Analysis on price volatility between WTI light crude and raw coal

The supply-demand relations of WTI light crude and raw coal are influenced by the rate of economic growth. Their supply-demand relations are stable in general. There exists interactivity and correlation when their prices fluctuate. Short-term speculation will make the bubble occur in their price volatility. A sliding correlation between the price growth rate of goods and global GDP growth rate is analyzed, and found that the changing tendency is almost the same between the two, however there are some lag in time. To study their interactivity, through the co-integration test between WTI light crude and raw coal, the author concluded that there is a first-order co-integration relationship between the two and their price changes are highly correlated. From the view of spectrum, fluctuations of raw coal prices into long-term and short-term behaviours are divided. We can judge which kind of behaviour plays a dominant role when price volatility happens, based on which we can analyze the liveness of market speculation.

Keywords: Commodity price; volatility period; spectral analysis; co-integration relationship; lag effect

1. Introduction

Econometric analysis of commodity price, which can be traced back to economics itself, has a long history and was born during the emerging science century in the 1920s and 1930s[1,2]. After that, some scientists began to concentrate on assessing the supply-demand prediction system, goods supply and price, and their effects on commodity pricing policy. Some scholars did a lot of research on this[3,4].

Commodity price volatility plays an important role in keeping a stable operation of macro economy. Studies showed that price changes of bulk commodity can be explained by the changing of related market economic fundamentals[5,6]. It is generally believed that if most commodity price changes are in accordance with economic fundamental changes, we can think market is effective in guiding resource allocation. On the other hand, if there is much volatility spillover which goes beyond economic fundamental changes, it can be thought that commodity market is full of speculative bubble and commodity price volatility becomes a signal of ineffective resource allocation.

Coal, raw oil, iron ore, copper ore, bauxite, gold and some other industrial and agricultural materials constitute so called bulk commodity. Bulk commodity has some features such as huge trading volume and mature supply-demand market. Its manufactured goods are closely related to the daily economic activities and its price fluctuations have a direct impact on the operation of national economy. For example, coal price fluctuations exerted significant long-term positive effects and short-term negative effects on China's output variables, with an average delay of 11 months; they had positive effects on investment and consumption over the long term and an increasingly negative effect on imports and exports. Since the 1980s, government regulation of coal prices has loosened due to Chinese economic reforms. From 1979 to 1992, China's coal industry introduced a market competition mechanism that focused on price adjustment and assigned less importance to price liberalization. Since 1993, reforms to China's coal price system have entered a new stage, in which a pricing mechanism based on market price has gradually formed. From 1994 to 2005, China's average coal prices rose by 161 yuan/ton, representing an average increase of 14.4%. Coal has a great influence on the daily lives of Chinese people, so the government controls its price by implementing macro controls and a price cap; these practices continue to this day. This road of reform with regard to coal prices toward market-oriented pricing has been full of twists and turns. The mechanism of coal pricing in China needs to change to a structure in which the price is determined by the coal market. Coal pricing has been completely limited by government policies to ensure coal supplies, with occasional modest adjustments made according to market price changes. However, the means of distribution for coal resources is market allocation, which promotes a market oriented reform.

Economic development is the base of bulk commodity's supply and demand. Macro-economic factors such as economic cycle, international trade status and economic

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climate have been factors which affected bulk commodity prices. Since 2004, institutional investors began to widely step into commodity future market. The behaviour of pursuing after hot money and hedge funds largely caused bulk commodity price fluctuations deviate from fundamentals[7]. Zhihua Ding et al (2016) emphasized investment hype is the main root of sharp fluctuations in commodity prices and suggested that governments should regulate it heavily[8].

In this paper, the author analyzed price volatility of WTI light crude and raw coal, studied periodic laws of price fluctuations and their relations with economic growth rate, discussed price relations between energy commodities such as raw oil and coal, and talked about the market running status.

2. Analysis of price volatility correlation and hysteresis between raw coal and WTI light crude

Starting from the actual situation of the research question, this article only gave a statistical analysis from the prices volatility of raw coal, WTI light crude, relevant gold future and global economic growth rate.

