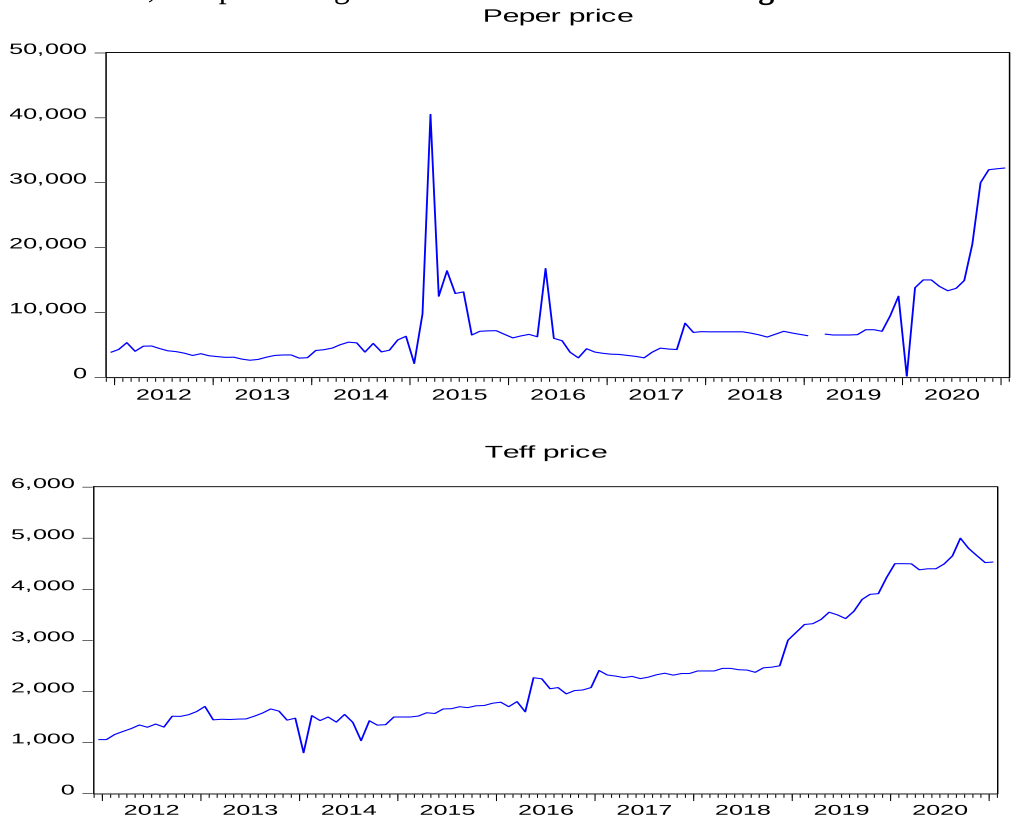
Graphical properties of the price and return series, which is the first step in analyzing time series data, are plotted against time as follows. This could help to understand the trend as well as pattern of movement of the original series.

