Journal of Economics and International Business Management
Vol. 5(1), pp. 1-13, March, 2017
ISSN: 2384-7328
Research Paper

Analysis of maize price volatility and price pass-through in Swaziland: Implications for price stabilization policies

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Accepted 27th January, 2017

Abstract. This paper investigates maize price volatility in Swaziland as offered by National Maize Corporation (NMC), an organization with a mandate of stabilising maize prices in the country. NMC is the sole importer and main trader of maize in Swaziland. The study further scrutinizes the price stabilising abilities of the organisation using price pass-through from the South African maize market where Swaziland imports most of its maize deficit. Price volatility is analysed using Autoregressive Conditional Heteroskedasticity/The generalized autoregressive conditional heteroskedasticity (ARCH/GARCH) modelling techniques while price pass-through is analysed using Vector Error Correction Model (VECM) cointegration methods. Results show that NMC prices exhibit spiky volatility even though this volatility is not persistent, given the insignificant GARCH short-run dynamics which is also supported by stationary of the prices. However, NMC prices react intensely to market dynamics with significant ARCH and GARCH effects. The reaction to market dynamics is basically as a result of high price pass through of almost 96% from the South African market to the local maize market. This is not surprising given the strong link between the two maize markets both in terms of Swaziland sourcing production inputs from South Africa and importing in cases of production deficit, which happen every year and has been increasing in recent years due to poor maize output in the country. No asymmetry effects on the maize price movements are detected meaning 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.

Keywords: Prices volatility, ARCH/GARCH, cointegration, VECM.

INTRODUCTION

Price volatility can be viewed as the dispersion of price levels from their mean or central tendency with reference to a given time period. High periods of price volatility refer to cases where prices diverge more from their mean values and vice-versa. Price volatility[1] has been a subject of intense study especially in financial markets, but almost all commodities exhibit such behaviour at some point. As in other markets, there are many factors that can cause price volatility of agricultural commodities. For example, Balcombe (2009) explored variables such as the level of stocks, yields, and export concentration, volatility of oil prices, interest rates and exchange rates as having an impact on price volatility of common agricultural products. Other studies (Rashid, 2007; Gilbert, 2010) have identified the most common causes of food price volatility as climatic factors, infrastructure, policy shocks and exchange rate uncertainty. Geyser and Cutts (2007) found that the South African Futures Exchange (SAFEX) price levels are determined mainly by

[1]Volatility refers to Price Volatility and these will be used interchangeable in this study

Chicago Board of Trade (CBOT), Rand/Dollar exchange rate, weather patterns and domestic stock levels. All these variables have been shown to be play a significant role in price volatility through introducing exogenous 'shocks' in commodities markets. Further, 'shocks' tend to have a memory or show some degree of persistence such that past volatility has an influence on current volatility. Volatility in agricultural commodities has important food and nutrition security implications especially for third world countries and this warrants its analysis. When shocks surpass a certain critical size or threshold and persist at those levels, traditional policy prescriptions and coping mechanisms are likely to fail (Wolf, 2005).

As noted by Prakash (2011:8), episodes of high prices and extreme volatility are a major threat to food security in developing countries. Their impact falls heaviest on the poor, who may spend well over 80 percent of their income on food. This means that positive shocks in agricultural prices especially of staple food like maize make poorer countries more vulnerable to food and nutrition insecurity.[2] Increase in prices of staple foods result in households engaging in various coping strategies which could lead to lower investments in health and education with worse socio-economic consequences. Aizeman and Pinto (2005) have shown that higher volatility also results in an overall welfare loss. Because of their potential negative impact on food and nutrition security, governments have enacted various measures to shield their food markets from extreme price volatilities. As to whether these measures are effective in controlling price volatility or not in a given country or region is a question of intense research.

Another related issue of interest is the correlation between prices in two markets, which can be viewed as domestic and world market prices. If domestic and world market prices are strongly linked then they will generally exhibit similar volatility patterns. This means that a shock in the dominant or world market prices will inevitable be transmitted to the laggard market. The extent to which prices are related in two markets is analysed using the concept of price pass through, which is basically the analysis of the strength and speed of price transmission from the dominant market to the laggard market. A World Bank Report (2012) noted that the extent to which global prices are transmitted to domestic markets depends on transport and marketing costs, policy measures, local currency valuation, market structure and degree of processing of final consumption goods. Policy measures that can affect price pass through involve government intervention in the marketing of commodities through price regulation. If government regulation of prices is effective, it is expected that where such measures are in place, there will be little or no correlation between the regulated market and world market prices. This means that volatility in world market prices will not be transmitted to the domestic prices.

Our study analyses maize price volatility and pass through in Swaziland, a small land locked country in Southern Africa whose agriculture is characterised by low productivity mainly due to low investment and dominance of rain-fed subsistence farming practices.[3] Maize price volatility and pass through analysis is particularly justifiable for Swaziland due to five main reasons as follows; 1. Maize is the staple food for the country especially the rural poor who spend most of their meagre income on food. 2. The country is a net maize importer, or food importer for that matter, which exposes it to external shocks in food price especially from South African where the country imports most of its maize requirements under a customs union (SACU) arrangement. 3. The country has high levels of poverty, meaning that increase in food prices and their unpredictability aggravate food insecurity. 4. Lack of dietary diversification implies that increase in price of maize cannot be counteracted by switching to other staple food types, and 5. The country exercises strong policy intervention in the maize market.