Coal is an important power for economic operation. Australian thermal coal is of good quality and stable supply. Many investors consider American West Texas Intermediate (WTI) sight contracts price as benchmark price in the international energy market. A lot of media articles also referenced WTI as representative prices while describing the crude oil prices. This article selected Australian thermal coal prices from January 1985 to December 2014 and WTI light oil data in the same period as research objects.

2.1 BULK COMMODITY PRICES AND MAIN CORRELATION INDEX

As for bulk commodity prices, we selected prices of WTI light crude, raw coal and gold for each month from 1985 to 2014, employed the method of general statistical analysis, calculated the mean, variance, standard deviation and did correlation analysis towards the price time series of these products above, and then gave a brief description of the basic price fluctuations. The price time series of the selected bulk commodity prices are shown in Fig. 1.
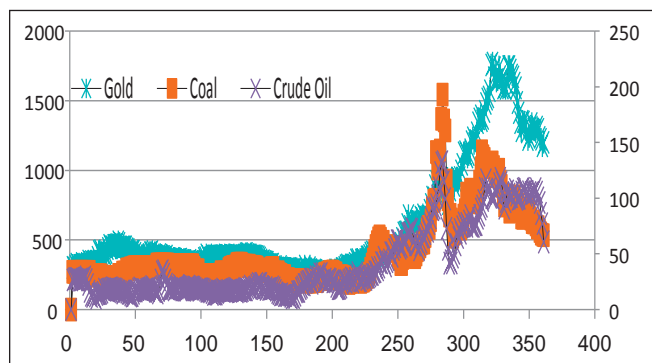

Fig. 1: Iron, copper, crude oil, coal price tendency (1985.1-2015.1)

2.2 BULK COMMODITY PRICE GENERAL STATISTICAL ANALYSIS
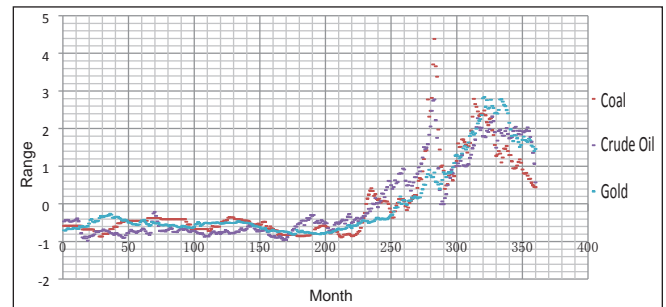

Fig. 2: Standard data tendency

From Fig. 2, we can see that price tendencies of crude oil, raw coal and gold futures are almost the same from January 1985 to January 2015. Early changes are quite gentle but prices sharply increase and then drop down after year 2000, while of gold price tendency presents a kind of feature that the middle is high but the two sides are low, its ups and downs are more severe.

2.3 BULK COMMODITY PRICE CO-INTEGRATION ANALYSIS

2.3.1 Co-integration relationships among bulk commodity

As is shown in Table 1, the correlation coefficient of copper ore and raw coal is 0.888, WTI light crude and raw coal is 0.902, WTI light crude and raw coal reaches up to 0.935, gold and raw coal is 0.850, gold and copper ore is 0.887, gold and WTI light crude is 0.904, iron ore and raw coal is 0.849, iron and copper ore is 0.857, iron ore and WTI light crude is 0.867, iron ore and gold is 0.904, M1(USA) and gold is 0.861, M2(USA) and crude oil is 0.901, M2(USA) and M1(USA) is 0.954.

From the aspect that normalized price time series among different kinds of bulk commodity have strong correlations, it is reasonable to believe there are long-term and stable correlation among the market prices of bulk commodity, which are called co-integration relationships.

2.3.2 Co-integration test among bulk commodity

To achieve the study goal, we did a co-integration test between WTI light crude and raw coal using bi-variate E-G. The correlation coefficient of WTI light crude and raw coal is 0.902, we employed least square method to get fitted curves.

