The Asymmetric Spillover Effects of Prices Volatilities in Energy and Corn Markets

Haixia Wu [1, a], Yan Ge [2, b]

[1] International Business School, Shaanxi Normal University, Shaanxi Xi'an 710119

[2] School of Public Finance and Tax, Central University of Finance and Economics, Beijing 100081

[a] email:hxia007@126.com; [b] email:machopku@163.com

Keywords: Crude Oil Futures, Corn Futures, Corn Cash, Asymmetry

Abstract: Based on the daily data of international crude oil futures, corn futures on the China's Dalian Commodities Exchange and the China's corn cash prices between June 1, 2010 and May 6, 2014, employing single variable EGARCH model and multivariables asymmetric BEKK-MVGARCH model, this paper empirically examines the prices volatilities asymmetry effects in one of markets and among markets. The results show that in terms of the single market, the volatilities caused by information of prices decreases on crude oil futures market and corn cash market are greater than the ones caused by the information of prices rises. On the contrary, for corn futures market, the volatilities caused by information of prices increases are greater than the ones caused by the information of prices decreases. In terms of multi-markets, the negative shocks to corn futures market from corn cash market are more obvious than positive shocks, however, the positive shocks to corn cash market from corn futures market are more significant than negative shocks, just as they are from crude oil futures market to corn cash and futures markets.

1. Introduction

In recent years, China's grain prices have fluctuated frequently, especially since 2006, food prices have increased significantly. Taking the corn market as an example, its wholesale market price index rose from 109.02 points in September 2003 to 237.94 points in September 2011, an increase of 118.5%. In the traditional sense, the rise in food prices is affected by the demand of the grain market and the fluctuation of supply in the main producing areas. However, the recent increase in food prices is closely related to the surge in international energy prices and the expected growth in finance (Campiche et al., 2007; Balcombe and Rapsomanikis, 2008). . For example, the international crude oil futures price was only 39.79 US dollars per barrel in February 2009. By September 2013, the price soared to 113.33 US dollars per barrel, and the price has nearly tripled. The corn futures price in China was only 1578 in February 2009. Yuan/ton, in September 2013, rose to 2,343 yuan / ton, an increase of 48.48%.

The high correlation between crude oil and corn market price fluctuations has led more and more scholars to pay attention to the transmission mechanism and conduction path of price fluctuation between the two, especially in the context of high energyization of food. In general, we believe that crude oil prices have an impact on corn price volatility through two paths: First, increase corn prices by pushing up production costs. From the mid-1980s to 2004, the international crude oil price remained at 20~40 US dollars/barrel. After 2006, it rose rapidly. In mid-2008, it broke through 140 US dollars/barrel. According to energy use, which accounts for 30% of the cost of food production (the United States and other countries even reach 40%), the increase in crude oil prices in 2004-2008 led to a 40% increase in corn production costs and transportation costs. The second is to increase corn prices by expanding demand. As a substitute for crude oil, biomass energy has expanded rapidly in the context of soaring crude oil prices, directly expanding the market demand for energy crops such as corn, and strengthening the impact of crude oil price fluctuations on corn prices. For example, from 2002 to 2008, international oil prices continued to rise, and biomass energy developed rapidly. Among the agricultural product price fluctuations in the first half of

  DOI: 10.25236/ssehr.2018.011

2005-2008, corn prices first rose by 114.5%, and then the prices of wheat and soybeans rose by 118.7% and 96.1% respectively..

Although the impact of energy price volatility on corn price volatility is significant, the reverse effect of corn price volatility on energy price volatility is not obvious (Wu Haixia et al., 2013; Wu Haixia and Huo Xuexi, 2014), that is, the relationship between the two has significant Asymmetry. The so-called asymmetry, that is, the price fluctuation of the same magnitude has different amplitude effects due to the difference between the positive and negative directions. This feature has important guiding significance for the formulation of market policies. In a single market, grasping the asymmetry of price fluctuations helps market participants to make reasonable expectations of price volatility through price fluctuations. The asymmetry between multiple markets is to accurately grasp the price conduction path and role between different markets. The important means of degree will help policy makers to better grasp the radiation effects of a certain market policy. Therefore, a correct understanding of the asymmetric spillover effect of the grain and energy futures market on the spot market price fluctuations is of far-reaching significance.

