Measuring Maize Price Volatility in Swaziland using ARCH/GARCH approach

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Abstract

This paper investigates maize price volatility in Swaziland as offered by NMC, an organization with a mandate of stabilizing prices in the country. Price volatility is analyzed using ARCH/GARCH modeling techniques. Results show that the organization has not been able to stabilize prices in the past years. This is likely because of exogenous global shocks in maize prices which are transmitted to the local market. These external shocks transmission are mainly because the organization imports a lot of maize to meet local demand. However, although prices have been volatile, the organization has been able to control persistence in volatility. Asymmetric analysis of the prices shows that prices have not reacted unequally to shock increase or decrease in prices. However, increase in maize prices has been seen as fueling volatility, which does not bode well for consumers. This analysis therefore has formed an important contribution to analysis of storage facilities and their role in stabilizing prices. Storage facilities will become important especially for third world countries with increased unpredictability in agricultural production due to climate change.

Key Words: NMC, Maize Prices, Volatility, ARCH/GARCH, Persistence, Climate Change, Storage Facilities

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1. Introduction

While an overwhelming amount of literature has used Autoregressive Conditional Heteroskedasticity / Generalized Autoregressive Conditional Heteroskadasticity (ARCH/GARCH) modeling techniques to study volatility in equity and financial markets, these models are gaining popularity in analyzing price volatility in agricultural commodities. For example Jordaan et al. (2007) used these models to analyze price volatility of common South African crops using data from South African Future Exchange (SAFEX). Others like Figiel and Hamulczuk (2010) used GARCH model to analyze price volatility in Polish monthly wheat prices. Pop and Ban (2011) used EGARCH to analyze wheat prices in Romania. Rovinaru et al (2012) estimated food price volatility in Romania compared to international markets. Apergis and Rezitis (2011) applied GARCH and GARCH-X to analyze food price volatility in Greece while, Pop et al. (2013) used these models to analyze sugar price volatility in Romania.

Our study aims to use ARCH/GARCH techniques to analyze price volatility in maize markets in Swaziland. Trends and developments in the maize market are particularly important for Swaziland. This is because maize is the stable food for the Swazi nation. Cereal intake in the country forms 75% of diet, 85% of which is from maize, meaning maize contributes 64% to total Swazi diet (Grant et. al, 2012). For this reason, price developments in the maize market are an important food security issue for the country, which need to be analyzed closely.

Maize production in Swaziland, which is expected to affect prices, is mainly through rain fed agricultural practices by most rural households at subsistence levels. This makes the country's ability to produce maize vulnerable to changes in weather patterns as a result of climate change. As has been noted by Oseni and Masarirambi (2011), since the 1990s, crop production in the country especially of maize has faced the negative impacts of extreme climate events which are believed to be manifestations of long-term climate change. Also, according to the World Food Program (2013), up until 2000, Swaziland was routinely harvesting more than 100,000 tons of maize per year. However, since then, the average harvest has dropped to some 70,000 tons. Factors cited as contributing to this decline include erratic weather, high fuel and input costs, the devastating impact of HIV and AIDS, and low implementation of improved agricultural practices.

Swaziland has traditionally been a maize deficit country, relying on imports mainly from the Republic of South Africa to meet local demand as Table 1 shows.

Table 1: Domestic Maize Production and Consumption

Cropping Season	Area Planted (Ha)	Production (MT)	Consumption Requirement (MT)	Maize Deficit (MT)
2000/2001	67 898	90 100	155 700	65 600
2001.2002	60 135	69 722	133 900	64 178
2002/2003	54 470	69 800	150 600	80 800
2003/2004	54 470	82 103	148 900	66 797
2004/2005	56 265	67 079	147 000	79 921
2005/2006	46 973	46 604	126 900	80 296
2006/2007	47 900	61 994	119 000	57 005
2007/2008	60 355	61 995	147 500	85 505
2008/2009	52 445	72 442	113 000	40 568
2009/2010	58 334	75 965	104 270	29 205
2010/2011	70 344	84 686	113 650	28 964
2011/2012	52064	76 091	115 380	39 290

Source: MOA, 2013

The continued increase in maize imports and slump in local production in recent years means the country is more exposed to global developments in maize markets and is becoming a price taker. This makes analysis of trends in the country's maize prices crucial. As noted by Prakash (2011), clarifying the characteristics of commodity prices, especially trends, is crucial for developing countries that rely on commodity exports or that import significant amounts of food. This is especially so if that food commodity is a stable food as is the case for maize in Swaziland.