A number of studies have been undertaken to investigate the two concepts, that is, price volatility and price pass through in agricultural markets especially in Sub Saharan Africa. This study aims to add into the growing literature by investigating these two concepts for the case of Swaziland maize market where no such study has ever been undertaken. For this study, price volatility and the volatility behaviour will be analysed using ARCH/GARCH modelling approach while price pass through between Swaziland and South African Market where the country imports all its maize shortages will be analysed using a Vector Error Correction Model (VECM) approach. These models and their choice justification are discussed in the next two sections.

LITERATURE REVIEW

For reasons of food and nutrition security, many governments in Sub-Saharan Africa have set up market boards to intervene in markets for agricultural commodities especially staple foods markets, and the government of Swaziland is no exception[4]. The country is

[2] Holzmann (2001) simplified food vulnerability for an individual or household can be measured as the probability that expected future consumption will fall below some minimum level. For a household at time t, let denote per capita consumption expenditure $c_{ht\pm1}$and let $\hat{c}$ denote the poverty line. Then, vulnerability, $v_{ht}$is the probability that the expected per capita consumption is below the selected poverty line, with an arbitrarily chosen probability threshold $\widehat{Pr}$ (of, say, 0. 25 or 50). i.e. $v_{ht} = \Pr(c_{ht\pm1} \leq \hat{c}) \geq \widehat{Pr}$

[3] Exception is sugar cane which accounts for more than 70% of Swaziland Agricultural GDP and is characterized by high investment and productivity.

[4] The Ethiopia Grain Trading Enterprise is involved in buying and selling grain on behalf of the government, but its operations are quite small relative to the size of the grain market. Similarly, Tanzania has maintained small emergency food reserves but does not actively attempt to stabilize prices. Uganda and

actively promoting local maize production and has set up the National Maize Corporation (NMC)[5], a government parastatal that is the main maize trader in the country. The mandate of NMC is to guarantee an all year round competitive market for Swazi maize farmers and reduce marketing barriers and costs by improving maize marketing and logistics services. A further critical mandate of NMC is to stabilize maize prices and shield the country's maize market from global shocks that tend to increase volatility and price unpredictability. As opposed to storage models[6] where traders aim to buy cheap, store the commodity and sell when prices are high, NMC does not support storage of maize since it involves storage costs. Instead, the parastatals main mandate is to guarantee a stable market for Swazi maize farmers and controls imports. If maize production in the country is low, the company fills the shortfall by importing from South Africa, who is also Swaziland's main trading partner. Traders and individuals are banned from importing maize in the country, NMC having the mandate of being the sole importer. NMC sells maize to millers and the price offered is controlled by NMC so that they do not get too high. In theory therefore, these prices do not necessarily follow the classical supply demand dynamics in laissez faire markets.

However, continued increase in maize imports due to slump in local production in recent years has increasingly exposed the country to global maize markets developments, which now necessitates the analysis of price stabilisation efficiency of NMC. As noted by Prakash (2011:15), 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 staple food as it is the case for maize in Swaziland. In this regard, the study has two objectives.

Firstly, it aims to determine if NMC intervention has been able to stabilize local maize prices, given the socio-economic significance of unpredictable maize price fluctuations in the country. Studies on government intervention in maize markets in Sub Saharan Africa have produced mixed results. For example, a study by Minot (2012) of selected Southern African countries[7] found that countries with high government intervention in the maize market paradoxically exhibit higher price volatility than those without government interventions. This study defined price volatility as the standard deviation of returns, where the return is defined as the proportional change in price from one period to the next. The main plausible reason forwarded for this ambiguity was that efforts to stabilize prices are counterproductive in that they create uncertainty and can cause private traders to withdraw from the market, thus reducing the effect of temporary arbitrage in smoothing prices over time. Further, Minot (2011) study found that landlocked countries showed higher volatility in maize prices than coastal countries.

Other researchers have allude to the fact that timing and extent of state intervention in the maize market fuel volatility and price increases in times of low harvest, and raised uncertainties for market stakeholders leading to inefficiencies (Chapoto and Jayne, 2009). Jayne and Meyers (2008) used a Vector Auto Regression (VAR) model to estimate the historical effects of National Cereals and Produce Board (NCPB) trading activities on private sector maize price levels in Kenya and concluded that NCPB's activities have reduced the standard deviation, and coefficient of variation of prices, consistent with its stated mandate of price stabilization. Ngare *et al*. (2014) analysed price volatility and implications of stabilization policies in Mozambique maize market using GARCH modelling techniques, where volatility is defined as the mean conditional variance based on the GARCH estimates. Their study revealed price seasonality and volatility in the maize prices. Mozambique does not have any state intervention in the maize market and is a net maize importer. Jordan *et al.* (2007) also used ARCH/GARCH modelling techniques to analyse price volatility in certain field crops in South Africa using SAFEX prices. Their study found most significant price volatilities in the yellow and white maize market.

