>0.00495</td>
</tr>
</tbody>
</table>
Conclusion

1 Copula Approach

A great many studies have investigated the linkage between Commodities spot and futures markets by utilizing the correlation coefficient. However, the information provided by the correlation coefficient is limited. What is the relationship between spot and futures markets when both are in a very good condition? What is their relationship when both markets are in a very bad condition? Finally, how do they differ in good and bad conditions? This paper designs a 4 Copula approaches to answer the above questions.

2 Results

Interesting results:
For each type of commodity we observe similar results
The dependence probability is remarkably larger than the independency probability + asymmetric dependency in Upper and lower tail for each commodity depending on its storage process

3 Economic effect

These information are very useful to investors and policy makers
All the abrupt changes are generally mis-estimated: Understanding price discovery process and price behavior during crash periods is very important
THANK YOU!

ANY QUESTIONS?

Sana BEN KEBAIER

MAIL: sana.ben-kebaier@dauphine.eu

The 35th USAEE/IAEE NORTH AMERICAN CONFERENCE
• **Copula** is a multivariate probability distribution for which the **marginal probability** distribution of each variable is **uniform**. Copulas are used to describe the **dependence** between random variables.

• Copulas link multivariate distributions to their univariate marginal functions
• It is represented as a multivariate distribution function $C$ with standard uniform marginal distribution.
• It depends on Sklar’s theorem: It states that every joint distribution function $H$ of a random vector $(X_1, X_2, ..., X_d)$ with marginal distribution $F_i(x) = \mathbb{P}[X_i \leq x]$ can be defined as $H(x_1, ..., x_d) = C(F_1(X_1), ..., F_d(X_d))$ Where $C= \text{Copula}$ and $C: [0,1]^d \rightarrow [0,1]$

The theorem states also that the copula is unique if the marginal $F_i$ is **continuous** and the converse is true.

$(X_1, X_2, ..., X_d)$ represents our commodities

There are many parametric copula families available, which usually have parameters that control the strength of dependence.
• **Copula** is a multivariate probability distribution for which the marginal probability distribution of each variable is uniform. Copulas are used to describe the dependence between random variables.

• Copulas link multivariate distributions to their univariate marginal functions
  • It is represented as a multivariate distribution function $C$ with standard uniform marginal distribution.
  • It depends on Skalar’s theorem: It states that every joint distribution function $H$ of a random vector $(X_1, X_2, ..., X_d)$ with marginal distribution $F_i(x) = \mathbb{P}[X_i \leq x]$ can be defined as $H(x_1, ..., x_d) = C(F_1(X_1), ..., F_d(X_d))$ Where $C=\text{Copula}$ and $C: [0,1]^d \rightarrow [0,1]$

The theorem states also that the copula is unique if the marginal $F_i$ is continuous and the converse is true.

$(X_1, X_2, ..., X_d)$ represents our commodities
There are many parametric copula families available, which usually have parameters that control the strength of dependence.