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Modeling and Forecasting the Volatility of the Export Price of Sesame in Ethiopia

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Abstract
The aim of this study is to model the export price of sesame as well as its volatility in Ethiopia using ARIMA and GARCH family models. The data used are monthly observations of the export price of sesame, food price index, fuel oil price and exchange rate from January 1998 to June 2013.Unit root tests of the series under study reveal that all the series are non-stationary at level and stationary after first difference. ARIMA and GARCH models were employed to analyze the monthly export price of sesame data. It was found that ARIMA(0,1,1) and ARMA(2,2)-GARCH(2,1) with normal distributional assumption for the residuals were adequate models for the data considered in this study. Among the exogenous variable that are considered in this study, food price index had an impact on the volatility of the export price of sesame in Ethiopia.Finally, various forecast accuracy statistics indicate that the estimated ARIMA model is good enough to describe the export price of sesame. Moreover, the out-of-sample forecasts indicate that the export price of sesame has an increasing trend. The in-sample forecast using the best-fit GARCH model indicates that the export price volatility of sesame steadily increased at the beginning of the study period, remained at almost a constant level till 2007 and then exhibited a downward trend around the end of the study period.
Keywords: Sesame, ARIMA, GARCH, Forecasting, Ethiopia

1. Introduction

Sesame (*Sesamum indicum* L.) is one of the world's oldest spice and oilseed crops grown mainly for its seeds that contain approximately 50% oil and 25% protein (Burden, 2005). The presence of some antioxidants (sesamum, sesamolin and sesamol) makes the oil to be one of the most stable vegetable oils in the world. The world production is estimated at 3.66 million tons with Asia and Africa producing 2.55 and 0.95 million tons, respectively (Anonymous, 2008). The continent of Africa is naturally endowed with favorable weather conditions that can support sesame production. The crop requires only 500-650 mm of rainfall per annum. Unfortunately, average world yield of sesame is still low at 0.46 ton ha^{-1} (FAO, 2004). Low yield had been attributed to cultivation of low yielding dehiscent varieties with low harvest index values, significant yield loss during threshing and lack of agricultural inputs such as improved varieties, fertilizers and other agro-chemicals (Ashri, 1994; Weiss, 2000; Uzun and Cagirgam, 2006). However, non- dehiscent sesame varieties with yield potential of over 1 ton ha^{-1} and suitable for mechanical combine harvest have been developed by Sesame Coordinators (SESACO) in USA (SESACO, 2007).

The plant is deep rooting and well adapted to withstand dry conditions. It will grow on relatively poor soils in climates generally unsuitable for other crops, and so it is widely valued for its nutritional and financial yield from otherwise inclement areas. It is well suited to smallholder farming with a relatively short harvest cycle of 90 –140 days allowing other crops to be grown in the field. It is often intercropped with other grains (Chemonics, 2002).

Ethiopian oilseeds and pulses are mostly organically produced, and are known for their flavor and nutritional value. The Ethiopian white sesame seed is used as a reference for grading in international markets. Ethiopia's major oilseeds and pulses exports include the following: sesame seeds, Niger seeds, linseeds, sunflower seeds, groundnuts, rape seeds, castor oil seeds, pumpkin seeds, haricot beans, pea-beans, horse beans, chick peas, beans and lentils. The European Union, Asia, the Gulf States and neighboring African countries comprise the major markets for Ethiopia's oilseeds and pulses exports (ECX, 2012).

Sesame is the second-largest export crop in Ethiopia, after coffee, and accounts for over 90% of the value of oil seeds exports. Different reports indicate that Ethiopia is among the top-five sesame producing countries in the world, ranked at fourth place in 2011/2012 (FAOSTAT, 2012). And it is the third largest exporter of sesame seed after India and Sudan (Alemu and Meijerink, 2010). Sesame is grown mainly for export markets and little value is added in Ethiopia (Wijnands et al., 2009). It is mainly grown by small-scale farmers in four regions of Ethiopia (Tigray, Amhara, Oromia and Beneshangul Gumuz). In the past decade, the area under production has grown 8-fold to 316 thousand ha, or 2% of Ethiopia's arable land (FAOSTAT, 2012).