Besides the analysis of Sub-Saharan markets, ARCH/GARCH techniques have been used to analyse price volatility in other parts of the world.[8] This shows that ARCH/GARCH modelling techniques, which have been traditionally been used to study volatility in financial markets are gaining popularity in the analysis of volatility in agricultural markets. The advantage of ARCH/GARCH models is that they can further analyse the volatility behaviour (for example if it has some degree of

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Mozambique have no state marketing board responsible for maize marketing, nor do they maintain food reserves.

[5] 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.

[6] Gustafson (1958); and Williams and Wright (1991) offered a comprehensive description of the storage model but these will not be discussed in detail since they divert from NMC practice.

[7] Minot (2012) divided the countries roughly into two groups: those with state marketing boards that maintain reserves and attempt to stabilize prices, and those that do not intervene as actively in maize markets. Kenya, Malawi, Zambia, and Zimbabwe were classified as high-intervention countries, while Chad, Ethiopia, Mozambique, Niger, Nigeria, Tanzania and Uganda were classified as low-intervention countries.

[8] Please see Figiel and Hamulczuk (2010); Rovinaru *et al.* (2012); Apergis and Rezitis (2011) and Pop *et al.* (2013).

symmetry) for better prediction of price movements and more robust volatility conclusions.

The second phase of the research aims to find out if there is a relationship between local maize prices and global maize prices as determined by SAFEX in South Africa. The hypothesis is that if NMC has been able to control maize price fluctuations there will be a poor correlation between SAFEX prices and those that prevail in the country. The relationship between the countries' maize prices will be investigated using the approach of price pass through.

Price transmission between two markets is an indicator of the link between those markets and their degree of interdependence. A large number of studies examine the degree of price transmission between markets within a country, including several for Sub-Saharan Africa (please see Abdulai, 2000 for Ghana, Kuiper *et al.*, 2003 for Benin; Negassa and Myers, 2007 for Ethiopia; Van Campenhout, 2007 for Tanzania and Moser *et al.*, 2009 for Madagascar). Besides these, within country price transmission, price transmission between countries has also been studied again with focus to the Sub-Saharan African region with interesting outcomes.

For example, an FAO Report (2010), using cointegration analysis, found strong evidence that local maize markets in Malawi and Zambia are integrated with both the international and the South African maize markets while Kenya and Uganda showed weak relationship between domestic prices and prices at SAFEX.

However, Meyers and Jayne (2010) found that in Malawi and Kenya, domestic maize prices are not linked with SAFEX prices even when these countries import maize from South Africa because imports are typically carried out by governments themselves and later sold at below market prices. They also found that in Zambia, when maize production shortfall is large, the government steps in to import and sell maize domestically at subsidized prices. Thus, during the periods of high imports there is a break between South African and Zambian prices, while during the periods of good harvests and active cross-border trade carried out by the private sector, the long-term price relationship between Zambia and South Africa holds. Traub *et al.* (2010) used a switching error correction model (SECM) to analyse the price relationship between maize prices at SAFEX and Mozambique and found no long-run relationship between maize prices in the two countries.

Our analysis will follow a study by Minot (2011) who used a VECM to examine the relationship between world food prices and domestic food prices in 9 African countries[9] following the classical steps as follows:

1. Testing the price variables individually to see if they are I(1).
2. Using the Johansen test to determine whether the two series are cointegrated, meaning that each variable is I(1) and a linear combination of the two variables is I(0).
3. If the Johansen test indicates that there is a long-run relationship between the two variables, then we estimate the VECM.

The advantages of using cointegration analysis and VECM in price transmission analysis have been outlined by Gilbert (2010) as being the following:

1. The number of cointegrating vectors is determined by the data.
2. Short run adjustment responses are distinguished from equilibrium outcomes (if present).
3. The equilibrium pass-through is not restricted to be unity. This allows for the possibility that local prices are either more or less volatile than world prices.
4. Adjustment of national and world prices is considered symmetrical, allowing the possibility of reverse pass-through from national prices to the world price as well as the forward pass-through from world to national prices.

METHODS

Modelling approach

ARCH/GARCH volatility modelling 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 were introduced by Engle (1982) in a study of inflation rates in UK and there have since been many derivatives of these models mainly directed at analysing 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 Equations 1 and 2:

$y_t = x_t\beta + \epsilon_t$ (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

[9] Ethiopia, Ghana, Kenya, Malawi, Mozambique, South Africa, Tanzania, Uganda and Zambia

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

$$\sigma_t^2 = \gamma_0 + \gamma_1\epsilon_{t-1}^2 + \gamma_2\epsilon_{t-2}^2 + \cdots + \gamma_p\epsilon_{t-p}^2 + \delta_1\sigma_{t-1}^2 + \delta_2\sigma_{t-2}^2 + \cdots + \delta_q\sigma_{t-q}^2 \quad (3)$$

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 behaviour with shocks that decrease prices (bad news). This is as a result of the leverage effect, with bad news tending to result in more price volatility in the stock market.