In general, agricultural commodity prices have exhibited extreme price volatility since mid-2007 (Schnepf, 2008). Prices of crops such as corn, wheat, rice and soybeans rose to record or near-record levels in early 2008, and then fell sharply in the second half of 2008. Once again, prices rose sharply in mid-2010 and peaked in early 2011 (McPhail *et al).* These volatilities have been attributed to volatile oil prices especially the oil price spikes experienced in 2008.

Recent price volatility in global oil and maize prices are therefore expected to have an influence on local maize prices. The issues of interest here are that Swaziland imports maize from South Africa. South Africa is a net importer of transport fuel (an oil product), which it uses for agricultural production. These dynamics strengthen the links between the South African maize market and global oil markets.

Further, the link between global oil prices and maize prices has been fortified by the boom in biofuel production, especially the bioethanol production program of USA which uses corn. These links have also been observed by Kunke (2011) who noted that the world price of maize soared by 105% from January 2006 to December 2008, while in the South African market, which also serves as a proxy for South African Customs Union

(SACU), the increase was 75%, from R 946/Mt[1] to R 1 652/Mt. In the same period the price of crude oil increased from US$66/barrel to US$141/barrel.

As a net importer of both maize and transport fuel, Swaziland's exposure to these developments is therefore two-fold. Firstly, it is exposed indirectly through its import of maize from South Africa, a net transport fuel importer. Secondly, Swaziland is also a transport fuel importer, which it used for maize production and its transport to markets.

The price development in the corn and global oil markets especially the oil and food spikes that have been observed in 2008 builds an interesting case for price volatility analysis in the Swaziland maize market.

The next question then is why food price volatility matters? This question is best addressed in an FAO report (2011) which stated that variations in prices become problematic when they are large and cannot be anticipated and, as a result, create a level of uncertainty which increases risks for producers, traders, consumers and governments and may lead to sub-optimal decisions. Price volatility in a stable food like maize is particularly important for Swaziland in that most Swazi are poor[2]. It is known that poor segments of society spend most of their income on food. This means that unpredictable spikes in stable food prices that form major caloric intake become an important food security issue especially for poor countries. Policies should therefore be directed at stabilizing food prices so that expenditure can be smoothed and the poor are shielded from unpredictability in their ability to obtain stable staple food supply for their sustenance.

For this reason, the government of Swaziland has initiated a move to promote commercial farming and has set up the National Maize Corporation (NMC)[3] who is the main buyer of corn in the country. The mandate of NMC is to guarantee an all year round competitive market for Swazi maize farmers, reduce marketing barriers and costs for Swazi farmers by improving maize marketing and logistics services (through running silos efficiently, registration of producers, provision of drying and shelling services, and provision of price information). This means that the mandate of NMC is also to stabilize

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[1] 'R' refers to the Rand, the currency of the South Africa that is held at par with the Swazi Lilangeni (*pl*. Emalangeni – 'E'). The approximate exchange rate is US$1≈R9. 'Mt' refers to Metric Tonne.

[2] According to the World Bank, 63% of the Swazi population was classified as poor in 2009 with a life expectancy of just 49 in 2011.