2. Methodology

2.1. Data

Data for the study were obtained from National bank of Ethiopia (NBE) and Central statistical agency (CSA).

Monthly time series data on export price of sesame, food price index, fuel oil price and exchange rate for the period from January 1998 to June 2013 were used for estimation process. The export price of sesame, exchange rate and fuel oil price data are obtained from NBE, and food price index data are obtained from CSA.

The variables of interest in this study are export price of sesame which is to be used as a dependent variable, and fuel oil price, exchange rate and food price index are exogenous variables used to model and forecast the volatility of the export price of sesame in Ethiopia.

2.2. Statistical model

The Box-Jenkins time series model such as Autoregressive (AR), Moving Average (MA) and ARMA are often very useful in modeling general time series data. However; they all require the assumption of homoskedaticity (or constant variance) for the error term in the model. But, this may not be appropriate when dealing with some special characteristics in the financial and agricultural price time series and this causes the introduction to ARCH (Autoregressive Conditional Heteroskedasticity) model which was proposed by Engle (1982) and generalized by Bollerslev (1986) and Taylor (1986). Therefore, to come up with the objectives of the study, after identifying the presence of ARCH effects, separate GARCH and EGARCH models has been employed in this study to investigate the pattern of export price volatility and its determinants for sesame with joint estimation of a mean and a conditional variance equation as model specification given below.

Let Y_t be the returns of average monthly export price for sesame under study at time t, ε_t be error term (residual) from mean equation with mean zero and conditional variance ${\sigma_t}^2$ and given the historical information on the average export price return series as $Y_1, Y_2, \ldots, Y_t$ under the presence of ARCH effect, for $GARCH(p,q)$ family model the conditional mean equation,

The $ARMA\ (p,q)$ mean model (Box-Jenkins, 1976) is given as:

$Y_t = \mu + \sum_{i=1}^{p} \emptyset_i y_i - \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} + \varepsilon_t$

An Autoregressive Conditionally Heteroskedasticity model for the variance of the errors which is known as an ARCH (q) model proposed by Engle (1982), the conditional variance is given by:

$${\sigma_t}^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}$$

We impose the non-negativity constraints $\alpha_0 > 0$ and$\alpha_i \geq 0, i = 1, 2, \ldots, q$.

Generalized by Bollerslev (1986) as GARCH (p, q) which allow the conditional variance to be dependent upon previous own lags as model, then the full model for $GARCH(p,q)$ has two parts the mean model and the conditional variance model given below;

${\sigma_t}^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i} + \sum_{j=1}^{p} \beta_j {\sigma^2}_{t-j}$ where $\alpha_0, \alpha_i \geq 0, \beta_j \geq 0\ for\ i = 1, 2, \ldots, q\ and\ j = 1,2, \ldots, p$ ensure that the variance is always greater than zero and the restriction $(\sum_{i=1}^{q} \alpha_i + \sum_{j=1}^{p} \beta_j < 1)$ is necessary and sufficient condition for the stability of the conditional variance equation (Cryer and Chan, 2008).

GARCH-X model proposed by Hwang and Satchell (2005) for modeling aggregate stock market return volatility includes a measure of the lagged cross-sectional return variation as an explanatory variable in the GARCH conditional variance equation. GARCH-X model where the basic GARCH specification of Bollerslev (1986) is augmented by adding exogenous repressors to the volatility equation:

${\sigma_t}^2(\vartheta)$ is the volatility process given by:

$${\sigma_t}^2(\vartheta) = \alpha_0 + \alpha {y_{t-1}}^2 + \beta {\sigma_{t-1}}^2 + \gamma {x^2}_{t-1}$$

For some observed covariate x_t which is squared to ensure that ${\sigma_t}^2(\vartheta) > 0$ and where $\vartheta = (\alpha_0, \theta')'$, with $\theta = (\alpha, \beta, \gamma)'$, is a vector of parameters.

2.3. Procedures for Model Building

The basic frameworks that were followed in order to investigate the pattern of export price volatility and its determinants on, sesame were follows the following Box and Jenkins approach:

- Test for the presence of unit root (non-stationary) case
- Test for ARCH effects
- Model order selection for GARCH family model
- Model parameter estimation
- Model adequacy checking

3. Results and Discussion

3.1. Descriptive Statistics

The data in this study consist of monthly export price of sesame (in birr per metric ton), monthly food consumer price index, monthly import fuel oil price (in US dollar) and monthly exchange rate (in birr against US dollar) in Ethiopia for the period spanning from January 1998 to June 2013.