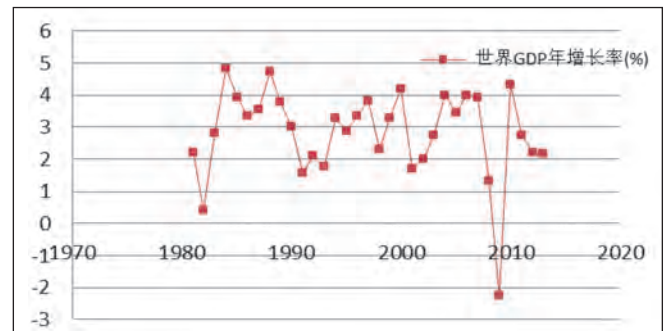The error between actual value and fitting value is:

Fig. 3: Time series fitted curves' residual errors of raw coal prices and WTI light crude prices

Use bi-variate E-G to test their correlation. It is seen as a stable series from Fig. 3, and then unit root test is given.

The result that null hypothesis is unstable series shows that the value P is -3.448363, which is smaller than significant α level under the 5% confidence interval, so it is supposed to reject null hypothesis, and consider the residual error's first-order difference sequence as stationary. So, according to bi-variate E-G judging rules, we can believe that coal prices and WTI light crude monthly data have (1,1) co-integration relationship.

2.4 ANALYSIS OF HYPOTHESIS EFFECT BETWEEN BULK COMMODITY PRICES AND GDP

2.4.1 Mobile related compare technology

Select two arbitrary curves from adjacent curves and divide them into series $[X_i]$, $[Y_i]$, of which i = 1, 2, 3... N, it indicates number of discretized sampling points.

Series $[X_i]$ and $[Y_i]$ are similar or not is equivalent to X_i and $[aY_i+b]$ are nearing or not, which means the mean square error Q between them reaches the minimum, that is:

Contrasting to the first line moving from top to bottom firstly, we selected N sampling points from-n points and compared them to other N points selected from another curve.

$A_i - A_1A_2$ value of sampling point i

$B_{i+\gamma} - B_1B_2$ value of sampling point i+I

N – number of sampling points in the compared line

γ – number of sampling points when curve B moves

B_γ^- – average of N sampling points selected from the first beginning on curve B1B2

$R_{(\gamma)}$ – correlation coefficient of curves A_1A_2 and B_1B_2 after they move γ sampling points

As is shown in Fig. 4, the world GDP growth rate is comparatively stable. Its fluctuation range is far less than the commodity price volatility, but the ascent and downturn of economic are obviously related to bulk commodity price fluctuation.
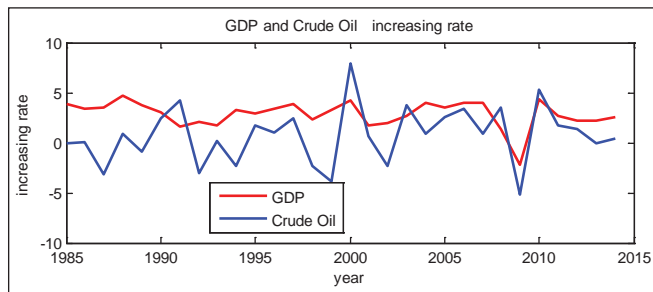

Fig. 4: 1985-2015 world inflation rate and GDP growth rate measured on CPI basis

Assuming that the GDP growth rate and commodity growth rate have a good correlation with each other and the lag effect exists, we use mobile-related measures and found that when

commodity growth rate slides a certain distance and then give it a correlation analysis with GDP rate, there will be a singular point of obvious value in either high or low.

2.4.2 Sliding correlation comparison of WTI light crude and GDP

As is shown in Fig. 5, the annual growth rate of WTI light crude has obvious similarities with GDP speed up waveform, but there is evident lagging and moving phenomenon between their peak values. Do a waveform match correlation analysis of GDP growth rate and WTI light crude price growth time series according to automatic pick-up technology.
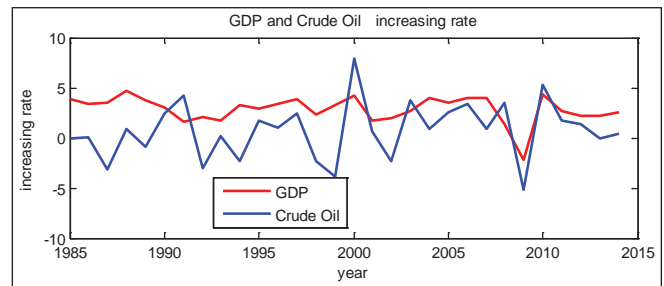