[3] The corporation was established in 1985 in accordance with the Companies Act of 1912 and, unlike most parastatals, there is no special Act of Parliament which incorporates it. Its two major shareholders are the Ministry of Agriculture and the National Agricultural Marketing Board. The corporation is presently involved in the business of commodity trading in white maize.

maize prices. In this way, NMC marketing dynamics in a way mimic those of classical storage models.[4]

Unpredictable weather patterns and climate change will result in unpredictable price movements in agricultural commodities because they will cause supply disruptions. The fact that agricultural commodities have low price elasticity of demand means that organizations line NMC will become vital in stabilizing prices as climate change effects intensify. In this regard, third world countries need to invest more in storage and post harvest facilities to build sustainable stockpiles of commodities for supply in glut years. Indeed, studies on the effects of climate change on price volatility of agricultural commodities are gaining momentum. For example, Tran *et al* (2012) noted that under the impact of climate change, world crop price level and volatility will both increase almost threefold between 2000 and 2080. Following this observation, unpredictable and depressed maize output as a result of climate change is expected to increase price volatility in the local maize market as well.

This paper therefore aims to analyze if indeed NMC has been able to stabilize maize prices as per its mandate, given these global developments and maize output glut that has been observed in the country in recent years. The NMC maize price volatility will be analyzed using ARCH/GARCH modeling techniques and policy recommendations will be drawn from our findings. Maize is a storable commodity and therefore, as noted by Beck (2001), it should be suitable for analysis of an ARCH process. A similar research approach to ours has been undertaken by Serra and Gil (2012) who analyzed whether stock building mitigate price volatility in food prices in USA and their conclusion was that building stock does significantly reduce corn price volatility. Studies like ours that aim to find out if grain storage boards do reduce price volatility will become useful with the developments in agricultural markets and production unpredictability as a result of changes in weather patterns.

In support of these arguments, Halsema and Keyzer (2013) have written a detailed proposal of the benefits stockholding, price volatility and food security, given recent developments of climate change and unpredictability in food production. Our study therefore aims to add some insights into these ideas more especially for third world countries like Swaziland that are envisage to suffer most from climate change and erratic agricultural outputs. Given the objective of our study therefore, our maize prices are sourced from NMC and they are the prices that the organization offers to millers.

With this introduction, the rest of the paper is organized as follows; Section 2 discussed the ARCH/GARCH model used in our analysis. Section 3 analyses the data characteristics and Section 4 runs the models and discusses the results. Section 5 is the conclusion and policy recommendation.

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[4] Please see Gustafson (1958) and Williams & Wright (1991) for a comprehensive description of the storage model.

2. ARCH/GARCH volatility modeling approach

The basis of ARCH and GARCH models is the observation that volatility of a series is not constant through time, with most series exhibiting periods of lows and highs. ARCH models are used to estimate such time-dependent volatility as a function of observed prior volatility.

ARCH models were introduced by Engle (1992) in a study of inflation rates in UK and there have since been many derivatives of these models mainly directed at analyzing price fluctuations in stock markets.

ARCH fits models solutions using conditional maximum likelihood estimation techniques. In such models, the likelihood is computed based on an assumed or estimated set of priming values of the squared innovations ϵ_t^2 and variance σ_t^2. The basic ARCH model as proposed by Engle (1982) has the form shown in equation 1 and 2 below:

$$y_t = x_t\beta + \epsilon_t$$

(Conditional Mean)

(1)

$$\sigma_t^2 = \gamma_0 + \gamma_1\epsilon_{t-1}^2 + \gamma_2\epsilon_{t-2}^2 + \cdots + \gamma_p\epsilon_{t-p}^2$$

(Conditional Variance)

(2)

Where:

ϵ_t^2 is the squared residual (or innovations) and;

γ_i are the ARCH parameters

This is then referred to as an *ARCH(p)* model, where *p* refers to the lagged values of the stochastic term.