Figure 1: Price series

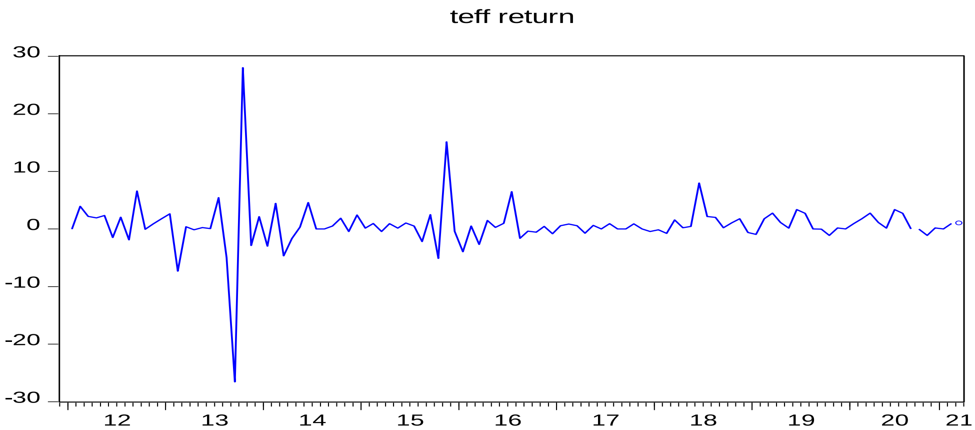


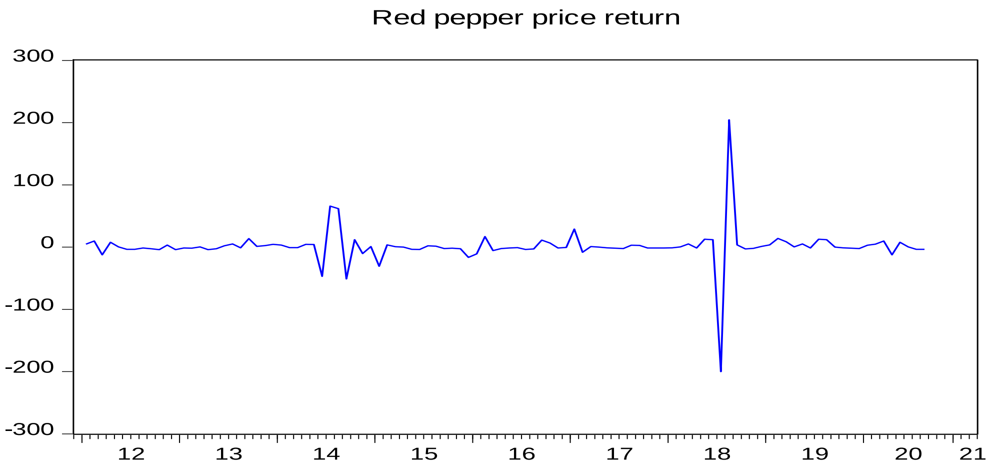
Source: Author's own

From the time plot of monthly Teff and Red pepper price movement, it is clearly seen that the trend movement in the plot is not smooth. This indicates that the means and variances of both the commodities are heteroskedastic and the series seems to be non-stationary. Transforming the monthly price data $\{Y_t\}$ to natural log returns $\{r_t\}$ is, therefore, made.

In addition, the plots of the commodities price returns as function of time are shown in the following figure. The time plot of price returns indicates that some periods are more risky than others. There is also some degree of autocorrelation in the riskiness of the log returns. The amplitudes of the price returns vary over time as large changes in returns tend to be followed by large changes and small changes are followed by small changes.

Figure 2: Return series





Source: Author's own

This is one of the stylized facts of the financial time series the so called volatility clustering. The volatility clustering in the series indicates that the returns are being driven by market forces. In order to meet the objective, GARCH family models were applied EViews 10 statistical package used to compute the estimates of the GARCH, volatility model parameters. In order to model price volatility, monthly price series for each selected commodity used to compute the logarithmic return series as $Yt = \ln(pt / pt\!-1)$.

Unit Root Test for Non-stationary Series

For a time series data, one should check for stationarity in order to find an appropriate model. Therefore, in this study, Augmented Dickey–Fuller (ADF) unit root test was used to check the stationarity of the monthly natural log return series. The result is presented in Table 2. As it is observed from the table, the null hypothesis of unit root would be rejected; that is, the series are stationary at level.

Table 2. Unit Root Tests for the Series (at level)

	ADF test		
Price return series	**test equation**	Test Statistics	P Value
Teff	With intercept	-8.443688	0.0000
	With rend and Intercept	-5.902060	0.0000
Red Pepper	With intercept	-8.552758	0.0000
	With rend and intercept	-8.538451	0.0000

Source: The Author

Test of ARCH effect

Test of ARCH effect is one of the most important issue to be checked before applying GARCH models. LM test for the squared residuals of the fitted model proposed by Engl (1982) was conducted for testing heteroscedasticity.

Table 3: Hetroskedasticity test: ARCH

		ADF test	
Price return series		**F Statistics**	**Chi square Statistics**
Red Pepper	ARCH (1)	5.24707	9.622873
		(0.0072)	**(0.0081)**
Teff	ARCH (1)	8.230019	7.723517
		(0.0051)	**(0.0055)**

Source: The Author

Although the null hypothesis states that there is no remaining ARCH effect, the finding indicates the existence of ARCH effect in both commodities; in fact, the null hypothesis is rejected. Therefore, it is better to estimate the ARCH model for better result since it shows the variance of return series for each commodity is time varying.