2. Literature Review

At present, domestic and foreign scholars have focused on the asymmetry of energy market and food market price fluctuations in the single market. Baharom et al. (2009) used the EGARCH model and the monthly data of world rice from 1961 to 2008 to find that the world price of rice has an asymmetry of price fluctuations. Luo Wanchun and Liu Rui (2010) analyzed the asymmetry of price fluctuations of China's major grain varieties based on the ARCH model. It was found that wheat price fluctuations have significant asymmetry characteristics, which is similar to Feng Yun's (2008) results. Sun Lin and Ni Kaka (2013) used the Chicago Futures Exchange's rice, wheat, soybean and corn futures products from 2005 to 2012 daily price yield series and EGARCH model to empirically find that there is a significant set of international grain futures prices. Clustering and asymmetry, but different futures products have different responses to “good” and “bad” news. Wu Haixia et al. (2013) used the EGARCH model and the weekly data of the national average crude oil ex-factory price from September 5, 2003 to July 6, 2012, the national corn wholesale market price index, and the national average price of fuel ethanol, and found that in a single market. The three market price fluctuations all showed significant asymmetry.

The existing literature on the price volatility between the energy market and the grain market mainly focuses on the causal relationship between price fluctuations between the two markets, while the focus on the asymmetric spillover effect is not much. Du et al. (2011) and Harri and Darren (2009) used a stochastic volatility model to find a two-way causal effect between the crude oil market and the corn market. Barrera et al. (2011) used data from 2006 to 2011 to find a one-way causal effect of the crude oil market on corn in the United States. Kaltalioglu and Soytas (2011) used the agricultural raw material price index, food, crude oil price week data and BEKK-GARCH model from 1980 to 2008 to conclude that there is a significant two-way causal effect between the food market and the agricultural raw material market, but crude oil Price volatility is not the cause of price fluctuations in food and agricultural raw materials. Zhang et al. (2009) divided the data from 1989 to 2007 into two parts, using the EGARCH model to compare the relationship between the gasoline, crude oil, corn and soybean markets in the US fuel ethanol market at different stages of development. At the stage of fuel ethanol promotion, fuel ethanol and corn price fluctuations are not significantly affected by fluctuations in crude oil prices; however, with the large-scale production of fuel ethanol, crude oil and fuel ethanol prices have become powerful driving forces for soybean and corn price fluctuations.

As far as the research method is concerned, the ARCH model can effectively retain the high-frequency information of economic and financial sequences and accurately simulate the fluctuation of time series variables, which helps market participants and policy makers to accurately grasp the magnitude and direction of market fluctuations. Great attention has been paid to the study of time series. The results of this study provide a rich reference and reference for the model construction of this paper. However, the existing research still has room for further deepening of discussion: First, the existing research mostly focuses on the asymmetry of price fluctuation in single market, and the analysis of integration between markets is insufficient. Second, the existing literature on the causal relationship between the energy market and the food market is mostly based on the overall grain market, which will inevitably reduce the guiding significance of the research conclusions to reality. Energy is an important material input for food production. It affects food prices from all aspects of production and transportation. Whether there is asymmetricity of price fluctuations in the two markets; for different markets, positive shocks from other markets are more volatile. The fluctuation caused by the negative impact is even greater. The answers to the above questions will have important reference significance for the formulation of relevant market policies.

3. The Theoretical Model and Data Description

3.1 Single Market Asymmetric Effect Model

The univariate EGARCH (exponential generalized autoregressive conditional heteroskedasticity) model proposed by Nelson (1991) solves the defect that the GARCH model proposed by Bollerslev is difficult to guarantee the non-negative coefficient, and can effectively capture the asymmetry of variable fluctuations. Great attention has been paid to the study of effects. Specifically, the model of the degree of volatility has the following assumptions:

$$y_t = \alpha + \sum_{i=1}^{k} \beta_i X_{i,t} + \varepsilon_t , \qquad \varepsilon_t \left| \Omega_{t-1} \sim N(0, \sigma_t^2) \right. \tag{1}$$

$$\log(\sigma_t^2) = \omega + \sum_{i=1}^{p} \alpha_i \left| \frac{\varepsilon_{t-i}}{\sigma_{t-i}} \right| + \sum_{j=1}^{q} \beta_j \log(\sigma_{t-j}^2) + \sum_{k=1}^{r} \gamma_k \frac{\varepsilon_{t-k}}{\sigma_{t-k}} \tag{2}$$

In equations (1) and (2), it is a random error; it is an information set of time; it is a conditional variance; under the condition of information set, it obeys a normal distribution with a mean of 0 and a variance of . The left side of equation (2) is the logarithmic form of the conditional variance, indicating that the predicted value of the conditional variance must be non-negative.