A GARCH model is an extension of an ARCH model as proposed by Bollerslev (1996) and include lagged values of the conditional variance. A simple *GARCH(p,q)* model is shown in equation 3 below:

$$\sigma_t^2 = \gamma_0 + \gamma_1\epsilon_{t-1}^2 + \gamma_2\epsilon_{t-2}^2 + \cdots + \gamma_p\epsilon_{t-p}^2 + \delta_1\sigma_{t-1}^2 + \delta_2\sigma_{t-2}^2 + \cdots + \delta_q\sigma_{t-q}^2$$

(3)

Where:

γ_i are the *ARCH* parameters and

δ_i are the *GARCH* parameters

In the model, $\gamma_t$is a measure of the effect of stochastic deviations in the previous period on σ_t (the conditional variance) and δ_t is the influence of the variance of previous period on current variance.

An extension of the simple *GARCH(p,q)* model shown in equation 3 is the threshold *GARCH* model or *T-GARCH* model as proposed by Zokoian (1991) and its founding is that positive price fluctuations do not carry the same weight as negative fluctuations. This model extension has been applicable to financial markets and stock exchange where shocks that increase prices (good news) do not have the same effect on subsequent price behavior with shocks that decrease prices (bad news). This is as a result of the leverage effect, with bad new tending to result in more price volatility in the stock market. Unlike in financial markets, in storage models it is price increases that tend to make prices more volatile because they deplete stocks (Prakash, 2011).

The T-GARCH model therefore introduces asymmetry in the conditional variation and this extension is shown in equation 4 below:

$$\sigma_t^2 = \alpha + \gamma_1 \varepsilon_{t-1}^2 + \partial d_{t-1} \varepsilon_{t-1}^2 + \delta_1 \sigma_{t-1}^2$$

(4)

Where:

$$d_t \begin{cases} 1 & \varepsilon_t < 0 \quad (Bad\ News) \\ 0 & \varepsilon_t \geq 0 \quad (Good\ News) \end{cases}$$

Therefore in the above specification, good news has impact of $\gamma_1$while bad news has impact $\gamma_1 + \partial$.

A further extension of the GARCH model is the GARCH-in-Mean as developed by Engle, Lilien and Robbins (1987) where the variance form part of the regression function as shown in equation 5 below:

$$y_t = \beta_0 + \vartheta \sigma_t^2 + \varepsilon_t$$

(5)

In the above model, if the coefficient ϑ is positive then higher variances will cause the average price to increase and vice versa.

Nelson (1991) developed the exponential GARCH or EGARCH model which has the form shown in equation 6 below:

$$\log\sigma_t^2 = \omega + \alpha_1 z_{t-1} + \gamma_1(|z_{t-1} - E[|z_{t-1}|]) + \beta_1 \log(\sigma_t^2)$$

(6)

The above specification is for a simple EGACH(1,1) and $z_t = {}^{\varepsilon_t}/_{\sigma_t^2}$ while γ is the asymmetric parameter.

In our analysis of maize price volatility in Swaziland we will pursue all these GARCH variations for an informed policy recommendation.

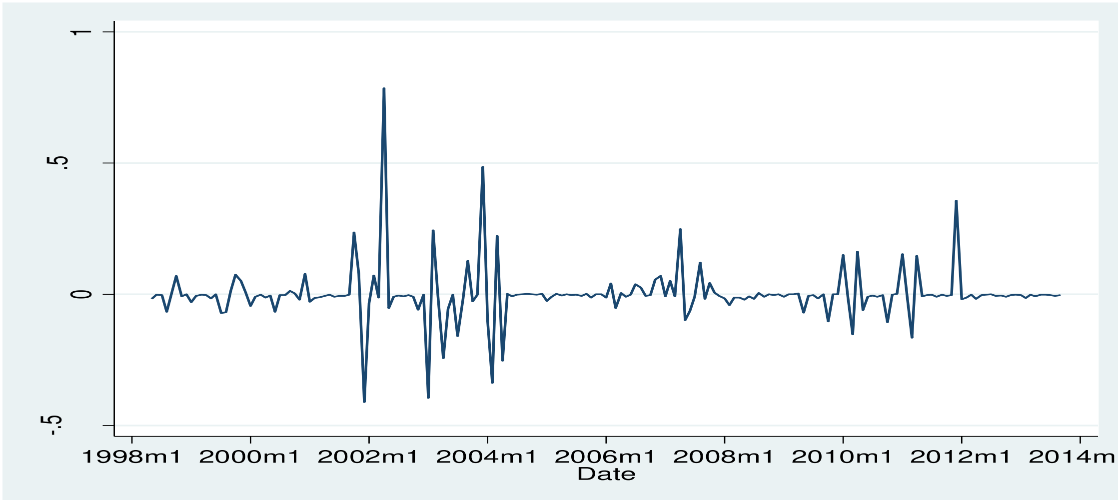
As observed earlier, these models have mostly been used to analyze financial markets, risk premiums and uncertainty but their application in agricultural commodities have important policy implication as we will discuss.