Table 1: Descriptive statistics for macroeconomic variables

	SESAME	FOOD	OIL	EXCHANGE
Mean	8275.182	40.331	57.647	10.456
Median	5284.207	28.600	57.538	8.919
Maximum	25070.650	102.100	123.259	18.887
Minimum	2510.336	17.300	9.824	6.709
Std. Dev.	5720.587	23.741	34.434	3.308

From the result Table 1 above, the mean value of the export price of sesame, food price index, fuel oil price and exchange rate over the study period were 8275.182, 40.331, 57.647 and 10.456, respectively. Moreover, the maximum and minimum values of the export price of sesame were 25070.650 and 2510.336, respectively.

3.2. Test for Stationarity

The time series under consideration should be checked for Stationarity before one attempts to fit a suitable model. The Stationarity of each series can be tested using the Augmented Dickey-Fuller test and the Phillips-Perron test. The results of ADF and PP tests with intercept but no trend and with intercept and trend both at level and in return form for the series are presented in Tables 2 and 3. Test results presented in Table 2 indicate that the null hypothesis that the series in levels contain unit root could not be rejected for the series.

Table 2: ADF and PP Unit root test results (At level)

Series	Include test equation	Test statistic		Prob.*		Test critical value		
		ADF	PP	ADF	PP	1% level	5% level	10% level
SESAME	with intercept	2.612	3.042	0.999	0.999	-3.466	-2.877	-2.575
	With trend and intercept	0.227	0.380	0.998	0.999			
FOOD	with intercept	5.108	6.755	0.999	0.999			
	With trend and intercept	1.011	1.351	0.999	0.998			
OIL	with intercept	-1.006	-0.971	0.751	0.763			
	With trend and intercept	-2.948	-2.974	0.150	0.143			
EXCHANGE	with intercept	3.642	3.828	0.999	0.999			
	With trend and intercept	1.103	0.999	0.999	0.999			

If a time series data is non-stationary, it is necessary to look for possible transformations that might induce Stationarity. In practice, researchers usually transform financial data series into return forms. Table 3 summarizes the unit root test of the return series for the export price of sesame. The table shows that the null hypothesis of unit root would be rejected. Hence the return series of the export price of sesame are stationary.

Table 3: ADF and PP Unit root test result the return series of the export price of sesame

Series Name	Include test equation	Test statistic		Prob.*		Test critical value		
		ADF	PP	ADF	PP	1% level	5% level	10% level
Return series of sesame	with intercept	-12.730	-12.759	0.000	0.000	-3.466	-2.877	-2.575
	With trend and intercept	-12.881	-12.884	0.000	0.000	-4.009	-3.434	-3.141

3.3. Specification of the mean equation

To specify the conditional mean equation for the series, comparison of various $AR(p)$, $MA\ (q)$ and $ARMA\ (p,q)$ models are performed and the one with smallest information criteria is selected. In this study, AR (0-3) and MA (0-3) were considered since the return series show insignificant spikes for all of the lags. Among the various ARMA models considered, ARMA (2, 2) model possesses minimum AIC and BIC and exhibits no serial correlation. Therefore, ARMA (2, 2) model is the best-fit model for the conditional mean equation for the return series of the export price of sesame. The maximum likelihood estimation method for monthly return series of export price of sesame are summarized in Table 4 below.

Table 4: Parameter estimate of $ARMA(2,2)$ model

Parameters	Coefficients	Std. error	t-statistic	p-value
Constant	0.011	0.005	2.446	0.015**
AR(1)	-1.078	0.223	-4.832	0.000*
AR(2)	-0.513	0.177	-2.898	0.004*
MA(1)	1.149	0.195	5.907	0.000*
MA(2)	0.647	0.153	4.234	0.000*

*Note: * and ** indicates significant at 1% and 5% level, respectively*

3.4. Test for ARCH effects

To proceed with volatility modeling ARCH effects (whether or not volatility varies over time) in the residuals from the selected ARMA (2, 2) model should be tested. The confirmation of the presence of ARCH effect indicates that the volatility in the average monthly return export price of sesame is time varying and appropriateness of employing GARCH family model.