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

$$\sigma_t^2 = \alpha + \gamma_1\varepsilon_{t-1}^2 + \partial d_{t-1}\varepsilon_{t-1}^2 + \delta_1\sigma_{t-1}^2 \quad (4)$$

Where:

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

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 *et al.* (1987) where the variance form part of the regression function as shown in Equation 5:

$$y_t = \beta_0 + \vartheta\sigma_t^2 + \varepsilon_t \quad (5)$$

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:

$$\log\sigma_t^2 = \omega + \alpha_1 z_{t-1} + \gamma_1(|z_{t-1} - E[|z_{t-1}|]) + \beta_1\log(\sigma_t^2) \quad (6)$$

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 a more robust characterisation of volatility in the maize market, if present. Next is the discussion of cointregration analysis as will be used in our analysis of price pass through.

Cointegration analysis and price pass-through

Cointegration analysis for a bivariate model starts with testing weather the two variables are unit root. Following Hendry and Juselius (2000), data can be unit root i.e. integrated of degree 1 (denoted as I(1)). Such data cannot be used to investigate relationships between the variables because of spurious regression and Ordinary Least Squares (OLS) estimates are not robust in this case.

However, data showing such properties can be made stationary by first differencing. If a series is such that its first difference is stationary (and has positive spectrum at zero frequency) then the series has an exact (or pure) unit root (Granger and Swanson, 1996).

The test for unit root starts with Equation 7, which is an autoregressive process of degree one, denoted as AR(1) process.

$$\mathrm{y_t} = \mathrm{y_{t-1}} + \ \varepsilon_\mathrm{t} \quad (7)$$

With;
$\varepsilon_\mathrm{t} \sim \mathrm{IN}\ [0, \sigma_\varepsilon^2]$

From this equation it can be shown that subtracting $\mathrm{y_t}$ (as data) on both sides will result in a stationary process even though $\mathrm{y_t}$ is non stationary, that is:

$$\mathrm{y_t} - \ \mathrm{y_{t-1}} = \Delta\mathrm{y_t} = \ \varepsilon_\mathrm{t} \quad (8)$$

Therefore;

$\Delta y_t \sim IN\ [0, \sigma_\varepsilon^2]$

Such differencing can be extended to twice-integrated series, that is, I(2), in which case it must be differenced twice to deliver a stationary process, etc.

Following this concept therefore, in a bivariate model with y_t and x_t variables, there exist a β such that $y_t - \beta x_t$ is I(0) even though x_t and y_t are non stationary processes. This means the two variables are cointegrated or have a stationary long run relationship even though individually they are stochastic. Investigation of long run relationship between variables starts with a Vector Autoregression (VAR) process.

Generally, a VAR model with p lags can be represented as shown in Equation 9, which is an extension of Equation 7:

$$\mathrm{y_t} = \rho_1\mathrm{y_{t-1}} + \rho_2\mathrm{y_{t-2}} + \cdots + \rho_\mathrm{p}\mathrm{y_{t-p}} + \varphi\,\partial_\mathrm{t} + \varepsilon_\mathrm{t} \quad (9)$$

In the above equation,
y_t is an kx1 vector of I(1) variables
∂_t is an kx1 vector of deterministic variable
ρ_i(i=1… p) is an kxk and φ is an kxn matrix of coefficients to be determined for a given data set
ε_t is an kx1 vector of identically and normally distributed errors with mean of zero and non-diagonal covariance matrix.

Given that the variables are cointegrated, equation 9 can be represented by an equilibrium correction model shown in Equation 10, that is:

$$\Delta y_t = \alpha\beta' y_{t-p} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \delta t + v + \varepsilon_t \quad (10)$$

Of economic importance are the α and β coefficients. β is an kxr matrix of cointegrating vectors that explain the long-run relationship of the variables. α is also an kxr matrix that explains long run disequilibrium of the variables. Γ_i are coefficients that estimate short-run shock effects on Δy_t and these explain the differences between the short-run and long-run responses. It is important to note that for cointegration to exist, matrices α and β should have reduced rank r, where r<k. The identification of the cointegrating vectors uses maximum likelihood (ML) method developed by Johansen (1988, 1991, 1995).

v and ∂t are the deterministic trend components which can be written as:

$$v = \alpha\mu + \gamma \quad (11)$$

$$\partial t = \alpha\rho t + \tau t \quad (12)$$

Where μ and ρ are rx1 vectors of parameters. γ and τ are also kx1 vectors of parameters. γ is orthogonal to $\alpha\mu$ and τ is orthogonal to $\alpha\rho$, such that $\gamma'\alpha\mu = 0$ and $\tau'\alpha\rho = 0$.

Having outlined the theoretical background of the modelling approach, the next section investigates the data used and its suitability for the chosen modelling techniques.

RESULTS

Data description and characteristics

To work with the data we have to scrutinise 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 February 2014 (193 observations). The prices are quoted in Emalangeni per Tonne and converted to natural logarithm format. These prices are the prices that NMC charges to millers and do not necessary represent forces or sentiments in the maize market, given that NMC aims to control price fluctuations. The SAFEX prices are average monthly spot prices of white maize as recorded in the SAFEX trade data. Spot prices are better since they tend to represent market sentiments at the time and are the true prices of commodities that prevail while futures prices tend to be distorted by speculation and hedging behaviour. SAFEX maize data characteristics have been described in details by Geyser and Cutts (2007).

To analyse the characteristics of NMC data, we first take the first difference to visualise its stability tendencies. Taking first difference of data is important in that various economic series have trends. These trends are sometimes stochastic and they have an impact on the volatility measure. Taking first difference therefore de-trends the data series.

