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Study on the Characteristics of International Grain Price Fluctuation with GARCH Models

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Abstract: The sharp fluctuation of international grain prices is the biggest threat to international grain security, and in the context of grain financialization, the volatility of international grain prices is becoming stronger and stronger, in order to prevent the risk of grain price volatility, it is particularly necessary to clarify its volatility characteristics. This paper empirically tests the volatility characteristics of international grain prices based on the data from January 2010 to October 2021 by employing GARCH models and using the spot price of hard wheat No. 2 in Kansas City, USA as an alternative index of international grain prices. The results show that the volatility of international grain price has the characteristics of aggregation. The fluctuation of international grain price is autoregressive and its residual has ARCH effect, which indicates that it can be studied by GARCH models. Both of GARCH model and TARCH model successfully described the volatility characteristics of international grain prices. Compared with GARCH model, TARCH model simulates the form and degree of international grain price volatility better than GARCH model, furthermore, the estimation of TARCH model shows that good news can reduce the volatility of international grain prices by comparing the different effects of good news and bad news on the volatility of international food prices.

Keywords: International Grain Price, Volatility, ARCH Effect, GARCH Model, TARCH Model

1. Introduction

Grain security has always been concerned at a strategic level, and the sharp fluctuation of international grain prices is the biggest threat to international grain security. Under the current situation of grain financialization, affected by market supply and demand and other external factors, the volatility of international grain prices is becoming stronger and stronger, and the close connection of the international grain futures and spot market increases the possibility of grain price volatility risk spreading globally. This has produced a lot of problems in theory and practice that need to be studied and solved urgently. In order to prevent the risk of grain price fluctuation, we must clarify its fluctuation characteristics.

The fluctuation of international grain prices shows a trend of rapid rise or decline, and the process of gradually decreasing and recovering to normal level has significant cyclical characteristics. Meanwhile, it also has the characteristics of aggregation and asymmetry. Compared with ARMA models, GARCH models, mostly used in micro financial markets, such as simulating the volatility of stock price, has obvious advantages to describe these characteristics.

Research on stock market volatility based on GARCH model is quite common in literatures. For example, Zakoian, Basel & Valentina etc. used GARCH model to fit stock price volatility and found that stock price volatility was asymmetric [1-2]. Sabiruzza-man et al. found that TARCH model could grasp the asymmetric effect of stock price fluctuations better than GARCH model based on data of Hong Kong stock market index [3]. Liu & Huang analyzed the accuracy of GARCH model in predicting the volatility under the condition that the disturbance terms obey different distributions [4].

In addition, there are many researches on the volatility characteristics of Chinese stock market based on GARCH model. For example, Yue Chaolong, Chen Qianli & Zhou Shaofu, Liu Jinquan & Cui Chang, Liu Xiao & Li Yimin etc. have empirically tested the GARCH effect of Chinese stock market volatility [5-8]. Gu Fengjuan & Cen Zhongdi compared the performance of GARCH and TARCH model in characterizing the volatility of Chinese stock market and the measurement and prediction of asymmetric effects, concluded that GARCH model performed better [9]. Zhang Jinlin & He Genqing tested the ARCH effect of stock price volatility in GEM market and the main board of Shanghai and Shenzhen stock markets [10]. Based on GARCH model, Yang Chenhui & Liu Xinmei studied the asymmetric effects of macroeconomic policy factors on the volatility of Shanghai and Shenzhen stock markets [11].

However, literatures pay more attention to the spillover effect of international grain prices, for example, Li Yushuang & Zhao Ting, Ding Cunzhen & Xu Xuanguo, Li Yushuang & Liu Yang and Zhang Jianhua etc. discuss the impact of international grain prices on domestic grain prices [12-15], but pay less attention to its volatility, Huang jing & Xiao Xiaoyong analyzes the characteristics and causes of the new round of international grain price rise [16]. Therefore, it is necessary to pay attention to the volatility characteristics of international grain prices in order to cope with its possible risks.

2. Variable Selection and Statistical Description

2.1. Variable Selection

Based on grain planting and consumption habits, this paper takes the international price of wheat as the research object. Due to the availability of data and the activity of varieties traded in international market, the spot price of No. 2 hard wheat in Kansas City, USA is selected as a substitute index for the international wheat price. The sample of the monthly data used in the following demonstration is from January 2010 to October 2021, which comes from the Wind database.