It is generally believed that the EGARCH(1,1) model is superior to the high-order EGARCH model in terms of data fitting because of the loss of data information, so the conversion of equation (2) to EGARCH (1,1) can be simplified to :

$$Ln(\sigma_t^{\ 2}) = \omega + \alpha \left| \frac{\varepsilon_{t\text{-}1}}{\sigma_{t\text{-}1}} - \sqrt{\frac{2}{\pi}} \right| + \beta Ln(\sigma_{t\text{-}1}^{\ \ 2}) + \gamma \frac{\varepsilon_{t\text{-}1}}{\sigma_{t\text{-}1}} \tag{3}$$

Verify the asymmetry of the impact, ie the size and positive and negative of the test.

(1) If there is no asymmetry in price fluctuations;

(2) If there is, there is asymmetry in price fluctuations.

At that time, the information of the price decline brings greater volatility; at that time, the information of the price increase brings greater volatility. The coefficient is used to measure the persistence of the impact of market volatility. If the absolute value is close to 1, the volatility shock is persistent.

3.2 Asymmetric Effect Model between Multivariate Markets

The multivariate BEKK-GARCH model proposed by Engle and Kroner (1995) not only guarantees the positive definiteness of the covariance matrix, but also requires fewer parameters to estimate in the model, which greatly reduces the “dimension disaster” problem of the multivariate GARCH model. The GARCH(1,1) model is generally considered to be a good representation of a high-order ARCH model, which makes the identification and estimation of the model easier. Therefore, the study of the volatility spillover effect will use BEKK-GARCH (1). Therefore, we will consider adding an asymmetry term that reflects this effect to the variance equation of the

BEKK-GARCH(1,1) model.

For the crude oil futures market, the corn futures market, and the corn spot market, the mean equation for the ternary BEKK-GARCH(1,1) model is:

$$\boldsymbol{r}_t = \alpha + \sum_{i=1}^{k} \beta_i \boldsymbol{r}_{t-i} + u_t, \quad u_t \mid \mathrm{I}_{t-1} \sim \mathrm{N}(0, H_t) \tag{4}$$

In the formula (4), it is the end of the lag. It is a 3x1 vector, indicating the price return rate of the crude oil futures market, the corn futures market, and the corn spot market; it is a 3x1 vector intercept vector, which is a 3x3 coefficient matrix. It is a 3x1 residual vector. Under the condition of information set, the residual term obeys a normal distribution with a mean of 0 and a variance of .

The setting form of the conditional variance equation in the ternary BEKK-GARCH(1,1) model is:

$$H_t = CC' + BH_{t-1}B' + A(u_{t-1}u_{t-1}')A' + D(\varepsilon_{t-1}\varepsilon_{t-1}')D' \tag{5}$$

Its matrix form is:

$$\begin{aligned}
\begin{pmatrix} h_{11,t} & h_{12,t} & h_{13,t} \\ h_{21,t} & h_{22,t} & h_{23,t} \\ h_{31,t} & h_{32,t} & h_{33,t} \end{pmatrix} &= \begin{pmatrix} c_{11} & 0 & 0 \\ c_{21} & c_{22} & 0 \\ c_{31} & c_{32} & c_{33} \end{pmatrix} \begin{pmatrix} c_{11} & c_{21} & c_{31} \\ 0 & c_{22} & c_{32} \\ 0 & 0 & c_{33} \end{pmatrix} \\
&+ \begin{pmatrix} b_{11} & b_{21} & b_{31} \\ b_{12} & b_{22} & b_{32} \\ b_{13} & b_{23} & b_{33} \end{pmatrix} \begin{pmatrix} h_{11,t-1} & h_{12,t-1} & h_{13,t-1} \\ h_{21,t-1} & h_{22,t-1} & h_{23,t-1} \\ h_{31,t-1} & h_{32,t-1} & h_{33,t-1} \end{pmatrix} \begin{pmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{pmatrix} \\
&+ \begin{pmatrix} a_{11} & a_{21} & a_{31} \\ a_{12} & a_{22} & a_{32} \\ a_{13} & a_{23} & a_{33} \end{pmatrix} \begin{pmatrix} u^2_{1,t-1} & u_{1,t-1}u_{2,t-1} & u_{1,t-1}u_{3,t-1} \\ u_{1,t-1}u_{2,t-1} & u^2_{2,t-1} & u_{2,t-1}u_{3,t-1} \\ u_{1,t-1}u_{3,t-1} & u_{2,t-1}u_{3,t-1} & u^2_{3,t-1} \end{pmatrix} \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \\
&+ \begin{pmatrix} d_{11} & d_{21} & d_{31} \\ d_{12} & d_{22} & d_{32} \\ d_{13} & d_{23} & d_{33} \end{pmatrix} \begin{pmatrix} \varepsilon^2_{1,t-1} & \varepsilon_{1,t-1}\varepsilon_{2,t-1} & \varepsilon_{1,t-1}\varepsilon_{3,t-1} \\ \varepsilon_{1,t-1}\varepsilon_{2,t-1} & \varepsilon^2_{2,t-1} & \varepsilon_{2,t-1}\varepsilon_{3,t-1} \\ \varepsilon_{1,t-1}\varepsilon_{3,t-1} & \varepsilon_{2,t-1}\varepsilon_{3,t-1} & \varepsilon^2_{3,t-1} \end{pmatrix} \begin{pmatrix} d_{11} & d_{12} & d_{13} \\ d_{21} & d_{22} & d_{23} \\ d_{31} & d_{32} & d_{33} \end{pmatrix}
\end{aligned} \tag{6}$$