The first difference of the log of NMC maize prices is shown in Figure 1. Figure 1 shows that the prices have been volatile especially around year 2003 and 2004, and also around 2008 and 2012. The data therefore shows clear variance clustering around these years. This variance clustering evidence means the maize prices are a suitable series for stochastic variation analysis using ARCH/GARCH models. If changes in price are not constant over time in that they persist or cluster, then volatility may be predictable e.g. through an ARCH specification (Prakash, 2011:15).

The summary statistics for the data are shown in Table 1. The skewness coefficient provides information about the asymmetry of a distribution. A value of 0 will indicate a symmetric distribution while a positive (negative) value will indicate a distribution skewed to the right (left). NMC prices generally exhibit a positive skewness and this is reasonable since maize inventories cannot be negative, which places a positive skewness bias in the data. Also, a commodity like maize that is storable tends to exhibit positive rather than negative skewness. This is the case for both the level prices and their first difference. Stigler (2011:39) observed that floor prices tend to introduce positive skewness while ceiling prices tend to promote negative skewness. This observation is in contrast to the NMC pricing behaviour which in a way aims to control large maize price increases through some kind of ceiling price setting. Stigler (2011:39) further observed that from a practical perspective, the presence of positive skewness can help policy design in that positive price asymmetry implies that one can be quite confident in establishing a minimum price level.

Table 1 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). Excess kurtosis is characteristic of markets that exhibit extreme price values. The excess kurtosis shown by the first difference of the maize prices can be attributed to the previously observed volatility clustering around the years 2003 and 2004, and also around 2008 and 2012.

Figure 2 summarises the distribution of the log of maize prices and its first difference. Figure 2 shows that the log

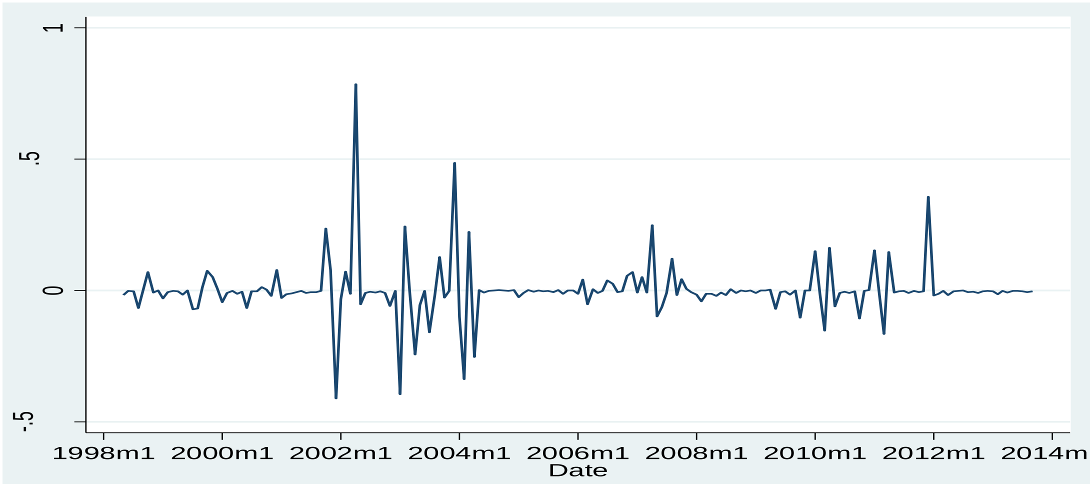

Figure 1. First differences NMC monthly maize prices – Feb 1998 to Sept 2013.

Table 1. Summary statistics of the level variable and the log difference.

Parameter	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

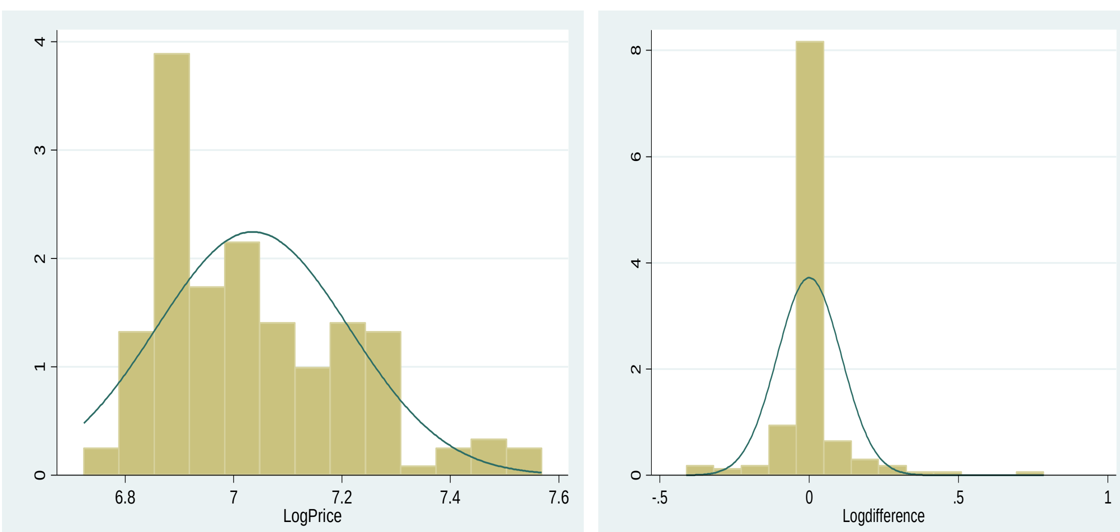

Figure 2. Distribution of log of maize prices and their first difference.