Fig. 5: WTI light crude annual price data and GDP growth rate
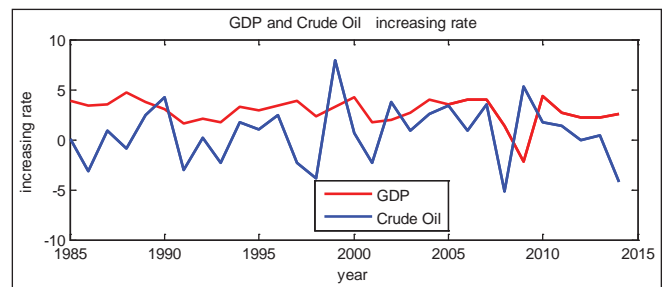

Fig. 6: WTI light crude annual price data after moving one step and GDP growth rate
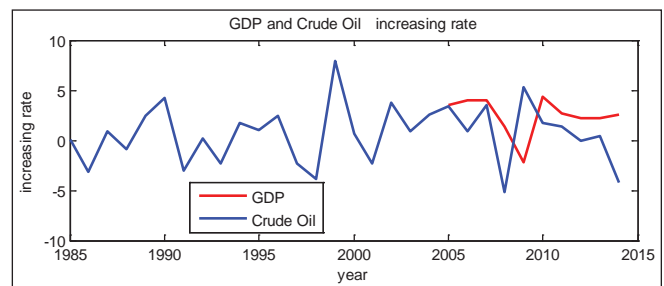

Fig. 7: WTI light crude annual price data and GDP growth rate

It is generally believed that data of nearly 10 years can reflect more about the lag relationship between current commodity price movements and GDP growth speed. So we gave 2005-2014 GDP growth rate a sliding matching analysis based on WTI light crude prices rate.

It can be seen from the above figure that WTI crude prices have obvious lag relationship with GDP growth during the last ten years. Sliding correlation results are shown in the figure below. Within the window size of 5 and 10, when mobile interval is 19, they reach the maximum correlation coefficient at the same time. It is generally believed the

greater the sliding window is, more is the reliable value. Crude oil price growth data began to slide from 1985 to 1994 and reached the peak. The sliding step is 19. So the largest correlation window is 2004-2013, just lag one year with GDP data.

3. Bulk commodity price spectral analysis

3.1 BULK COMMODITY PRICE FLUCTUATION NORMALIZATION PROCESSING

Commodity prices are mainly influenced by commodity value, supply and demand, inflation and speculative factors. Value of goods is relatively stable in a certain period while the change of supply and demand is cyclical or sudden, and it has the long-term impact on the price changes. Speculative behaviour is a kind of favourable operation based on the market fundamentals according to the principle of doing something good for itself. It relies on the basic market fundamentals and cannot fully reflect the supply-demand relationship.

Spectrum analysis shows that it is still low frequency components contribute more to the overall price range, which indicates that long period behavior decide the overall gold price trend. Short-term behavior exists stably within a certain cycle and the changing range is comparatively balanced.

Analysis is done on the gold price change within one year according to spectrum Fourier analysis method.
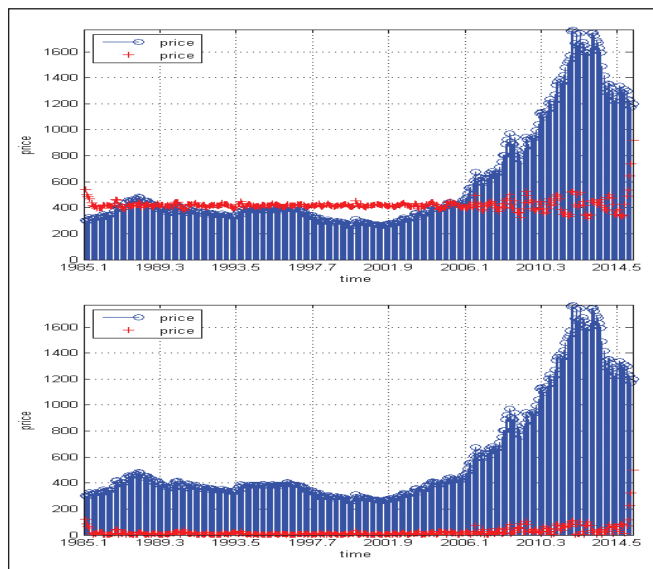