In the formulas (5) and (6), the variance covariance matrix of the conditional residual in the period; the lower triangular matrix; the ARCH coefficient matrix, which is used to measure the influence of the previous impact on the current condition variance; The coefficient matrix is used to measure the influence of the variance of the previous period on the variance of the current conditions; it represents the conditional variance of the crude oil futures market, the corn futures market, and the corn spot market; respectively, indicating the conditional covariance between the three markets. It is a matrix of asymmetric effect term coefficients to reflect the degree of asymmetry caused by positive and negative impacts. The element of the vector is defined as , where the vector is used to characterize the asymmetrical effects of positive and negative shocks on the market's rate of return.

It can be seen from the matrix form of the asymmetric ternary BEKK-GARCH(1,1) model that the volatility spillover effect between the three markets is investigated, that is, the significance of the coefficient and ( ) is investigated. Taking the crude oil futures market and the corn futures market as examples, to investigate whether there is a volatility spillover effect from the crude oil futures market to the corn futures market, the correctness of the following assumptions is examined:

There is no volatility spillover effect from the crude oil futures market to the corn futures market;

At least one is not zero, there is a volatility spillover effect from the crude oil futures market to the corn futures market.

Investigating whether there is a volatility spillover effect in the corn futures market to the crude oil futures market is to examine the correctness of the following assumptions:

There is no volatility spillover effect from the corn futures market to the crude oil futures market;

At least one is not zero, there is a volatility spillover effect from the corn futures market to the crude oil futures market.

To examine whether there is a positive or negative impact between the crude oil futures market and the corn futures market, consider the correctness of the following assumptions:

There is no asymmetric effect between the crude oil futures market and the corn futures market;

Or, there is at least one asymmetric effect from one market to another.

3.3 Data Description

The data used in this paper is the closing price of international crude oil futures from June 1, 2010 to May 6, 2014 (US$/barrel). 4. The closing price of China's Dalian Commodity Exchange yellow corn futures (yuan/ton), the spot price of Chinese yellow corn. Due to the difference in domestic and international holidays, the data of spot trading market at home and abroad is not synchronized, so data alignment is a very important task. For the lack of data caused by domestic and international holiday differences, this paper deletes data that does not coincide in several markets (Hamao et al. (1990), for the lack of data due to statistical factors, the missing data was taken from the average of the closing prices of the two consecutive days, and 947 data samples were obtained. The data comes from the Flush Futures Market database.

From June 2010 to May 2014, the closing prices of crude oil, corn futures and corn spot prices showed different stage characteristics. From June 2010 to April 2011, the three market prices showed an obvious price increase trend; from May 2011 to August 2013, the three market prices fluctuated sharply; from September 2013 to May 2014, the three market prices relatively stable, the fluctuation is small. At the same time, it shows that crude oil futures and corn futures prices fluctuate ahead of corn spot price fluctuations for about three months, indicating that the futures market has a significant price-directing function for the spot market. Therefore, in the empirical analysis, the price of the futures market is three months ahead of the spot market price. After aligning the data, 887 final data samples are obtained.

Since the logarithmic data has good statistical characteristics, the price yield of this paper is expressed as the first-order difference between the closing price of the adjacent two-day crude oil futures, the closing price of corn futures, and the spot price of corn. Taking the closing price of crude oil futures as an example, the calculation is made. The formula is as follows:

$$r_{o_f,t} = Ln(p_{o_f,t} / p_{o_f,t-1}) = Lnp_{o_f,t} - \ln p_{o_f,t-1} \tag{7}$$

(11), which represents the price return rate of the crude oil futures market on the first day; and the logarithm of the price of the crude oil futures market in the week and week respectively; correspondingly, respectively, the corn futures market and the corn spot market are on the first day. Price yield.

Table 1 Basic statistics of crude oil, corn futures closing price and daily spot rate of corn spot price

	Average Value	Standard Deviation	Skewness	Kurtosis	JBStatistics
r_{o_f}	0.0004	0.0148	-0.3682	6.7530	539.9944***
r_{c_f}	0.0002	0.0079	0.1557	19.4791	10028.6400***
r_{c_c}	0.0001	0.0028	-4.6057	60.2237	124017.9000***

Note: ***, **, and * indicate significant levels at 1%, 5%, and 10%, respectively.