of maize prices is 7 on average which ranges from 6 to 7.6. The distribution also shows that log difference of maize prices ranges from -0.4 to 0.4 with a lot of observations around 0. This makes the log-differenced maize prices more kurtotic than the log-prices as shown in Table 2. Figure 2 also shows that log difference of maize prices show leptokurtic characteristics, that is, 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. The leptokurtic characteristics displayed by the data means it is amenable to be analysed using ARCH/GARCH approach, and the test for ARCH effect, which is conducted in the next section confirms this.

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

Having determined that the series is a candidate for ARCH/GARCH volatility modelling, we proceed to undertake the analysis in the next section and discuss our findings.

DISCUSSION

Volatility analysis

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 *et al.* (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 *et al.* (2007) used South African crop prices as quoted by 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, especially when using spot prices.

Because NMC has the mandate of stabilizing prices there is no need to seasonally adjust the data series. Following these arguments then, analysis first eliminates the effects of inflation on maize prices before testing for unit root by converting all the prices to real prices.[10] Elimination of the effects of inflation on prices uses the monthly Consumer Price Index (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 NMC 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. This observation is in contrast to that of the series exhibited by white maize future prices from SAFEX (Jordan *et al.*, 2007).

As observed by Shiller and Perron (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 this reason, to make the unit root test more robust, the Phillips-Perron[11] test for unit root is applied and the results (all summarised in Table 2) also eliminates unit root in the series.

The lack of random walk in the NMC data is reasonable since the organisation tend to control prices fluctuations. In this case, changes in prices are not expected to be permanent, if they are, the organisation will try to make prices revert to stationarity. Lack of random walk means that NMC future prices are predictable, which is good for policy making and consumer decision and consumption patterns. However, price movement predictability is in contrast to the efficient market theory. This theory posits that for markets to operate efficiently, prices should be unpredictable in that if they are stationary and predictable they will attract investors and their active participation will ultimately lead to cancellation of the predictability.

Since the NMC price series is stationary, it can be used at level 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, although the prices tend to revert to stationarity as we have seen. 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 in Figure 3.

The ARCH plot confirms increased volatility in maize prices between the years 2002 and 2004, around 2008 and in 2012. Becks (1993) empirical investigation of the annual prices of diverse agricultural commodities confirmed ARCH effects as more present in storable commodity prices, but not in non-storable ones. This is in line with findings of ARCH effect in this study since maize

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

[11] 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.

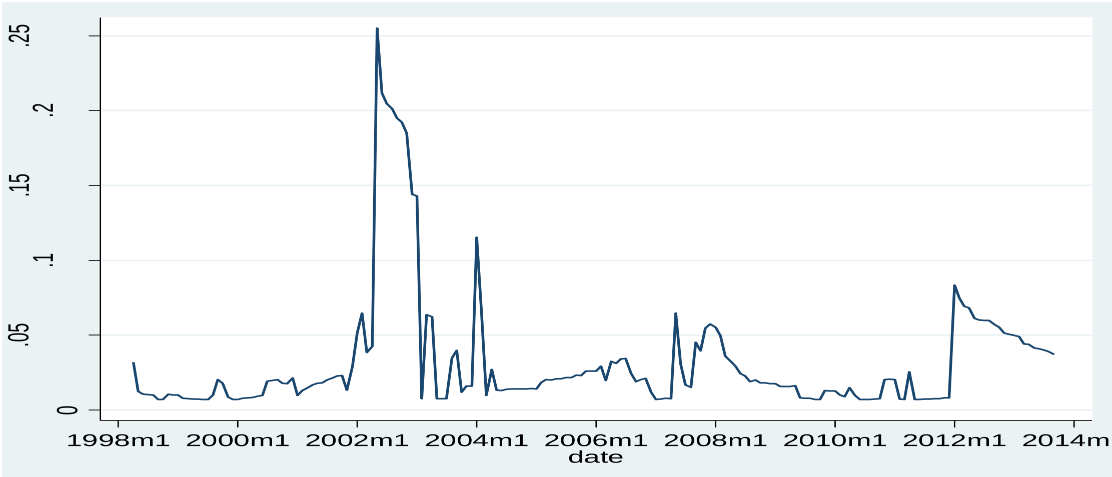

Figure 3. The ARCH (1,1) conditional standard deviation.

Table 3. ARCH (1), GARCH (1,1), TARCH (1,1,1) and ARCHM (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
ARCHM (1) - θ	9.72***	0.027987

***Significant at 1% confidence level.

is a relatively storable commodity although NMC does not promote storage as a means of reducing costs.

Next we extend our analysis of volatility to scrutinize its properties. The extensions of the ARCH which we run are the GARCH, T-GARCH and MGARCH model extensions. The results of this battery of volatility analysis are summarised in Table 3.