2.2. Statistical Description of Data

The international wheat price change rate in Figure 1 shows that international grain price fluctuations are not only cyclical, but also clustered, that is, the volatility is high in one period of time and low in another period of time. The reason is that the response of international grain prices to market supply and demand or external factors appears to be relatively sharp at first, and then gradually reduce.

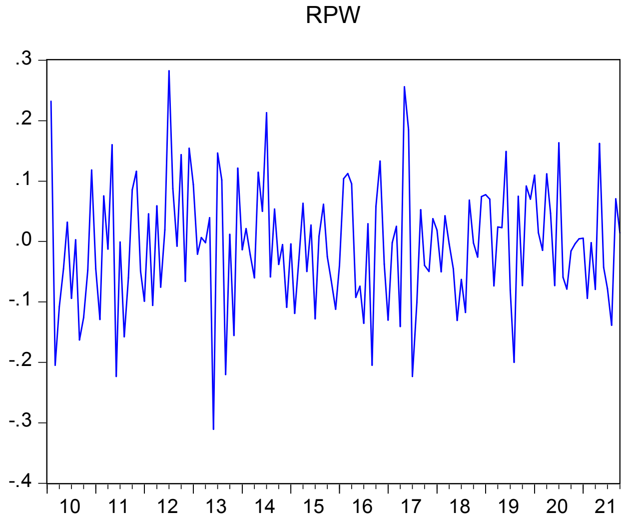

Figure 1. *International wheat price volatility.*

3. ARCH Effect Test of International Grain Price Fluctuation

3.1. Autoregressive Order Selection

The fluctuation of international grain price shows autoregressive characteristics. In this part, partial autocorrelation coefficient PAC is used to determine the form of conditional mean equation in autoregressive conditional heteroscedastic ARCH model, that is, the order of autoregression. The test of PAC in Figure 2 shows that the autoregressive order of the conditional mean equation is selected as 1, because PAC is truncated when the PAC lags by 1 order.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.901	0.901	117.69	0.000
		2	0.800	-0.064	211.07	0.000
		3	0.725	0.089	288.47	0.000
		4	0.667	0.036	354.37	0.000
		5	0.607	-0.031	409.28	0.000

Figure 2. *Autoregressive order selection of ARCH model.*

The first order autoregressive process of international wheat price fluctuation can be estimated by least squares:

$$PW_t = 0.49996 + 0.90638 PW_{t-1} + \varepsilon_t$$
$$(0.0107) \quad (0.0000) \tag{1}$$
$$R^2 = 0.8512,\ Log\ likelihood = -138.1164, AIC = 1.9875, SC = 2.0293$$

The numbers in parentheses in equation (1) are the probability values for which the true value of the parameter is 0, both of which are less than 1% significance level, indicating that the two regression coefficients are significantly different from 0.

3.2. ARCH Effect Test

Observing the residual of the equation (1), it can be seen that the fluctuation of the residual presents aggregation, indicating that the error term may exist ARCH effect.

Table 1. *ARCH LM test of international wheat price fluctuations.*

ARCH test			
F-statistic	16.87533	Prob. F(1,138)	0.0001
Obs*R-squared	15.25450	Prob. Chi-Square(1)	0.0001

Table 1 shows the ARCH LM test results of the residual series of the autoregressive equation (1), in which the lag order of ARCH term is selected as 1. It can be seen from Table 1 that the ARCH LM statistic value is 15.25450, and the probability of the null hypothesis of conditional heteroscedasticity is 0.0001, which is less than 1%, so, the null hypothesis is rejected, indicating that the residual of the equation (1) of international wheat price has ARCH effect.

3.3. GARCH Effect Test

The above analysis shows that the GARCH model can be used to describe the volatility characteristics of international wheat prices. The mean equation in the model still adopts the form of random walk autoregression, the order of ARCH term and GARCH term in the conditional variance equation can be determined by comparing different models. In order to determine the order of ARCH and GARCH term in the conditional variance equation, four models such as $GARCH(1,1)$ etc. are selected for comparison.