Fig. 8: Cycle component within 1 year (top) and stacking line of cycle component within 1 year and dc component (bottom)

According to the relatively stable change of frequency components within one year, the superposition of frequency components and dc components is also stable, which shows the gold market is stable. The long-term behaviour of market plays a leading role in price fluctuations. The price of gold is mainly depending on that its value is less affected by speculative factors.

3.2 SPECTRUM ANALYSIS OF WTI CRUDE OIL FUTURES PRICE INDEX BASED ON THE GOLD PRICE

Influenced by inflation, the premise of measuring commodities prices fluctuation intensity and cycle behaviour is correcting their prices to the same baseline time. According to the previous analysis, the purchasing power of gold is relatively stable under the condition of market. Considering gold current prices as a reference standard and the same amount of the goods as cardinality, we used time series index of gold amount consumed when buy units sold to measure the price volatility intensity and cycle behaviour of bulk commodity.

Put the current gold as the valuation scale and calculate the price index of crude oil 1985.1-2015.1-time sequence as below.
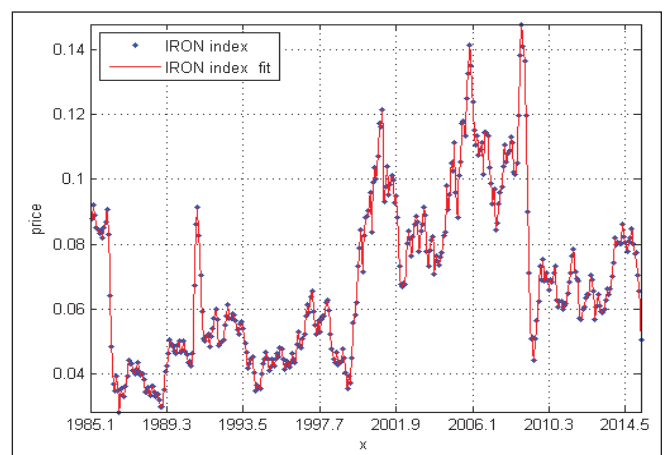

Fig. 9: 1985-2014 WTI crude price index based on gold price

From the figure, we can directly see from 1985 to the early 21st century, deducting the effect of inflation, the price of crude oil in the first decade of the 21st century is generally in a comparatively high position. Its short-term change in acute, reflecting the overall market demand is strong but the market is not stable affected by various factors.

Do a discrete Fourier analysis of crude oil price index and get its frequency spectrum as follows:
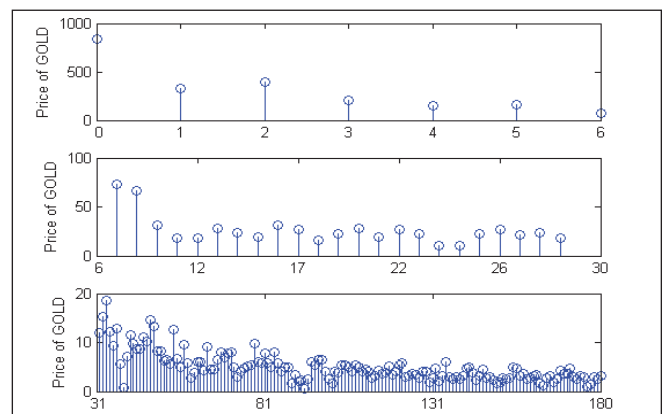

Fig. 10: 1985-2014 WTI crude price index spectrum based on the price of gold

Spectrum analysis still shows that it is lower frequency components (long-periodic behaviour) decide overall prices trend. Short-term behaviour, according to the overall situation of price index, exists stably within a certain range cycle and its change range is more balanced.