3.5. Specification of Volatility Model

Once the ARCH effects are determined, then the optimal lag specifications for GARCH family models were determined prior to the construction of the final model to investigate the determinants of export price volatility. In our model selection procedure we first fit different GARCH family models of different orders of m and r. GARCH(2,1) and EGARCH(1,1) models under normal distributional assumption for residuals, GARCH(1,1) model under both GED and student's t-distributional assumption for residuals, and EGARCH(2,1) and EGARCH(1,1) models under GED and student's t-distributional assumptions for residuals, respectively, were selected as candidate models for the export price volatility of sesame since they possess minimum AIC and/or BIC.

To select the appropriate conditional volatility model, we consider the forecasting performance of the selected GARCH family models. The forecast performances of the fitted GARCH family models are evaluated by RMSE, MAE, MAPE and Theil inequality coefficients. The model with the smallest statistics is considered to be better fit for modeling the conditional volatility of the export price of sesame in Ethiopia. The summary results are displayed in Table 5 below.

Table 5: Forecast accuracy statistics for residuals from the variance equation of the export price of sesame

Model	Error distribution	Forecast accuracy measures				Asymmetric effect
		RMSE	MAE	MAPE	Theil	
GARCH(2,1)	Normal	0.056995	0.043515	2758.162	0.809679	-
GARCH(1,1)	t-distribution	0.057060	0.043500	3079.246	0.793866	-
GARCH(1,1)	GED	0.057002	0.043515	2769.448	0.809174	-
EGARCH(1,1)	Normal	0.056917	0.043375	2625.691	0.815293	Non-significant
EGARCH(1,1)	t-distribution	0.056920	0.043369	2646.200	0.814062	Non-significant
EGARCH(2,1)	GED	0.056922	0.043414	2426.306	0.825612	Non-significant

The forecast accuracy measures indicate that EGARCH models with different error distributional assumption possess smallest accuracy measures in the majority of the statistics. However, the asymmetric effects are insignificant in all these models. Therefore, the best-fit model is selected from the symmetric GARCH models. Among the symmetric models, GARCH (2,1) model with normal distributional assumption for the residuals possesses the smallest forecast accuracy measures in most of the statistics. Thus, this model is a best-fit model to describe the volatility of the return series of the export price of sesame.

Table 6: Maximum likelihood Parameter Estimates of the Volatility Models for Selected Orders with the Incorporated Exogenous Variables for sesame

Parameters	Variables	Coefficients	Std. error	Statistic	P-value
Mean equation	Constant	0.012	0.003	3.973	0.000*
	AR(1)	-0.941	0.305	-3.087	0.002*
	AR(2)	-0.396	0.212	-1.873	0.061***
	MA(1)	1.013	0.296	3.419	0.001*
	MA(2)	0.476	0.206	2.311	0.021**
Variance equation	Constant	1.73E-04	7.67E-05	2.260	0.024**
	ARCH(-1)	-0.087	0.019	-4.607	0.000*
	ARCH(-2)	0.126	0.034	3.704	0.000*
	GARCH(-1)	0.926	0.030	31.322	0.000*
	Food price index	-8.68E-05	2.05E-05	-4.247	0.000*
	Fuel oil	-5.26E-06	1.47E-05	-0.359	0.720
	Exchange rate	-2.48E-04	5.90E-04	-0.420	0.674

*Note: *, ** and *** indicates significant at 1%, 5% and 10% level, respectively*

The coefficient estimate of food price index is negative and statistically significant at the 1% level, that is, food price index has a significant influence on the export price volatility of sesame. This indicates that an increase in food price index leads to a decrease in the monthly export price volatility of sesame. This result is consistent with the findings of Sorsa (2009) and Zheng et al. (2008).

As can be seen in Table 4.12, the coefficient of fuel oil price is statistically insignificant. This shows that fuel oil price has no significant effect on the export price volatility of sesame. This result is consistent with Khin (2010).