GARCH component Model Specification

After confirming the presence of ARCH effect in the residuals of the mean model, one needs to estimate GARCH model to test for the presence of asymmetry and time varying unconditional variance in the series. Various symmetric (GARCH) and asymmetric (EGARCH, TGARCH) models for the price return series were considered. Then, for the model selection procedure, different symmetric and asymmetric GARCH models of different orders of p and q. were fitted for each series. Out of these symmetric GARCH model and Asymmetric EGARCH and TGARCH models under normal assumption for residuals were selected as possible models for the price volatility based on the Akaika information Criteria AIC and Schwarz criterion (SIC). Table 4 displays the summary results. Additionally, forecasting performance of the selected GARCH models is considered in the selection of the appropriate conditional volatility model.

Table 4: Model selection

		Information criteria	
Series	**Model**	**AIC**	**SIC**
Red pepper price return	GARCH 11	8.336949	8.413230
	GARCH (2, 0)	8.336940	8.413220
	TGARCH (1, 1)	**8.245998**	**8.347705**
	EGARCH (1, 1)	8.351618	8.453326
Teff price return	GARCH (1, 1)	5.002132	5.075782
	GARCH (2, 0)	5.002132	5.075781
	TGARCH (1, 1)	**4.809872**	**4.908071**
	EGARCH (1, 1)	4.839534	4.937733

Based on the Akika information criteria (AIC) and Schwarz criterion (SIC), TGARCH model with normal distributional assumption performs better in describing volatility of Teff price return and Red pepper price return in Ethiopia under the years reviewed. The coefficients of the asymmetric terms are positive 3.091644 and negative 8.057376 for Teff price return and Pepper price return, respectively, and both are statistically significant at 1% (0.01) level.

The estimate of tie varying volatility is given as follows:

$\delta = \omega + \alpha_1 \varepsilon^2_{t-1} + \beta \delta_{t-1} + \gamma \varepsilon^2_{t-1} d_{t-1}$

$\boldsymbol{\delta}_{teffreturn} = 5.218448 + 0.01089\, \boldsymbol{\delta}_{t-1} + (-0.026055 + 3.004058)\, \varepsilon^2_{t-1}$

$\boldsymbol{\delta}_{Pepper\ return} = 20.51134 + 0.178795\, \delta_{t-1} + (8.702471 - 8.057376)\, \varepsilon^2_{t-1}$

The difference between good news and bad news, which is the coefficient of asymmetry term, is 3.004058 for Teff price Return and – 8.057376 for pepper price return. It is inferring to that there are asymmetries in the news, in which the bad news has larger effect on the volatility than the good news for both Teff and Red Pepper price returns. In finance theory, the relationship between risk and returns plays a pivotal role in asset pricing. If the risk is conditional and not constant over time, then the conditional expectation of the market returns is not only linear function of the conditional variance but also the information asymmetries too. Like financial time series, the leverage effect is exhibited in the return series of Teff and Red pepper prices. The result is consistent with findings of (Musunuru et al., 2013) and Le Roux, (2018) who asserts TGARCH model, also called GJR-GARCH, is the a best fit model for corn, coffee and cocoa, respectively, in which they assert the existence of leverage effect where negative shocks have a greater effect than positive one. In conclusion, the modeling of information, news or event is very significant determinant of assets volatility.

Checking the Adequacy of the Fitted Models

So far it has been mentioned that TGARCH was the best model for the series, diagnostic checking for this model employed to check the ARCH effect, serial correlation and normality. Breusch–Godfrey serial correlation LM test was employed in order to check for possible ARCH effects on the residuals, Corrologram of standardized residual squared and Jarque – Bera for normality tests. Results are presented as follows:

Heteroskedasticity test

Table 5: Heteroskedasticity Test: ARCH

F-statistic	0.006897	Prob. F (1,107)	0.9340
Obs*R-squared	0.007025	Prob. Chi-Square (1)	0.9332

Source: Author's own

From the results presented in Table 5, one can observe that the standardized residuals of the fitted model did not exhibit any additional ARCH effect for both series as both the F statistics and observed R squared are not significant.

Test for serial correlation

The null hypothesis states that there is no serial correlation in the residuals. It is implied that the statistical result of both the autocorrelation function (ACF) and partial autocorrelation function (PACF) lies within the confidence interval, and all the p value are more than 5% (0.05) or are not significant. It indicates that there is no serial correlation in the residuals; therefore, it fails to reject the null hypothesis

Finally even though the Jarque - Bera test statistic was significant, and hence, there was an evidence to reject the null hypothesis of normality, the selection of TGARCH (1, 1) model with Normal distributional assumption of residuals was well justifiable.