The statistical results in Table 1 show that: the standard deviation of crude oil futures closing price, corn futures closing price and corn spot price return rate during the sample period are 0.0148, 0.0079, 0.0028, respectively, indicating that the closing price of crude oil futures is significantly larger than the closing price of corn futures and the spot price of corn. The corn spot price yield is the most stable; 2 the crude oil futures closing price and the corn spot price yield are obviously left-biased, while the corn futures closing price yield is obviously right-biased; 3 kurtosis and JB statistics show three the price return rate sequence is different from the normal distribution. Since the distribution can well capture the peak and tail characteristics of the sequence, the subsequent estimation process uses the distribution instead of the normal distribution to characterize the peak and thick tail characteristics of the price return. It shows that crude oil, corn futures closing prices, and corn spot price daily price returns fluctuate around zero mean and have a significant "fluctuation cluster" characteristic.

4. Empirical Analysis

4.1 Data Basic Feature Test

Stationarity test. Select the lag order to 0, no intercept term and trend item, at the 1% significance level, Table 2 crude oil futures closing price, corn futures closing price and corn spot price daily price yield series ADF test and PP The test results show that the horizontal sequence of the three daily price returns is a stable time series. Therefore, the pseudo-regression problem does not occur in modeling the three.

Table 2: Sequence stability test of price return rate of each variable

	ADF Statistical value	PP Statistics	1% Horizontal Threshold	Conclusion
r_{o_f}	-32.2295***	-32.2393***	-2.5676	Smooth
r_{c_f}	-18.0264***	-40.9541***	-2.5676	Smooth
r_{c_c}	-7.1155***	-30.7961***	-2.5676	Smooth

Note: ***, **, and * indicate significant levels at 1%, 5%, and 10%, respectively.

Autocorrelation test. The autocorrelation and partial autocorrelation tests were carried out on the sequence. The results showed that there was a first-order autocorrelation in the yield futures price of crude oil futures, while there were 1, 2, and 3 order autocorrelation in the corn futures closing price yield series; There are 1, 2, and 3 order autocorrelations in the sequence. Therefore, in order to eliminate the sequence autocorrelation, the average equations of the crude oil, corn futures closing price, and corn spot price daily price return rate are set as follows:

$$r_{o_f,t} = c + r_{o_f,t-1} + \mu_{o_f,t} \tag{8}$$

$$r_{c_f,t} = c + \alpha r_{c_f,t-1} + \beta r_{c_f,t-2} + \gamma r_{c_f,t-3} + \mu_{c_f,t} \tag{9}$$

$$r_{c_c,t} = c + \alpha r_{c_c,t-1} + \beta r_{c_c,t-2} + \beta r_{c_c,t-3} + \varepsilon_{c_c,t} \tag{10}$$

The newly established (8), (9), and (10) types no longer have autocorrelation.

ARCH effect test. Table 3 gives the results of the ARCH-LM test. The crude oil futures and corn spot price yield series have an ARCH effect at the 1% significance level; while the corn futures price return sequence has an ARCH effect at the 5% significance level. . Therefore, the BEKK-GARCH model can be used to investigate the asymmetric spillover effects of price fluctuations between crude oil futures, corn futures and the corn spot market.

Table 3 ARCH effect test of price return rate series of variables

	r_{o_f}	r_{c_f}	r_{c_c}
F statistic	10.2317***	27.1056***	6.3209***
$N*R^2$	57.8127***	118.1046**	18.3103***

Note: ***, **, * are respectively indicated at the level of 1%, 5%, and 10%; the ARCH effect test of crude oil futures price return rate and corn futures price return rate lags first order; corn spot price return rate The ARCH effect of the sequence tests the third order of lag.

4.2 The Univariate EGARCH Model Empirical Results

The EGARCH model test results show that the crude oil futures closing price and the corn spot price are negative during the sample period, and are significant at the 1% significance level, which are -0.0589 and -0.0454, respectively, indicating the crude oil futures market and the corn spot market. In other words, the fluctuation caused by the price decline information is greater than the fluctuation caused by the price increase information; the corn futures closing value is 0.0566, and is significant at the 1% significance level, indicating that the fluctuation of the price increase information is greater than that for the corn futures market. Fluctuations caused by price decline information. French et al. (1993), Campbell and Hentschel (1992) proposed that the wave feedback effect can explain the degree of volatility asymmetry, that is, the price fluctuation caused by price increase or decrease and the current price increase or decrease offset or overlap. The effect of the same magnitude of price shocks brings different magnitudes of price response.