For the simple GARCH (1,1) model, 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, which are basically the SAFEX market dynamics as we will see later. However, because δ_1 is small and insignificant, Swaziland maize price volatility is not persistent, which supports the price stationarity determined earlier. Further, because γ_1 is much larger than δ_1 this means that volatilities tend to be spiky as confirmed by the ARCH (1,1) plot. 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.

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 and since the mandate of NMC to stabilize prices, we do not expect an asymmetric effect in price movements, which our analysis confirms.

Since the leverage effect is insignificant, we do not run the EGARCH extension as proposed by Nelson (1991). A run of the GARCH in mean model result in a positive and significant theta (θ) of 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 endeavour to keep prices stable and less variable in that variability will cause prices to increase more, which does not bode well for consumers. This variability tendency are likely the effects of the SAFEX price pass through into the local maize market as analysed in the next section.

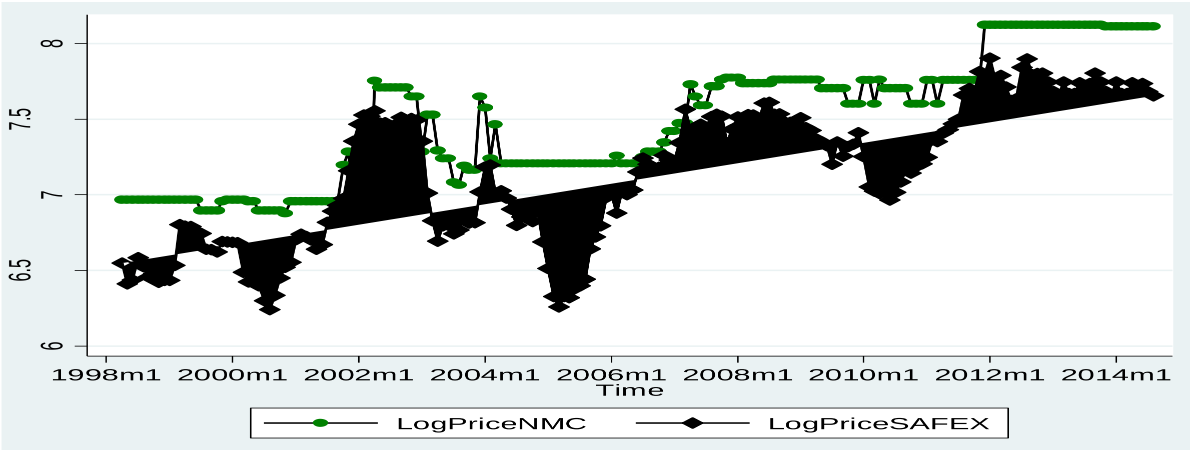

Figure 4. SAFEX and NMC maize price trend.

Table 4. Johansen test for cointegration between SAFEX and NMC white maize prices.

Maximum rank (r)	LL	Trace statistic	5% critical value
0	370.848	29.4396	15.41
1	384.192	2.7517*	3.76
2	385.567	-	-

Lags = 2, Trend: Constant; N = 195.

Price pass-through analysis

As discussed in the theoretical outline, cointegration analysis start with testing if data in the variable of interest are I(1). Unit root testing shows that NMC prices are stable while SAFEX prices follow a random walk process as discussed in Jordan *et al.* (2007). Although SAFEX prices are I(1), the two variables could have a long run stable relationship. Even though Johansen's methodology of testing for cointegration is commonly applied where all variables in the system are I(1), this is not supported by theory. In a bivariate model, if a single variable is I(0) instead of I(1), this will reveal itself through a cointegrating vector whose space is spanned by only the stationary variable in the system model (Hjalmarsson and Osterholm, 2007:5). This means the two variables are cointegrated or have a stationary long run relationship even though one of them is stochastic.

Figure 4 plots the two price series of interest to visually analyse their behavior. Figure 4 shows that both price series have been volatile but the NMC prices show some constant trends at certain times. However, visual inspection of the two series show some clear positive correlation and that SAFEX prices tend to be much lower than NMC prices. This is not surprising since NMC imports maize from South Africa and therefore the margin reflect transport and storage costs. There are no levies reflected since the countries are members of a customs union. Further, it is expected that maize prices in Swaziland are higher than those in South Africa because Swaziland imports most of their maize production inputs from South Africa. In this way, Swaziland production costs are expected to be much higher to feature in transport of inputs, and generally, maize production in Swaziland is underdeveloped and less efficient.

From this visual inspection of the variables, cointegration analysis seems plausible. As mentioned before, cointegration analysis of this bivariate model will use VECM. In the determination of cointegration or long run relationship in our bivariate model, we still need to determine the number of lags to be included in the VECM, following a basic VAR process discussed previously.

Selecting the number of lags to be included in the VECM follows a paper by Tsay (1984). Reports of the Final Prediction Error (FPE), Akaike's Information Criterion (AIC), the Hannan Quinn Information Criterion (HQIC), the Log Likelihood (LL) and Likelihood-Ratio (LR) test all chose two lags. This means that our SAFEX maize prices and NMC maize prices will be explained by two lags.