Table 2. *Selection of GARCH model.*

	$GARCH(1,1)$	$GARCH(1,2)$	$GARCH(2,1)$	$GARCH(2,2)$
loglikelihood	-122.9429	-122.1594	-121.4728	-124.0288
AIC	1.8148	1.8179	1.8081	1.8586
SC	1.9194	1.9433	1.9336	2.0050
R^2	0.8489	0.8485	0.8480	0.8508

The selection rule of the optimal GARCH model is the log-likelihood value of the model is large, while the values of SC and AIC are small, and the estimators are significant. As shown in Table 2, the optimal model should be $GARCH(1,1)$, and its estimated results are as follows:

$$
\begin{aligned}
&PW_t = 0.5842 + 0.8803 PW_{t-1} + \hat{u}_t \\
&\qquad (0.0004) \quad (0.0000) \\
&\hat{\sigma}_t^2 = 0.09657 + 0.26957 \hat{u}_{t-1}^2 + 0.45032 \hat{\sigma}_{t-1}^2 \qquad (2) \\
&\qquad (0.1075) \quad (0.0566) \quad (0.0671) \\
&R^2 = 0.8489, Loglikelihood = -122.9429, AIC = 1.9194, SC = 1.9194
\end{aligned}
$$

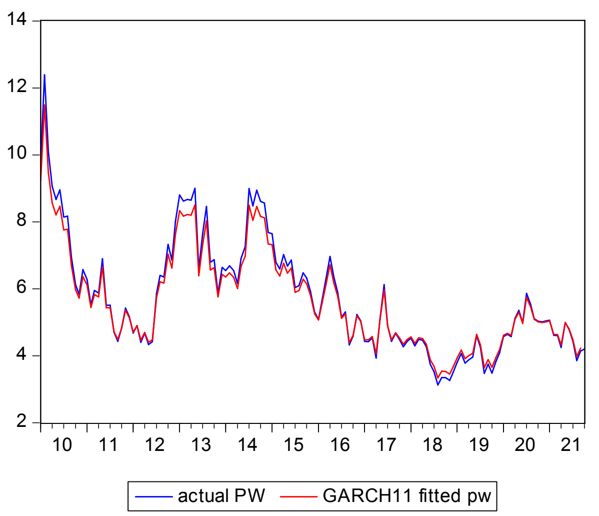

Figure 3. *Simulation of international wheat price volatility by $GARCH(1,1)$ Model.*

Compared with the first-order autoregressive random walk model in equation (1), the mean equation in Equation (2) has larger log-likelihood values and smaller AIC and SC values. Meanwhile, the parameters of the conditional variance equation in the model are all positive, statistically significant, indicating that the $GARCH(1,1)$ model is superior and can better simulate the volatility characteristics of international wheat prices. And, as seen from Figure 3, the model not only successfully simulates every fluctuation of international wheat price, but also has an ideal grasp of the fluctuation intensity of international wheat price.

In addition, the $GARCH(1,1)$ model overcomes the conditional heteroscedasticity of the international wheat price autoregressive residual series, as shown in Table 3: the ARCH LM test statistics of the residual heteroscedasticity of the $GARCH(1,1)$ model accepts the null hypothesis that the probability of no conditional heteroscedasticity was 0.6557 with high confidence, and the AC and PAC of the residual of the autoregressive equation are about 0, the probability that the Q statistic is not significant is above 0.156.

Table 3. *ARCH LM test of the $GARCH(1,1)$ model of international wheat price fluctuation.*

ARCH effect test			
F-statistic	0.196252	Prob. F(1,138)	0.6585
Obs*R-squared	0.198813	Prob. Chi-Square (1)	0.6557

4. Test of Asymmetric Effects of International Grain Price Fluctuations

In capital market, the fluctuations of financial asset prices often show different reactions to good news and bad news in the market, usually the impact of bad news on the volatility of financial asset prices is greater than that of good news, that is, there is an asymmetric effect. In this part, TARCH model is used to test the asymmetric effect of international grain price fluctuations.

4.1. TARCH Model Estimation

The comparison of the relevant indicators of the TARCH model estimation results with the threshold values of 1 and 2 in Table 4 shows that the $TARCH(1,1)$ model has a relatively good performance in describing international wheat price fluctuations. Therefore, the $TARCH(1,1)$ model is adopted to test the asymmetric effect of international wheat price fluctuations.