3. Data characteristics

To work with the data we have to scrutinize its characteristics to determine if it is indeed amenable to analysis by ARCH/GARCH techniques. The data for this study is obtained from NMC as mentioned and is monthly data from February 1998 to September 2013 (188 observations). The prices are quoted in Emalangeni per Tonne and converted to natural logarithm format.

To analyze the characteristics of the data we first take the first difference to visualize its stability tendencies. The first difference shows that the prices have been volatile especially around year 2003 and 2004, and also around 2008 and 2012 as shown in Figure 1 below:

Figure 1: First Differences NMC Monthly Maize Prices – Feb 1998 to Sept 2013



This volatility evidence means the maize prices are a suitable series for stochastic variation analysis using ARCH/GARCH models.

The summary statistics for the data are shown in Table 2.

Table 2: Summary statistics of the level variable and the log difference

	Log of price – level variable	Log differenced price
Mean	7.0355	0.000600
Standard Deviation	0.1775	0.10728
Skewness	0.8159	2.1974
Kurtosis	3.1085	22.4307

The table shows that the average of the log difference of maize prices is about zero and the standard deviation is 0.107.

The log differenced and the log of maize prices are both asymmetrically distributed and the upper tail of the distribution is thicker than the lower tail (positive skewness) and the tails of the distribution are thicker that the normal (kurtosis coefficient of >3).

Figure 2 below summarizes the distribution of the log of maize prices and its first difference.

Figure 2: Distribution of log of maize prices and their first difference

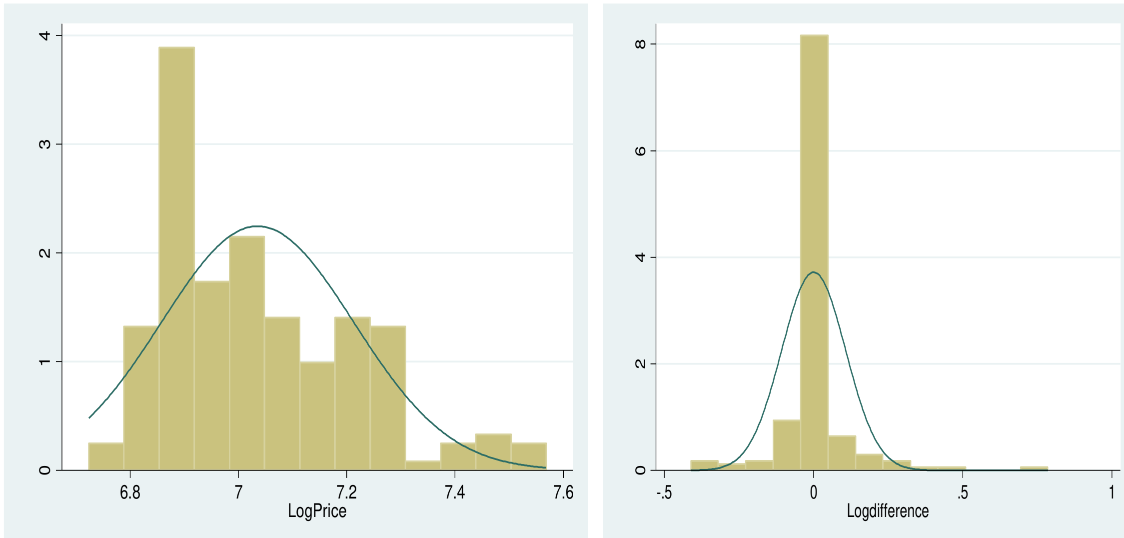


Figure 2 also shows that log difference of maize prices show leptokurtic characteristics, i.e. they have lots of observations around the average and a relatively large number of observations that are far from average, the tails of the distribution are relatively heavy on the left.

