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Measuring the Wheat Price Volatility in Global Commodity Market: GARCH Family Models

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ABSTRACT

Food price volatility is considered a global problem affecting many poor and rich countries, severely impacting developing countries. So, understanding the volatility pattern is essential for policymakers to take global and local actions to reduce food price spikes, manage price trends, and protect vulnerable households. This study aims to accurately measure wheat price volatility in the global market to determine its pattern and help policymakers make more informed decisions. A monthly series of 719 observations spanning from January 1960 to December 2019 was used to model the global wheat price volatility. Symmetric and asymmetric GARCH models were used to measure the price volatility. Based on model selection criteria, Asymmetric EGARCH (1,1) model proves to be fit. The results show that positive shocks have a more significant effect on volatility than negative shocks, which implies that policymakers react differently when making decisions. Moreover, these findings suggest that long–term contracts and sustainable investments in improving the wheat value chain will help the domestic market hedge against the risks of global price volatility.

Keywords: GARCH Models**,** Wheat, and Volatility.

INTRODUCTION

Being susceptible to climatic conditions and vulnerable to supply shocks, Agriculture is also characterized by the uncertainty of crop yields and price volatility (D'Odorico *et al*., 2014). Wheat is one of the three basic cereals (after rice and corn), providing the necessary calorific intake for the vast majority of the world's population. In this regard, Egypt comes first among wheat importing countries, with 11.73 million tonnes, followed by Algeria and Italy (Gutiérrez-Moya *et al*., 2021).

Price variability is a critical component of profit variability. It has received much attention in the last decades as it causes generates instability and uncertainty in agricultural markets (Wright, 2011; Acosta *et al*., 2014; Brümmer *et al*., 2016). an increasing body of literature distinguishes the drivers of price volatility in market-based drivers (demand or supply shocks) and external shocks (trade policy, the dynamics of real and financial markets, and unforeseen natural events) (Santeramo and Lamonaca,2019).

This study aims to accurately measure wheat price volatility in the global market to determine its pattern and help policymakers make more informed decisions. There exists a considerable literature on the role of GARCH family models in analyzing volatility in stock and commodity markets (Bonga,2019) which gives room to the current study to determine the most suitable model representing the data pattern. The data was collected from the world bank spanning from January 1960 to June 2020, leaving the period starting from January 2020 for testing purposes.

The remainder of the paper is arranged as follows. The second section presents the research methodology, The results and their implications are discussed in the third section. Some conclusions are drawn in the final section. Further work should concentrate on Speculation in commodity futures.

Methodology

When large changes in prices occur due to previous significant changes and vice versa, regardless of the sign, this can be described as a volatility clustering. This concept enabled Engle (1982) to develop the class of autoregressive conditional heteroscedastic (ARCH) models (Aljandali& Tatahi,2018).

Equation (1) presents the fitted AR(1) model:

$$Z_t = \mu + \varphi_1 Z_{t-1} + u_t \quad (1)$$

Where u_t represents the error term which has zero mean.

Examining the ACF of u_t may suggest volatility clustering. The conditional variance of the error term indicates that the errors in previous periods was accounted for when calculating σ^2_t. Specifically, if the conditional variance at the time (t) relates to the squared error at the time (t -1), there will be an ARCH (1) process (equation (2))

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 \quad (2)$$

The ARCH(1) model indicates that a big shock in period (t -1) is more likely to make u_{t-1} have a large (absolute) value also. Put simply, when u^2_{t-1} is large, the variance at the subsequent time (t) will be significant. The initially fitted AR(1) model with ARCH(1) errors can be represented as AR(1)-ARCH (1). The first part points out the mean equation, while the second one refers to the variance equation.

Equation (3) represents an ARCH(q) process where the conditional variance at time t is affected by the squared errors at times (t -1), (t -2), . . ., (t -q).

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$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \alpha_2 u_{t-2}^2 + \ldots + \alpha_q u_{t-q}^2. \quad (3)$$

Generating Change Rates

To analyze volatility, it is necessary to calculate rates of change (returns) for the available dataset of global wheat prices using the following formula (equation (4));

$$R_t = Ln(P_t / P_{t-1}) \quad (4)$$

Where; **R is the change rate, P is the price, and t is the time.**

Testing for ARCH Effects

To test for potential ARCH effects, fitting the mean equation is first required. Then checking whether the AR(1) model has ARCH errors. The following null hypothesis of all coefficients being jointly zero, indicating nonexistence of ARCH effects up to q lags, is tested from equation (3) :

$$H_0 : \alpha_1 = \alpha_2 = \alpha_3 = \ldots = \alpha_q = 0.$$

ARCH provides a framework for analyzingand developing time series involving volatility. However, several difficulties, such as determining the number and value of lags, make it less attractive. Being developed independently by Bollerslev (1986) and Engle (1982), the Generalised ARCH process (or GARCH) has become widely applied as an extension of the ARCH(q) process(Aljandali& Tatahi,2018).