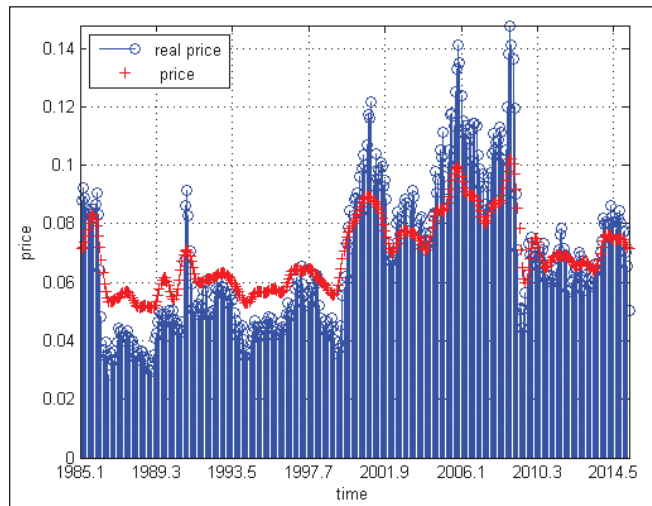### 3.3 SPECULATIVE ACTIVITY TEST BASED ON SPECTRUM ANALYSIS

Fig. 11: Superposition of cycle component greater than one year and within a year and dc component

According to data obtained from the actual situation, we see the components whose cycle is of more than one year as long-term market behaviors, and less than a year as short-term market behaviors. Superimpose all components whose cycle is of more than one year and dc components, and compare it with the superposition result of components whose cycle is within a year and dc component.

Short-term volatility has a certain degree of deviation compared with long-term behavior, for example, in 2010 and at the end of 2014, short-term trend line within 1 year and trend line after 1 year have basically the same degree of volatility, but the line within a year is significantly higher than the one after 1 year, which is a clear sign of significant market short-term behavior. This kind of phenomenon is in practically corresponded to some phenomenon such as prices dramatically increasing because of war or geopolitical reasons. But considering the commodity production consumption and relatively long storage period can buffer the price increase, it is considered much like a kind of speculation, so the price will naturally fall in the short term.

3.4 SPECTRUM ANALYSIS BASED ON GOLD FUTURES PRICE INDEX

Futures price depends on its own value, but the value of futures products is stable in a certain period. The factor caused prices' long-term change is the market behaviour of long period. The short-term price fluctuations are beneficial as operations towards the market based on long-term price movements. The decisive factor caused its short-term price change is the short-term market behaviour, but in the long run it is the value of goods which plays a part.

4. Conclusions

Energy commodities' supply and demand such as crude oil and raw coal is affected by strict and unstick factors, their prices fluctuations are also cyclical, but their movements have strong correlations with each other. Doing a sliding correlation analysis of price growth and global GDP growth, we found that the two movements are almost the same; and there exist different degrees of lag effect in time; the lag time is commonly a year. The quantitative propose of lag effect may provide a basis for government intervention of commodity markets to prevent overheating economic.

After a spectrum analysis for crude oil future prices, we further verified that the future price depends on its value. Prices fluctuate around the value, the factor caused its long-term price changes is the long-period market behaviour. The short-term price fluctuations are beneficial operations of the market situation based on long-term price movements, while the decisive factor caused short-term price change is its short-term market behaviour. From their composition deviation, we can detect the market bubble. Using spectrum analysis to test market bubble, we can not only review past policies, but also can monitor the current market operation is effective or not.

By doing co-integration analysis of price swinging with each other, we found that energy commodities: coal and crude oil, present features of rising and falling with each other. The price change of crude oil and coal is highly relevant. In actual market, the supply and demand of crude oil and coal is not highly consistent with each other, but no matter seeing from long-term or short-term behaviour, their ups and downs of price are strongly correlated, which reflects that the energy products pricing behaves more and more like a performance of indiscriminate standard commodity pricing. There exists complementarities between each other, and their correlation is long-term and stable; promoting factors of price change are highly consistent, on the basis of which energy consumption market can put forward a new valuation mode and provide a reference basis for new energy pricing or subsiding.

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