Having determined that the series is a candidate for ARCH/GARCH volatility modeling, we proceed to run the models.

4. Volatility Modeling

Analysis of volatility has to begin by first making sure that the series under analysis is not a unit root process. As noted by Moledina et al. (2003), it is important that other causes of non stationarity, like the effects of inflation and seasonal variations of prices in agricultural commodities are first removed. This approach has also been followed by Jordan (2007) in his analysis of price volatility of common agricultural crops in South Africa where he corrected for inflation and seasonal variation in his data series.

However, Jordan (2007) used South African crop prices as quoted by South African Futures Exchange (SAFEX) and because of hedging by traders and speculators, seasonal variation in prices should not be an issue. In this case, price variation should mainly reflect production costs and market sentiments of traders in terms of subsequent production projections and risks therein. In other words, short futures contracts should not reflect seasonal variations but volatility could be due to long term sentiments and market outlook and other factors like oil prices, transport costs and production costs not production levels.

For the case of our analysis the prices are from the NMC. Because the NMC has the mandate of stabilizing prices there is no need to seasonally adjust our data series. Further, because of arbitrage, millers would not buy from NMC if it is better to import from SA. In this way, the NMC prices also reflect the market sentiments in the SA maize market, with prices discovered by SAFEX traders.

Following these arguments then, our analysis first eliminates the effects of inflation on maize prices before testing for unit root by converting all the prices to real prices.[5] Elimination of the effects of inflation on prices uses the monthly CPI with year 2000 chosen as the base year.

Once the prices are converted to real values, the series is tested for unit root using the Augmented Dickey-Fuller (ADF) test.

The ADF test including a constant show that the maize prices do not exhibit a unit root process (including a constant and trend, the ADF statistic is -4.442 and is -4.012, -3.439 and -3.139 at 1%, 5% and 10% critical values respectively. This means the series will remain in levels. However, as observed by Kim and Schmidt, 1993, the ADF test is not reliable if errors of the data series are not homogenous. Furthermore, as observed by Perron and Shiller (1985), the power of unit root tests depends more on the span of the data which is our case is only 15 years, than on the observations.

For these reason, to make the unit root test more robust we applied the Phillips-Perron[6] test for unit root and the results for this test also eliminates unit root in the series. The results of these tests are summarized in Table 2 below:

[5] Real price = Current price*Base CPI/Current CPI

[6] Phillips and Perron’s test statistics can be viewed as Dickey–Fuller statistics that have been made robust to serial correlation by using the Newey–West (1987) heteroskedasticity- and autocorrelation-consistent covariance matrix estimator.

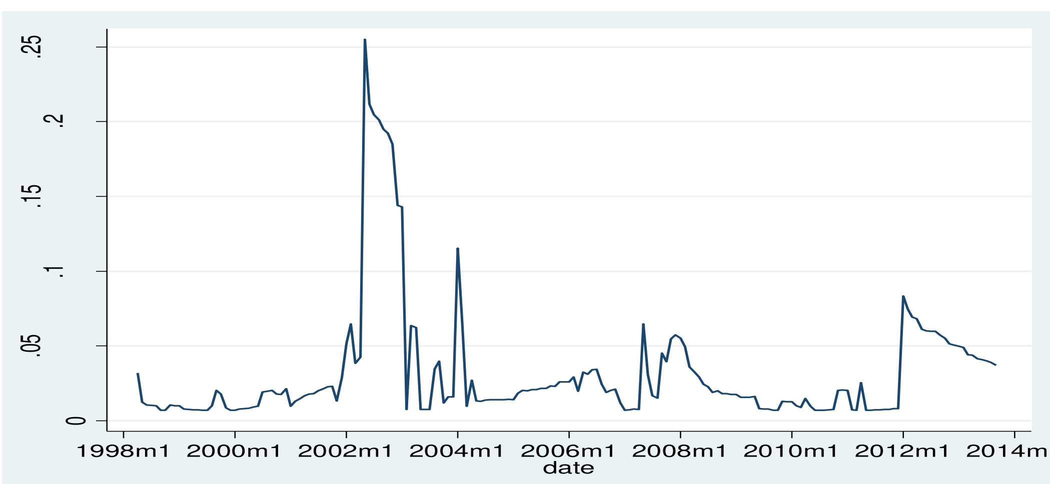
Table 2: ADF and Phillips-Perron Unit Root Test Results