Table 4 Crude oil, corn futures closing price and corn spot price daily price return rate fluctuation EGARCH model empirical results

	Crude oil futures closing price	Corn futures closing price	Corn spot price
ω	-0.3010***	-0.7256***	-12.9406***
	（-3.5984）	（-9.5379）	（-25.6294）
α	0.1220***	0.3845***	0.0511***
	（5.4730）	（12.9882）	（2.7457）
β	0.9755***	0.8541***	0.9267***
	（10.1407）	（50.7374）	（21.5242）
γ	-0.0589***	0.0566***	-0.0454***
	（-4.1131）	（2.6801）	（-14.4390）
Model standardized residual ARCH effect test（H_0: no ARCH effects）：			
Ljung-Box(6)	0.2640	0.6723	6.7769
	（0.6011）	（0.8543）	（0.6848）
Ljung-Box(12)	0.4855	2.1998	8.1767
	（0.7933）	（0.9656）	（0.7782）
Jarque-Bera	1556.3478	925.5541	78.5779
	(0.0000)	(0.0000)	(0.0000)

Note: ***, **, and * indicate significant levels at 1%, 5%, and 10%, respectively. The number in the parentheses is the statistic of the coefficient, which is the EGARCH model to check whether the crude oil, corn futures closing price, and corn spot price daily price return fluctuations are asymmetric.

4.3 Asymmetric BEKK-MVGARCH Model Empirical Results

Table 5 estimates of the three-variable asymmetric BEKK-MVGARCH(1,1) model show that in the conditional mean equation, the coefficients, and the significance level at 1% are highly significant, indicating that the three market price fluctuations have significant autocorrelation. The significance of the coefficient reflects the degree of interaction between price fluctuations between markets. The results in Table 5 show that only the coefficient is significant at the 10% significance level, indicating a one-way volatility spillover effect from the crude oil futures market to the corn futures market.

In the parameter estimation results of the conditional variance, the coefficient and the estimated value are highly significant at the 1% level, indicating that the corn spot and futures price fluctuations have a strong ARCH effect, that is, the time variation of the variance is exhibited, and the price change is affected by itself. The influence of the previous fluctuations is more significant, which is consistent with the estimation results of the mean equation; the coefficients, and the estimated values are all significant at the level of 1%, indicating that the price fluctuations in the corn spot, corn futures and crude oil futures markets have a strong GARCH effect. That is, the persistence of fluctuations and the significance of external factors.

Table 5 Estimation results of asymmetric BEKK-MVGARCH(1,1) model parameters for crude oil futures, corn futures, and corn spot market

parameter	Corn spot market ($i=1$)	Corn futures market ($i=2$)	Crude oil futures market ($i=3$)
Conditional mean equation：			
Constant	0.0001*** (3.9814)	0.0001 (0.1744)	0.0008** (2.1130)
$ar(1)_{1i}$	0.1046*** (5.0340)	0.0022 (0.4533)	-0.0017 (-0.5659)
$ar(1)_{2i}$	0.1596 (3.9814)	-0.1491*** (-5.2407)	0.0216 (1.0184)
$ar(1)_{3i}$	0.0242 (0.1801)	-0.0919* (-1.6820)	-0.0980*** (-3.1645)
Conditional Variance-Covariance Equation:			
c_{1i}	0.0008*** (4.6887)	—	—
c_{2i}	0.0002*** (0.0779)	0.0039*** (5.3999)	—
c_{3i}	0.0066*** (3.0069)	-0.0023 (-0.4825)	-0.0000 (-0.0000)
a_{1i}	0.2323*** (3.4292)	0.1776 (0.8886)	0.0870 (0.3691)
a_{2i}	-0.0017 (-0.1667)	0.7124*** (5.6012)	0.1933 (0.9868)
a_{3i}	0.0125** (1.9550)	0.1331*** (3.6738)	-01506 (-1.3996)
b_{1i}	-0.8925*** (-29.1886)	0.3768 (0.8756)	0.2966 (0.3342)
b_{2i}	0.0179* (1.6894)	0.6678*** (10.4633)	0.2069 (1.3130)
b_{3i}	0.0102* (1.6204)	0.0111 (0.4656)	0.8781*** (19.7663)
d_{1i}	-0.0994 (-0.8916)	-0.5125*** (-2.8443)	-0.2802 (-1.2055)
d_{2i}	0.0130** (2.1649)	-0.3575* (-1.6077)	0.0008 (0.1010)
d_{3i}	0.6600*** (2.7029)	0.0819* (1.6257)	0.5149*** (3.4683)
Model standardized residual ARCH effect test（H_0: no ARCH effects）:			
Ljung-Box (6)	5.6346 (0.5578)	0.6898 (0.9947)	4.1785 (0.6525)
Ljung-Box (12)	10.9886 (0.5933)	2.4519 (0.9983)	9.3226 (0.6752)
Log likelihood function values:	10290.7072		
Number of valid samples：	885		

Note: ***, **, and * indicate significant levels at 1%, 5%, and 10%, respectively. The numbers in parentheses are the statistics of the coefficients.