GARCH Models

GARCH estimation can be performed with different specifications if the model detects the ARCH effect. The GARCH model portrays the relationship between the conditional variance and its own previous lags as well as the squared error terms of the ARCH models. Equation (5) presents the model in its simplest case.

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta_1 \sigma_{t-1}^2. \quad (5)$$

This model is known as a GARCH(1,1) model. It declares that the current conditional variance depends on an intercept term, volatility during the previous period $\alpha_1 u^2_{t-1}$, and the fitted conditional variance during the previous period $\beta_1 \sigma^2_{t-1}$.

GARCH-M (1,1)

the change rates could depend on its volatility (risk) and hence need to be modeled. Therefore, a heteroskedasticity term was added into the mean equation.

EGARCH (1,1)

As the leverage effect is not considered in GARCH (1;1), which hypothesizes that both positive and negative shocks have a similar impact on volatility, Exponential-GARCH (EGARCH) model overcomes the weakness of the GARCH model. This model represents normal circumstances in which shocks affect commodity market volatility differently (Murekachiro, 2016).

Post-Estimation Test

To confirm the model efficiency, a post-estimation test for further ARCH effects was conducted.

RESULTS AND DISCUSSION

Descriptive statistics

To grasp the nature and distribution of the price return series, summary statistics were computed and presented in figure (1).

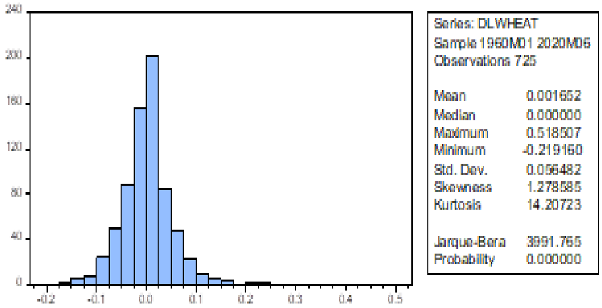

Figure 1. descriptive statistics for wheat price returns during the period (January 1960 – June 2020).

Source: Own calculation in Eviews 9 based on World Bank data, 2021.

As shown in figure 1, the summary statistics indicate that the average monthly price return is 0.002, with a monthly standard deviation of 0.0585. These indicate the existence of high dispersions from the average return in the global market over the study period.

The gap between the maximum and minimum price returns shows the variability of price changes over time. The high kurtosis value of 14.207 implies that big shocks (of either sign) may be presented in the series, making it leptokurtic. The skewness coefficient of 1.279 indicates that the monthly price returns series does not follow a normal distribution. The same conclusion could be reached from the Jarque-Bera test for normality.

Graphical representation of the price and return series (figure (2) & (3)) is the first step to analyses time series data as it helps understand the trend and pattern of the original series.

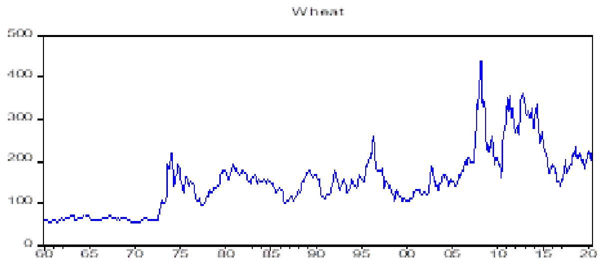

Figure 2. global wheat prices series during the period (January 1960 – June 2020).

Source: Own calculation in Eviews 9 based on World Bank data, 2021.

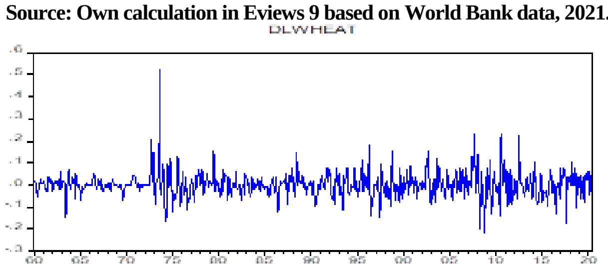

Figure 3. global wheat prices returns during the period (January 1960 – June 2020).

Source: Own calculation in Eviews 9 based on World Bank data, 2021.

From the time plot of monthly price movement, it is evident that the trend movement is not smooth, and the series is assumed to be non-stationary. In addition, the time plot of price returns indicates that there is also some degree of autocorrelation. The amplitudes of the price returns differ over time as large changes in returns are followed by large changes, and small changes follow small changes.

Unit Root Test

To find an appropriate model, the time series is required to be checked for stationarity using a common test known as Augmented Dickey-Fuller (ADF) unit root test. As observed from table (1), the series is stationary at level.