Once we have determined the number of lags, our next task is to test for cointegration amongst the variables. Cointegration analysis is undertaken using the solution for the rank of the bivariate model by applying the Johansen's static method which is based maximum likelihood (ML) estimator of the parameters of a cointegrating VECM as motivated by Anderson (1984) and Johansen (1995). Results of the Johansen Test for Cointegration are shown in Table 4.

Table 5. Vector error correction model estimates for SAFEX and NMC prices.

Parameter	Coefficient	Standard error
$\propto_1$ - LogSAFEX prices	0.0613	0.02988
$\propto_2$- LogNMC prices	-0.1614***	0.03380
ν_1 - LogSAFEX prices	-0.06076	0.00622
ν_2- LogNMC prices	0.00231	0.007039
β_1 - LogSAFEX prices	0.960***	0.0868
β_2- LogNMC prices	1	-
Long run constant	0.651	-
$\hat{\Gamma}\ Matrix$	$\begin{bmatrix} -0.1253 & -0.06224 \\ 0.07474 & 0.28250 *** \end{bmatrix}$	$\begin{bmatrix} 0.06792 & 0.08229 \\ 0.06003 & 0.07273 \end{bmatrix}$

** Significant at 5%; *** Significant at 1%

Table 4 shows that the trace statistics at *r*=0 of 29.4396 exceeds its critical value of 15.41. We therefore reject the null hypothesis of no cointegrating equations. The trace statistics at *r*=1 of 2.7517 is less than the critical value of 3.76; we cannot reject the null hypothesis that there is at least one cointegration relationship between SAFEX white maize prices and NMC white maize prices. This finding is reasonable, since for a bivariate model with I(1) and I(0) variables, one cointegrating vector is expected.[12]

After determining that there is indeed a long run cointegration relationship between the price series, the next step is to collect the VECM estimates. From Equation 10, our estimates of interest are the matrix β which contain the cointegrating parameters, α which is the adjustment coefficient and the short run coefficients, Γ. The parameters are presented in Table 5.

Since the prices are expressed in logarithms, the cointegration factor (β) is the long-run elasticity of the domestic price with respect to the international price. Thus, β is the long-run elasticity of price transmission. The expected value for imported commodities is 1 > β > 0 for imports. Overall, output of the model showed that it is well specified. Using the log of NMC prices as the dependent variable allows us to determine the rate of price transmission from SAFEX prices to NMC prices. The value of β is 0.96 which means that 96% of the proportional change in SAFEX price will be transmitted to NMC price in the long run. This virtually means that the two price series are almost cointegrated on a 1:1 basis as Figure 4 suggest.

The adjustment parameters in general are small but significant, implying a slow correction to equilibrium. The adjustment parameter on the NMC prices is larger and significant, meaning that NMC prices adjust contemporaneously to changes in the SAFEX white maize prices as expected from the mandate of the parastatal. The estimate of the coefficient for the NMC prices is -0.1614, meaning when NMC prices are high, they quickly fall back to match SAFEX prices. The short run coefficient on SAFEX prices is small (0.0613) and insignificant, meaning that SAFEX maize prices do not adjust to developments in NMC prices in the short run. This is as expected, with SAFEX being the price leader.

The long run relationship between SAFEX white maize spot prices and NMC maize prices is summarized as follows:

NMC Price = 0.960 SAFEX Price + 0.651

Testing for Granger causality plays an important part in many vector error correction models, but it is less important when examining the transmission of international prices to domestic prices. This is because causality from domestic to international prices is implausible (Minot, 2012).

In summary therefore, lack of random walk means that NMC future prices are predictable, which is good for policy making, consumer decision and consumption patterns. However, presence of a significant ARCH effect means that maize price exhibit volatility which varies over time but turns to revert to stationarity. This is supported by the results of the GARCH which shows that maize prices in the country, even though volatile, such volatility is not persistent and tend to revert back to stationarity. There is no asymmetry effect in the prices, although higher variances will tend to cause the average price of maize in the country to increase. This could be as a result of the strong linkages between NMC price and SAFEX prices. NMC has therefore not been able to shield the maize prices from international trends and prices trend with those of South Africa. This is reasonable given the strength of the relationship between the two maize markets, both from input supply where Swaziland source most of maize production inputs from South Africa and also from the direct maize imports in cases of shortages. Such shortages have been persistent in recent years, meaning that Swaziland continues to rely on the South African maize market to meet demand. The strong evidence of the close relationship between the two maize markets and the evidence of the South African market being the leader are therefore plausible.

12 For full exposition of this process, please see Hjalmarsson and Osterholm (2007: 5-6)

Conclusion

Our analysis has shown that maize prices have been volatile in the past years and NMC has not been able to properly stabilise prices as per its mandate and expectations. However, volatility has not been persistent and has been spiky. The observed volatile phases could be exogenous and outside the control of the parastatal. This is especially so since the organisation also imports a lot of maize from South Africa to meet Swaziland demand. Indeed a strong price pass through has been determined from SAFEX prices to NMC prices and this not surprising given the strength of linkages between the two markets. Whether NMC can do better in stabilizing prices than the laissez faire situation is a question of further scrutiny, given the findings that the prices in the local markets tend to be higher. Probably arbitrage and traders behaviour can do better in stabilizing prices and competitions amongst the traders has the potential to bring prices down.

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