Table 4. *Selection of TARCH mode.*

model	Loglikelihood	AIC	SC	R^2
$TARCH(1,1)$	-120.2844	1.7613	1.9167	0.8503
$TARCH(2,1)$	-120.3029	1.7764	1.9318	0.8501

The estimated result of the $TARCH(1,1)$ model is shown as equation (3):

$$\begin{aligned} PW_t &= 0.5993 + 0.8838 PW_{t-1} + \hat{u}_t \\ &\quad (0.0002) \quad (0.0000) \\ \hat{\sigma}_t^{\,2} &= 0.1191 + 0.4851 \hat{u}_{t-1}^2 - 0.4448 \hat{u}_{t-1}^2 d_{t-1} + 0.3731 \hat{\sigma}_{t-1}^2 \\ &\quad (0.0367) \quad (0.0589) \quad (0.0861) \quad (0.1238) \\ R^2 &= 0.8503, Loglikelihood = -120.2844, AIC = 1.7613, SC = 1.9167 \end{aligned} \tag{3}$$

In equation (3), the estimated coefficient of the asymmetric effect term is -0.4448, which is statistically significant, indicating that there is an asymmetric effect in the volatility of international wheat price, and the volatility becomes smaller. According to equation (3), the impact of good news on the volatility of international wheat prices is 0.0403 times, while that of bad news is 0.4581 times.

4.2. Effect Analysis of TARCH Model

Compared with the simulation of international wheat price volatility by TARCH and GARCH model in Figure 4, it can be seen that TARCH model performs better than GARCH model, and is better in simulating the form and degree of international wheat price volatility.

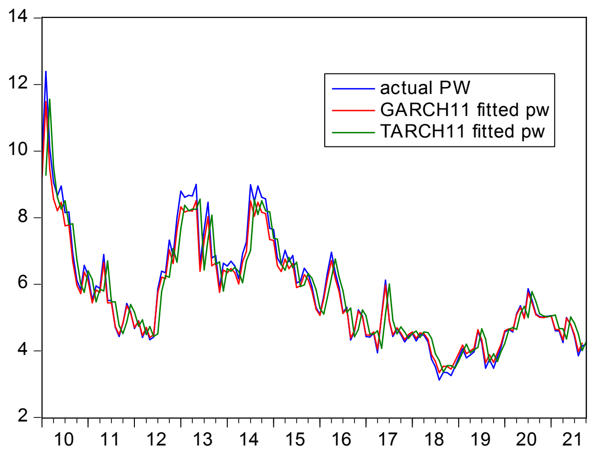

Figure 4. *Comparison of TARCH and GARCH models.*

Similarly, the $TARCH(1,1)$ model overcomes the conditional heteroscedasticity of the autoregressive residual series of international wheat prices, as shown in Table 5: the ARCH test statistics of the residual series of the $TARCH(1,1)$ model show that the probability of no conditional heteroscedasticity is 0.5827 and the confidence is high, indicating the model overcomes the ARCH effect in the residual of the international wheat price fluctuation equation.

Table 5. *ARCH test of $TARCH(1,1)$ model.*

ARCH test			
F-statistic	0.387453	Prob. F(1,138)	0.5437
Obs*R-squared	0.391967	Prob. Chi_Square(1)	0.5313

5. Conclusion

This paper analyzes the volatility characteristics of international wheat price by using GARCH models. Based on the spot price data of No. 2 hard wheat in Kansas City, USA from January 2010 to October 2021, the empirical research finds that:

(1) Based on the statistical analysis of the change rate of international wheat prices, it is found that the volatility of international grain prices presents a clustering effect.

(2) GARCH model is suitable for the study of international grain price volatility. Based on the spot price of No. 2 hard wheat in Kansas City, USA, a AR(1) model of international grain price fluctuations is established, and it was found that the international wheat price fluctuation has ARCH effect. The GARCH model is suitable for the study of international grain price volatility.

(3) TARCH model is better than GARCH model in characterizing the volatility of the international grain prices. The empirical results show that both GARCH and TARCH model successfully describe the volatility characteristics of the international wheat price, and overcome the conditional heteroscedasticity in the residual of the international grain

price autoregressive equation. In comparison, the TARCH model considers the different effects of good news and bad news on the volatility of international grain prices, and finds that good news can reduce the volatility of international grain prices. Meanwhile, TARCH model is better than GARCH model to simulate the form and degree of international grain price volatility.

The above findings on the characteristics of international grain prices fluctuation are more meaningful, because it is helpful to predict its changing trend, and then deal with the risks that may be caused by international grain prices fluctuation.

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