Table 1. Augmented Dickey-Fuller test

Level			
Test statistic with constant		Test statistic with constant and trend	
t-Statistic	Prob.*	t-Statistic	Prob.*
-20.77742	0.0000	-20.76816	0.0000

Source: Own calculation in Eviews 9 based on World Bank data, 2021.

ARCH Effects Test

The ARCH-LM test is conducted to detect the ARCH effect in the residuals. Table (2) presents the test results which point out that AR(1) is significant besides the F-statistic for the heteroscedastic ARCH effect. After confirming the existence of the ARCH effect in the residuals of the mean model, the GARCH model can be estimated.

Table 2. Estimation of conditional mean model and testing for ARCH effect

Variable	
μ	0.001775 (0.002928)
AR(1)	0.252981** (0.024213)
ARCH Effect	
Constant	0.002713** (0.093380)
ε^2_{t-1}	0.093380** (0.037208)
HO: No ARCH Effect	
F- Statistic	6.298625
Probability	0.0123

Standard Errors are in Parenthesis, ** significant at 5%.
Source: Own calculation in Eviews 9 based on World Bank data, 2021.

Symmetric, as well as asymmetric GARCH models namely: GARCH (1,1), GARCH-M (1,1), and EGARCH (1,1), were investigated (Table (3)). Out of these models, the most suitable one will be selected based on commonly used selection criteria such as the Akaike Information Criteria (AIC) and Schwarz information criterion (SIC).

Estimating GARCH Models

Based on model selection criteria, it is evident that GARCH (1,1) is preferable to the GARCH-M (1,1).

Regarding the mean equation, AR terms are positive and significant for both models, which indicates the positive impact of that past changes.

The results in table (3) also show that the estimated parameters of both models are statistically significant. The EGARCH (1,1) proved to be more preferable to the GARCH (1,1) and GARCH-M (1,1) depending on AIC and BIC criteria [-3.182132&-3.143930]. The persistence parameter, C (6) = 0.968, is huge, indicating that the variance moves slowly over time.

Investigating the presence of asymmetry, the coefficient C (5) = 0.125 is positive and statistically significant, indicating that the variance rises more after positive residuals than after negative ones. That is, bad and good news will increase the price volatility in different magnitude.

The Adequacy of the Fitted Model

So far, it is evident that EGARCH was the best model for the series. Diagnostic checking for this model was employed to check the ARCH effect, serial correlation, and normality. As indicated from table (3), there is no additional ARCH effect in the standardized residuals of the fitted model as the F statistic is not significant.

On the other hand, the statistical result of both the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) lies within the confidence interval, and all the p-value is not significant, indicating the nonexistence of serial correlation in the residuals.

Finally, even though the Jarque-Bera test indicates rejecting the null hypothesis of normality, the selection of the EGARCH (1,1) model with residuals being assumed normally distributed was well justifiable.

Table 3. Estimation Results of GARCH Family Models.

variable	GARCH(1,1)	GARCH-M(1,1)	EGARCH(1,1)
Mean Equation			
C	-0.000177 (0.002668)	0.001218 (0.003697)	0.002379 (0.002606)
AR(1)	0.293161** (0.040087)	0.293776** (0.039983)	0.301150** (0.035549)
GARCH		-0.861492 (1.289785)	
Variance Equation			
C	7.49E-05** (1.23E-05)	7.61E-05** (1.25E-05)	
ε^2_{t-1}	0.096116** (0.013504)	0.097187** (0.013478)	
GARCH(-1)	0.888169** (0.015855)	0.886823** (0.015945)	
C(3)			-0.284123** (0.052938)
C(4)			0.130161** (0.021480)
C(5)			0.124695** (0.008778)
C(6)			0.967586** (0.006761)
Log-likelihood			
Log-likelihood	1138.208	1138.545	1149.977
SIC	-3.120344	-3.112132	-3.143930
AIC	-3.152179	-3.150334	-3.182132
ARCH-LM	0.048200	0.038287	0.732212
Statistics Probability	0.8263	0.8449	0.3925

Standard Errors are in Parenthesis, ** significant at 5%.
Source: Own calculation in Eviews 9 based on World Bank data, 2021.

CONCLUSION AND RECOMMENDATION

Though formulating global policies to prevent price spikes is much more effective than local ones, reaching a multilateral consensus is a time-consuming and demanding process. Moreover, global-level actions must be supported with local-level strategies. The latter could range from subsidizing poor consumers to making long-term investments in agriculture (Von Braun& Tadesse,2012).

The current work has led to conclude that there is an asymmetric effect on volatility concerning positive and negative shocks of equal magnitude. i.e., the volatility goes up more after positive than negative shocks. The upshot of this is that policymakers will react differently depending on whether the information is positive or negative.