Forecasting accuracy

The second objective of the study was to predict price volatility of agricultural commodities. And following the selection of the best fit model and the diagnostic tests, an attempt was made to use the model for forecasting volatility of future series. The forecast performance of fitted GARCH family models was evaluated through the four conventional error measurements (forecast accuracy statistics): root mean square error (RMSE), mean absolute error (MAE), and Theil inequality coefficient and mean absolute percentage error (MAPE). The GARCH models with the lowest statistics were considered a better fit for modeling the conditional volatility of the price series. The summary results are displayed in Table 8 below.

Table 8 Evaluating forecast performance of fitted GARCH family models

			Forecast accuracy measure			
	Model	**Error Distribution**	**RMSE**	**MAE**	**Theil**	**MAPE**
Teff	**GARCH (1, 1)**	Normal distribution	4.613	2.157	0.83088	136.36
	GARCH (2,0)	Normal distribution	4.693	2.16	0.84747	139.692
	TGARCH (1, 1)	Normal distribution	**4.603**	**2.157**	**0.82145**	**139.677**
	EGARCH (1, 1)	Normal distribution	4.606	2.186	0.83528	136.98
Pepper	**GARCH (1, 1)**	Normal distribution	32.644	10.831	0.99	197.038
	GARCH (2,0)	Normal distribution	32.648	10.811	0.994	190.668
	EGARCH (1, 1)	Normal distribution	32.663	10.848	0.995	165.515
	TGARCH (1, 1)	Normal distribution	**32.641**	**10.818**	**0.984**	**193.163**

Source: The Author

In time series forecasting theory, one can do forecasting when the estimated model has no statistical problem, i.e. when there is no serial correlation, no heteroskedasticity and residuals are normally distributed. Since all these situations were satisfied, the model is ready for forecasting. From the table above, it is observed that TGARCH model has a better forecasting accuracy in both the in sample and out of sample forecast, since it possesses the smallest forecast error measures in the majority of the statistics.

Conclusion

The main objective of this study was to model and forecast price volatility for selected agricultural commodities in Ethiopia. Specifically, it aimed to identify the best fit GARCH Family models and predict price volatility of agricultural commodities in Ethiopia. To meet these objectives, monthly price data on Teff and Red pepper were collected from ANRSTMDB focusing on the data recorded from 2011 up to 2011. The actual price data of the commodities were transformed to log return series taking into account its better statistical properties. Enabling conditions for a financial time series data were considered in the analysis; for this purpose Akaike information criterion (AIC) and Schwarz information criteria (SIC) were applied for the selectin of appropriate model. Residuals were dragonized through Breusch–Godfrey serial correlation LM test for ARCH effects on the residuals, Corrologram of standardized residual squared for serial correlation on the residuals and Jarque – Bera for normality tests for normality on the residuals. Akaike information criterion (AIC) and Schwarz information criteria (SIC) were applied for the model selection purpose

The data analysis results showed that the price return series of Teff and Red Pepper demonstrated the characteristics of financial time series, such as leptokurtic distributions and volatility clustering which provides an adequate ground for the use of GARCH family models. Moreover, the presence of ARCH effects in the residuals of the conditional mean equation is supported by the ARCH-LM tests. In this study, both symmetric GARCH (1, 1), GARCH (2, 0) and asymmetric (EGARCH) and TGARCH models were considered in order to model the price return volatility of Teff and Red Pepper in the Ethiopian market. Accordingly, based on the Akaika information Criteria and AIC and/or Schwarz information criteria (SIC), asymmetric TGARCH model with Normal distributional assumption of residuals was found to be a better fit for the price return volatility of Teff and Red Pepper. This implies that there is asymmetry in the news, in which the bad news has larger effect on the volatility than the good news for both Teff and Red Pepper price returns. In conclusion, as TGARCH is the better fit model for the Teff and Red Pepper price returns, modeling of information, news or event are very significant determinant of assets volatility.

Moreover, forecast performance of the model is evaluated using the mean squared error measurements such as RMSE, MAE, Theil inequality coefficient and MAPE in which it possesses the smallest forecast error measures in the majority of the statistics. Thus the accuracy of the TGARCH model was found to be good in forecasting price return volatility of Teff and Red Pepper.