Among the explanatory variables which are considered in this study, the coefficient of exchange rate (in birr against US dollar) was negative and statistically insignificant. This results is inconsistent with the findings of Abule (2012) and Serge (2006).

The results from the variance equation show that the coefficient of the ARCH(-1) and ARCH(-2) term were statistically significant at the 1% level. This shows that the current month export price volatility of sesame was affected by its 1-month and 2-month lagged shocks. Similarly, the GARCH(-1) term is statistically significant at the1% level. This indicates that the current month export price volatility of sesame was affected by its 1-month lagged price volatility.

3.6. Diagnostic checking of the fitted model

For diagnostic checking of the presence of remaining ARCH effect in the residuals, ARCH LM test and Ljung-Box Q-test are used. The p-values of both tests are greater than 5%. These results imply that we do not have enough evidence to reject the null hypothesis that there is no ARCH left in the residuals. Additionally, the Jarque-Bera statistic is used to test the normality of the residuals in the fitted model. The result shows that the normality of the residuals in the fitted model is not rejected. Therefore, we conclude that the residuals of the fitted model are normally distributed.

3.7. Forecasting price volatility

One of the fundamental applications of developing GARCH family model is forecasting. In this section we make in-sample forecasts based on the fitted ARMA (2,2)-GARCH(2,1) model with normal distributional assumption for residuals. The plot of the dynamic in-sample forecast is presented in Figure 1.

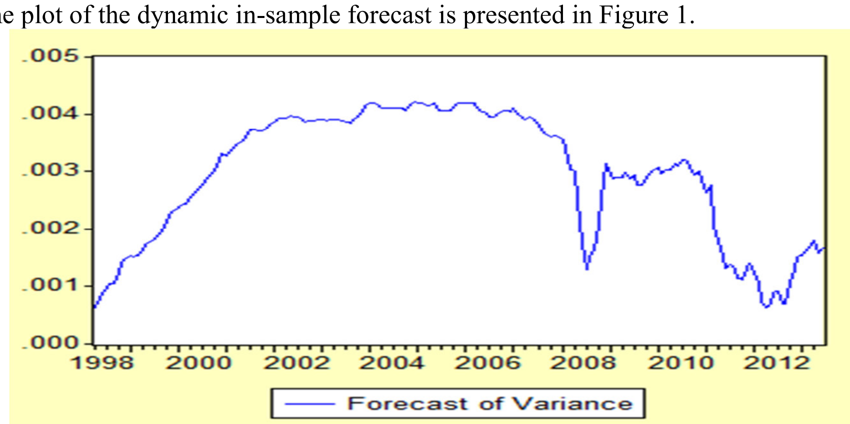

Figure 1: In-sample forecast of monthly export price volatility of sesame

As we can see from Figure 4.3, the export price volatility of sesame steadily increased from the years 1998 to around 2002, remained at almost a constant level till 2007 and then drops sharply. Moreover, low export price volatility was observed from around the year 2010 up to the end of the study period.

4. Conclusion and Recommendation

4.1 Conclusion

In this paper, we have examined GARCH family models for the export price of sesame. The conditional mean equation was estimated using ARMA model and the conditional variance equation using GARCH family models with different error distributions. After examining different competitive models ARMA (2, 2)-GARCH (2, 1) model with normal distributional assumption for the residuals provides the best-fit model for the export price volatility of sesame in Ethiopia.

Among the exogenous variable that are considered in this study, food price index had a significant effect on the volatility of the export price of sesame in Ethiopia. Moreover, the ARCH and GARCH terms were found to be statistically significant. These show that the current month export price volatility of sesame is affected by the recent past shocks and volatility.

Finally, forecasts are made using GARCH model. The in-sample forecast using the best-fit GARCH model indicates a steady increase at the beginning of the study period followed by a period where volatility remained at almost a constant level. Moreover, low volatility was observed around the end of the study period.

4.2. Recommendation

The focus of this study was estimating and forecasting the export price volatility of sesame in Ethiopia. Further studies may employ multivariate models such as seasonal or dynamic conditional correlation multivariate model to analyze the time varying correlation of export price of sesame with other variables. Additionally, there are also other variable that might affect the volatility of the export price of sesame in Ethiopia.

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