As achieving the self-sufficiency goal and delivering domestically produced wheat to the government through price policy proved to be expensive and unwise, Egypt could boost yields and productivity by directing its efforts to strengthen agricultural research, improve extension service, and spread market information. On the other hand, subsidizing Baladi bread for the poorest household would lower subsidy costs and help achieve efficiency gains tariff rate regime could help control wheat price volatility. A flexible tariff rate regime is more effective than fixing consumer or producer prices (Kherallah,2000).

Therefore, hedging against global price fluctuations through long-term contracts and sustainable investing in improving the local wheal value chain to reduce food loss and wastage will reduce the risks of the global price volatility on the one hand and protect the environment on the other hand (Yigezu *et al*., 2021).

Summary

Modeling the volatility of agricultural commodity price series has become an attractive area for research. The current research explores the volatility of the wheat price returns in the global market using both symmetric and asymmetric models after testing the existence of ARCH effects. GARCH (1,1), GARCH-M (1,1), and EGARCH (1,1) models were estimated to identify the most fitted one. The Exponential GARCH (1,1) model proved to be the most efficient model for modeling volatility, with asignificant asymmetric coefficient.

The results indicate an asymmetric effect on global wheat price volatility concerning positive and negative shocks of equal magnitude, .i.e, positive shocks have a more significant impact on volatility than negative shocks.

Policymakers could adopt policies that range from subsidizing poor consumers to making long-term investments in agriculture. It is recommended that long–term contracts and sustainable investments in improving the wheat value chain will help hedge against the risks of global price fluctuations caused by market-based or external shocks.

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قياس التقلبات السعرية لمحصول القمح في السوق العالمي: منهجية نماذج الانحدار الذاتي المعممة المشروطة بعدم ثبات التباين (GARCH)

فاطمه حفناوي و فيكتور شاكر

كلية الزراعه – جامعة القاهرة.

تعد تقلبات أسعار الغذاء مشكلة عالمية تلقى بظلالها على الدول الفقيرة والغنية على حدا سواء، الا انه قد يتمخض عنها آثار كارثية على الدول النامية بصفة خاصة. لذلك فإن معرفة نمط تلك التقلبات ضروري لصانعي السياسة على المستويين العالمي والمحلى وذلك لاتخاذ الإجراءات التي من شأنها تقليل الارتفاعات الفجائية في الأسعار، والإدارة الجيدة للاتجاهات السعرية، والعمل على حماية الافراد والقطاعات والجماعات المعرضة للضرر من جراء ذلك. في هذا الإطار، تم دراسة التقلبات في الأسعار العالمية للقمح باستخدام سلسلة زمنيه شهرية تتكون من ٧١٩ مشاهدة للفترة من ١٩٥٠ إلى ٢٠١٩ باستخدام مجموعة من النماذج المتماثلة وغير المتماثلة التي تنتمي لعائلة نماذج الانحدار الذاتي المعممة المشروطة بعدم ثبات التباين (GARCH)، حيث تبين أن نموذج الانحدار الذاتي المعمم المشروط بعدم ثبات التباين (غير المتماثل) (EGARCH) كان أفضل النماذج المدروسة لتمثيل البيانات وذلك بالاعتماد على مجموعة من معايير المقارنة. ولقد اشارت نتائج الدراسة إلى أن الصدمات الموجبة أو السالبة سيكون لها تأثير مختلف على حجم تلك التقلبات، حيث تبين ان الصدمات الموجبة ستؤدى إلى تقلبات أكثر ارتفاعاً مقارنة بالصدمات السالبة مما يعنى أن صانعي السياسة سيخذون قرارات مختلفة تتفق ونوع تلك الصدمات. وحيث أن توحيد الجهود الدولية لمواجهة تلك التقلبات تتطلب وقت ويتمخض عنها تكلفة، يمكن لصانعي القرار على المستوى المحلى وضع سياسات تتعلق بدعم البحوث الزراعية، رفع مستوى الخدمات الارشادية، اتاحة المعلومات السوقية، واستهداف الطبقات الأكثر فقراً للاستفادة من الخبز البلدي المدعم، حيث أن تحقيق الاكتفاء الذاتي من القمح أو اتباع سياسة سعرية محفزة للمزارع للقيام بتوريد القمح للحكومة تعد سياسات مكلفة وغير رشيدة. لذلك، توصى الدراسة بأهمية تدبير السلع الاستراتيجية كالقمح من خلال التعاقدات طويلة الاجل كوسيلة للتحوط ضد تذبذبات الأسعار في السوق العالمي إلى جانب توجيه الاستثمارات نحو تحسين سلسلة القيمة للقمح مما سيؤدى إلى تقليل الفاقد ومن ثم خفض حجم الواردات من ناحية وإلى تحسين جودة البيئة من ناحية آخري.