In general, the findings of this study demonstrates that, TGARCH was the best fit model in modeling and forecasting price return volatility of Teff and Red Pepper, which suggests that market participants, whether they be farmers or investors, can get prepared for shifts in market momentum and in dealing with market choices.

Reference

[1]. Abebe, T. H., Woldesenbet, E. G., & Zeleke, B. L. (2020). Statistical Analysis of Price Volatility of Agricultural Commodities Traded at the Ethiopian Commodity Exchange (ECX) Using Multiplicative GARCH-MIDAS Two-component Model. Global Business Review, 0972150919895628.

[2]. Adugh, K. D. (2019). *Modeling Volatility of Agricultural Commodity Food Price Index in Nigeria using ARMA-GARCH Models Modeling Volatility of Agricultural Commodity Food Price*

Index in Nigeria using ARMA-GARCH Models. *3*(1), 55–75.

[3]. Arezki, R. (2012). *Commodity price volatility and inclusive growth in low-income countries / editors, Rabah Arezki [and three others]*. (R. Arezki & International Monetary Fund (eds.)) [Book]. International Monetary Fund.

[4]. Ayele, A. W., Gabreyohannes, E., & Tesfay, Y. Y. (2017). Macroeconomic Determinants of Volatility for the Gold Price in Ethiopia: The Application of GARCH and EWMA Volatility Models. *Global Business Review*, *18*(2), 308–326. https://doi.org/10.1177/0972150916668601

[5]. Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics*, *31*(3), 307–327. https://doi.org/10.1016/0304-4076(86)90063-1

[6]. Engle, R. F. (1982). Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation. *Econometrica*, *50*(4), 987. https://doi.org/10.2307/1912773

[7]. Getnet, K. (2009). From auction market to Commodity Exchange: Managing coffee price risk in Ethiopia. *Quarterly Journal of International Agriculture*.

[8]. Lama, A., Jha, G. K., Paul, R. K., & Gurung, B. (2015). Modelling and Forecasting of Price Volatility: An Application of GARCH and EGARCH Models. *Agricultural Economics Research Review*, *28*(1), 73. https://doi.org/10.5958/0974-0279.2015.00005.1

[9]. Le Roux, C. L. (2018). *Volatility Modelling of Agricultural Commodities: Application of Selected GARCH Models*. 343–356. https://doi.org/10.1007/978-3-319-70055-7_27

[10]. Musunuru, N., Yu, M., & Larson, A. (2013). Forecasting Volatility of Returns for Corn using GARCH Models. *The Texas Journal of Agriculture and Natural Resources*, *26*, 42–55. http://txjanr.agintexas.org/index.php/txjanr/article/view/33

[11]. Nelson, D. B. (2011). Conditional Heteroskedasticity in Asset Returns : A New Approach Author (s): Daniel B . Nelson Published by : The Econometric Society Stable URL : http://www.jstor.org/stable/2938260 . CONDITIONAL HETEROSKEDASTICITY IN ASSET RETURNS : A NEW APPROACH. *Society*, *59*(2), 347–370.

[12]. Pindyck, R. S. (2001). The dynamics of commodity spot and futures markets: A primer. *Energy Journal*, *22*(3), 1–29. https://doi.org/10.5547/ISSN0195-6574-EJ-Vol22-No3-1

[13]. Rezitis, A. N., & Sassi, M. (2013). *Commodity Food Prices : Review and Empirics Commodity Food Prices : Review and Empirics*. *November 2015*. https://doi.org/10.1155/2013/694507

[14]. Shiferaw, Y. A. (2012). Modeling Volatility of Price of Some Selected Agricultural Products in Ethiopia: Arima-Garch Applications. *SSRN Electronic Journal*, 1–13. https://doi.org/10.2139/ssrn.2125712

[15]. Thiyagarajan, S., Naresh, G., & Mahalakshmic, S. (2015). Forecasting volatility in Indian agri-commodities market. *Global Business and Finance Review*, *20*(1), 95–104. https://doi.org/10.17549/gbfr.2015.20.1.95

[16]. Zakoian, J. M. (1994). Threshold heteroskedastic models. *Journal of Economic Dynamics and Control*, *18*(5), 931–955. https://doi.org/10.1016/0165-1889(94)90039-6