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		ADF Test		
Z(t)	-4.442	-4.012	-3.439	-3.139
		Phillips-Perron test		
Z(rho)	-30.732	-20.083	-13.870	-11.113
Z(t)	-4.076	-3.482	-2.884	-2.574

Since the price series is stationary, it can be used at the level stage without taking lagged differences for ARCH/GARCH analysis. The next step is to test the data series for ARCH effect. The Lagrange Multiplier (LM) test shows a p value of 0.0000, which is well below 0.05, and we therefore strongly reject the null hypothesis of no ARCH (1) effects. This means that the volatility of maize prices in Swaziland varies over time. For this reason, we therefore estimate a GARCH process for the series. The presence of ARCH effect means that maize price volatility is time varying and hence amenable to the GARCH approach.

The ARCH(1,1) conditional standard deviation is plotted below:

Figure 3: The ARCH (1,1) conditional standard deviation



The ARCH plot shows a lot of volatility in maize prices between the years 2002 and 2004, around 2008 and in 2012.

The extension of the ARCH is the GARCH model. We analyze the series using a simple GARCH(1,1) model and the results are shown below:

Table 3: GARCH (1,1) Model Results

	Coefficient	Std. Errors
Mean Equation		
Constant	6.996***	0.007726
Variation Equation		
Constant (γ_0)	0.005046***	0.001167
ARCH (1)- γ_1	0.70719***	0.25666
GARCH (1)- δ_1	0.1267	0.1508

***Significant at 1% confidence level.

γ_1 and δ_1 measure the short-run volatility dynamics of the time-series. Since γ_1 is large and significant, this means that maize price volatility reacts intensely to market dynamics. However, because $\delta_1$is small and insignificant, maize price volatility is not persistent. Further, because γ_1 is much larger than δ_1 this means that volatilities tend to be spiky. The sum of the coefficients γ_1 and δ_1 (0.8339) are close to one, which supports the presence of a strong ARCH and GARCH effect.

Next we run the T-GARCH model to find out if there is an asymmetry effect in the maize price series. The results for the asymmetric specification are shown in Table 4 below:

Table 4: TARCH (1,1,1) Model Results

	Coefficient	Std. Errors
Mean Equation		
Constant	6.9968***	0.008530
Variation Equation		
Constant - α	0.004848***	0.001143
ARCH(1)- γ_1	0.7986	0.3077
GARCH(1)- δ_1	0.1318	0.1646
TGARCH(1)- ∂	-0.1460	0.4955

In the estimated TGARCH(1,1) model, the coefficient of leverage effect is negative and insignificant, meaning that there is no asymmetry effects on the maize price movements to subsequent movements. This means that our model simply reverts to the standard GARCH specification. This finding is reasonable in that NMC is ideally not for profit organization and will not have the sell effect when prices rise as Prakash (2011), suggested.