The coefficient, is not significant at the level of 10%, that is, the spot price fluctuation of the previous period of corn and the conditional variance of the previous period have no significant effect on the fluctuation of the current corn futures price, and the price fluctuation of the first period in the corn futures market is for the current spot of corn. The impact of price volatility is not significant; however, the estimate is significant at the level of 10%, that is, the current corn market volatility is significantly affected by the impact of the first phase of the corn futures market, that is, there is a significant one-way volatility in the corn futures market for the corn spot market.

The coefficient and the significance level of 5% and 10% are significant, that is, the previous fluctuation of crude oil futures price and the conditional variance have a significant effect on the current spot price fluctuation of corn spot; the coefficient is not significant at the 10% significance level. That is, the fluctuation of current crude oil futures price is not significantly affected by the impact of the previous spot price of corn and the variance of the previous period, that is, there is only one-way volatility spillover effect of crude oil futures price on corn spot price.

The coefficient is significant at the significance level of 1%, that is, the impact of the first period of the crude oil futures market has a significant impact on the current price fluctuation of the corn futures market; but the coefficient, at the 10% level, is not significant, that is, on the corn futures market. The impact of the first period and the conditional variance of the previous period have no significant effect on the conditional variance of the current crude oil futures (corn futures) market fluctuations, that is, the crude oil futures market has a one-way volatility spillover effect on the corn futures market.

The coefficient value is -0.5125, which is significant at the 1% significance level, indicating that the impact of the price drop information from the corn spot market on the corn futures market is significantly greater than the impact of price increase information; the coefficient value is 0.0130, at a significance level of 5%. Significantly, it indicates that the corn futures market price increase information impact on the corn spot market is significantly greater than the price decline information; the coefficient value is 0.6600, which is significant at the 1% significance level, indicating that the crude oil futures market price increase information on the corn spot The impact of the market is significantly greater than the impact of price decline information; the coefficient value is 0.0819, which is significant at the 10% significance level, indicating that the impact of the price increase information in the crude oil futures market on the corn futures market is significantly greater than the impact of price decline information.

The 6th and 12th steps of the lag, respectively, the statistical test of the model normalized residuals shows that there is no ARCH effect in the standardized residual sequence, that is, the asymmetric BEKK-GARCH (1,1) model can well fit the corn spot and corn futures. And the asymmetric effect of price fluctuations between crude oil futures markets.

5. Conclusion

This article is based on the use of the ARCH model and the closing price of international crude oil futures from June 1, 2010 to May 6, 2014 (US dollars / barrel), China's Dalian Commodity Exchange corn futures closing price (yuan / ton), China corn spot price The daily data (yuan/ton) is an empirical analysis of the asymmetry of price fluctuations in a single market and the asymmetry of price fluctuations between markets. The results show that during the sample period, the three market price volatility showed significant autocorrelation, that is, the price volatility of each market was significantly affected by the past price fluctuations in its own market.

The results of the univariate EGARCH model test show that the crude oil futures closing price and the corn spot price are both negative, indicating that the fluctuation caused by the price decline information is greater than the fluctuation caused by the price increase information in the crude oil futures market and the corn spot market; The closing value is positive, indicating that for the corn futures market, the fluctuations caused by the price increase information are greater than the fluctuations caused by the price decline. Therefore, for single market participants and policy makers, in order to stabilize the crude oil futures market and the corn spot market, we should focus on those factors that may cause price declines; while stabilizing the corn futures market, we need to focus on those factors that may cause price increases. .

The test results of the multivariate asymmetric BEKK-MVGARCH model show that the corn futures market and the crude oil futures market show a significant one-way asymmetric spillover effect on the corn spot market. At the same time, the impact of the price drop information from the corn spot market on the corn futures market is significantly greater than the impact of the price increase information; the impact of the corn futures market price increase information on the corn spot market is significantly greater than the impact of the price decline information; the crude oil futures market price increase information pair The impact of the corn spot market is significantly greater than the impact of price decline information; the impact of the price increase information on the corn futures market in the crude oil futures market is significantly greater than the impact of price decline information.