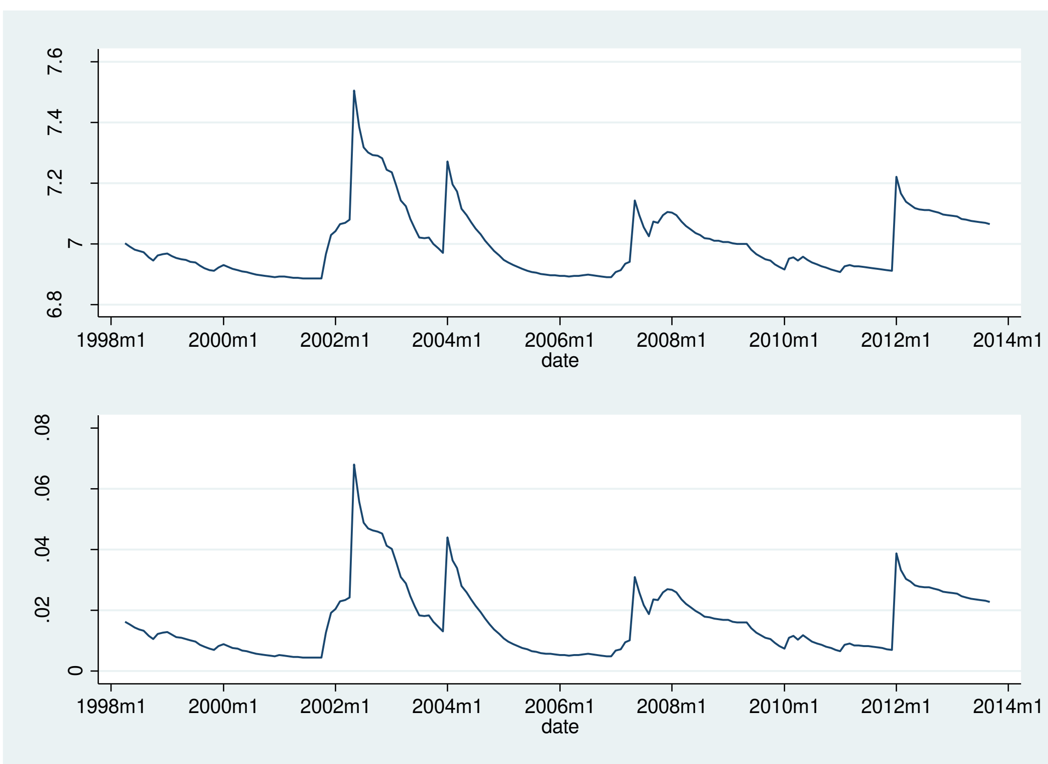
Since the leverage effect is insignificant, we do not run the EGARCH extension as proposed by Nelson (1991).

GARCH-in-Mean

It can be seen that sigma is positive and significant (9.716). This means that higher variances will cause the average prices of maize to increase. This has important implications for policy in that the NMC has to endeavor to keep prices stable and less variable in that variability will cause prices to increase more, which does not bode well for consumers.

To summarize the results we plot the mean and variance of the series in Figure 4 below:

Figure 4: Mean and Variance Plot



The mean and variance follow very similar patterns and show clearly the years of increased volatility as discussed.

5. Conclusion and policy recommendations

Our analysis has shown that maize prices have been volatile in the past years and NMC has not been able to properly stabilize prices as per its mandate and expectations. The maize price volatility has shown notable spikes around 2002-2004, 2008-2009 and in 2012. However, volatility has not been persistent as our GARCH analysis shows. In this regard, NMC has been able to somewhat control volatility and the observed volatile phases could be exogenous and outside the control of the parastatal. This is especially so since the organization also imports a lot of maize from South Africa to meet Swaziland demand. These imports expose the country to volatile international maize prices which are beyond the control of NMC. For the organization to be able to effectively control maize price volatility it is therefore important that Swaziland increase internal maize production to shield the country from external shocks.

Organization like NMC will become vital as weather patterns and agricultural productivity becomes unpredictable, especially in poor countries. In this regard, countries need to increase investments in reducing post harvest losses and storage facilities to ensure food security and stable prices in the coming years. Reliance on food imports will remain risky in that it cannot guarantee constant food supply and stable prices for consumers as we have seen.

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