The price volatility spillover effects and asymmetric effects of crude oil futures, corn futures and spot markets provide theoretical references for investment activities, policy formulation and policy regulation. For investors, building a diversified portfolio based on the three-market price volatility spillover effect and asymmetric effects can effectively avoid market risks. As the degree of integration between the futures market and between the futures market and the spot market deepens, the value assessment of related industries should also be adjusted accordingly. For policy makers and financial regulators, the effective connection between the futures market and the spot market price volatility and the establishment of a standardized futures market trading system are the policy points.

Acknowledgements

Fund Project: This paper is funded by a sub-project of the National Key Research and Development Program of China “Economic and Social Benefit Evaluation and Long-term Mechanism Construction of Northern Wheat Weight Loss and Drug Reduction” (2018YFD020040810); National Natural Science Foundation of China Youth Fund Project “Transmission Mechanism and Forecasting Effect of Financial Factors on Corn Price Fluctuation :Based on the perspective of food finance (Project No. 71603153); Key Research and Development Program of Shaanxi Province “Study on Long-term Multidimensional Poverty, Poverty Factors and Poverty Reduction Policies for Children in Shaanxi” (2018KW-065); Fundamental Scientific Research Funds of Central Universities in Shaanxi Normal University The special fund project “Evaluation of Comprehensive Benefits of Fertilizer and Pesticide Reduction Technology in Dryland Wheat in the Loess Plateau” (GK201803092).

References

[1] Feng Y. An Empirical Analysis of China's Grain Price Fluctuation. Price Monthly, 2008(2): 41-44.

[2] Luo W, Liu R. Analysis of China's Grain Price Fluctuation: Based on ARCH Model.China Rural Economy, (4): 30-37, 2010.

[3] Sun L, Ni K. Analysis of International Food Price Volatility Asymmetry-Based on EGARCH Model under T Distribution. Journal of Nanjing Agricultural University (Social Science Edition), 13(2): 68-75, 2013.

[4] Wu H, Wang J, Rausser G. Research on Volatility Spillover Effects of Crude Oil, Corn and Fuel Ethanol Markets. China Rural Economy, (2): 71-82, 2013.

[5] Wu H, Huo X. Research on the Impact of Macroeconomic Policies on Price Fluctuation in China's Grain Market. Systems Engineering, (4): 61-69, 2014.

[6] Baharom A H, Radam A, Habibullah M S. The Volatility of Thai Rice Price. Mpra Paper, 2009.

[7] Balcombe, K. Rapsomanikis, G. Bayesian Estimation and Selection of Nonlinear Vector Error

Correction Models. The Case of the Sugar-ethanol-oil Nexus in Brazil, American Journal of Agricultural Economics, 90 (3): 658-668, 2008 .

[8] Barrera T A, Mallory, M. Garcia, P. Volatility Spillovers in the US Crude Oil, Corn, and Ethanol Markets. Paper presented at the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management St. Louis, Missouri, 2011.

[9] Campiche J L, Bryant H L, Richardson, J W, Outlaw, J L. Examining the Evolving Correspondence between Petroleum Prices and Agricultural Commodity Prices. Selected paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Portland, OR, 2007.

[10] Campbell J Y, Hentschel L. No News Is Good News: An Asymmetric Model of Changing Volatility in Stock Returns. Journal of Financial Economics, 31(3): 281-318, 1992.

[11] Du X, Yu C L, Hayes D J. Speculation and Volatility Spillover in the Crude Oil and Agricultural Commodity Markets. A Bayesian Analysis. Energy Economics, 33 (3): 497-503, 2011.

[12] Engle R F, Kroner K F. Multivariate Simultaneous Generalized Arch. Econometric Theory, 11 (1): 122-150, 1995.

[13] Hamao Y, Masulis R W, Ng V. Correlations in Price Changes and Volatility across International Stock Markets. The Review of Financial Studies, 3 (2): 281-307, 1990.

[14] Harri A, Darren H. Mean and Variance Dynamics between Agricultural Commodity Prices and Crude Oil Prices. Paper Prepared for Presentation at the Economics of Alternative Energy Sources and Globalization: The Road Ahead Meeting, Orlando, FL, 2009.

[15] Kaltalioglu M, Soytas U. Volatility Spillover from Oil to Food and Agricultural Raw Material Markets. Modern Economy, 2:71-76, 2011.

[16] Nelson B D. Conditional Heteroskedasticity in Asset Returns: A New Approach. Econometrica, 59 (2): 347-370, 1991.

[17] Wu H, Li S. Volatility Spillovers among China's Crude Oil, Corn and Fuel Ethanol Markets. Energy Policy, 62: 878-886, 2013.

[18] Zhang Z, Lohr L, Escalante C, Wetzstein, M. Ethanol, Corn, and Soybean Price Relations in a Volatile Vehicle-fuels Market. Energies, 2(2): 320-339, 2009.