Impact of Food Reserve Programs on Price Levels and Volatility: Natural Experiment from Benin Rice Market in West Africa.

Abdelaziz Lawani, Ph.D. Candidate

University of Kentucky, Department of Agricultural Economics

abdelawani@uky.edu

Prof. Michael R. Reed, Ph.D.

University of Kentucky, Department of Agricultural Economics

mrreed@email.uky.edu

Rose E. Fiamohe, Ph.D.

Africa Rice Center (AfricaRice)

E.Fiamohe@cgiar.org

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Abstract

Following the food price crisis of 2007-2008 many governments has responded with food reserve/stock programs. The role of those programs is to regulate price levels and reduce price volatility. These programs have been controversial for many decades because of the cost associated with their implementation and their effectiveness to regulate and stabilize prices. The present research uses the food reserve program implemented by the Benin government from 2008 to 2016 following the food prices crisis of 2007-2008 as a natural experiment to test the impact of such programs on prices levels and volatility. Using the model of competitive storage as theoretical background and the exponential generalized autoregressive conditional heteroskedastic (EGARCH) regression model as an estimation method, the study shows that the food reserve program has not been effective in regulating prices level and in stabilizing prices on rice market in Benin.

Key words: Asymmetric EGARCH, Stabilization program, Competitive commodity storage model

JEL classification: Q18, Q17, F14

Introduction

During the last decade, food prices twice hit record levels, driving hundreds of thousands of the world's most vulnerable people, especially those living in the developing world, further toward hunger and poverty (IRIN, 2012). In developing countries, food price volatility affects numerous consumers who spend most of their income buying cereals, causing nutrition and health problems and even stimulating political instability at times (such as urban riots in some forty countries in the developing world following the price spike of 2008) (Demeke, et al., 2009). Price volatility also affects producers by discouraging investment, blocking the modernization of agriculture, and thereby slowing economic development (Timmer, 2009, Von Braun, 1992).

Many governments have responded to soaring prices and growing price volatility with policies to stabilize producer and consumer prices (Barrett, 2002, Demeke, et al., 2009). Among government interventions used to stabilize prices are food reserves or stocks. This stabilization policy, which has been controversial for over three decades, is again becoming more prominent because of the unprecedented rise in international food prices in 2008 and 2010. The basic function of food stocks is to regulate the supply in time and space. On the one hand, government purchasing and stockpiling of food products during abundant harvest raises the average level of producer prices; but, on the other hand, it moderates price increases in lean periods by increasing the supply available through the quantities originally stored. But the impacts of price stabilization measures through government purchasing and storage are still unclear empirically, especially in Africa. This study uses the Benin food stock program that started in 2008 as a natural experiment to evaluate the success of government purchasing and storage interventions in stabilizing prices on domestic markets.

The study extends the model of competitive stock holding to predict price changes (Williams and Wright, 1991) by including government stockholding behavior in the model. It uses the asymmetric Exponential Generalized Autoregressive Conditional Heteroskedastic (EGARCH) regression model to test the impact of this behavior on cereal price levels and volatility in Benin. Results from the study show that during the period of the food stock program, from 2008 to 2016, the government's stockholding behavior has not been effective in stabilizing prices on rice market in Benin.

The paper proceeds as follows. After the introduction in section 1, section 2 presents the food reserve program in Benin. Section 3 presents the theoretical model of competitive storage used for this study and section 4 outlines the estimation methodology. Section 5 presents and discusses the results, and section 6 concludes.

The food reserve program in Benin

The *Office Nationale de la Securite Alimentaire* (ONASA) is the Benin national office for food security, a government institution whose role is to fight against hunger and prevent food crises in Benin by making quality food available and accessible to vulnerable unsecured households (Kpenavoun Chogou, et al., 2013).

Following the 2007-2008 food crisis, the government developed a buffer stock program implemented by the ONASA. The objective of the buffer stock program is to build and use food stocks to stabilize agricultural product prices. This institution's responsibility is to reduce supply by buying cereals in times of oversupply, guaranteeing producers a fair remunerative price, and increasing the supply during the lean period to ensure consumers an affordable price. This measure is frequently used in many other countries (e.g., Burkina-Faso, Niger, Nigeria, Ghana, Zambia, Philippines, China, India) (Demeke, et al., 2009).

In July 2008, ONASA installed proximity shops in all of the 72 municipalities of the country (91 in total with larger municipalities benefiting from 2-4 shops). In these proximity shops, food products, such as maize, rice, and sorghum are sold to the population at reference prices set by the ONASA. These prices are below market prices. ONASA stocks consist of purchases from farmers during the harvest period, food aid (essentially Japanese rice) and stocks carried over from the previous year. ONASA handles transports, processes stocks and distributes food products to the proximity stores. The government covers the cost associated with these operations. ONASA makes no profit from its operations, but it might add up to $0.002/kg to the purchase price at times to cover operational costs, but this is a very insignificant share of the purchase price. Through its operations, ONASA expects to reduce prices levels and prices volatility.

Model of competitive storage

This section presents the theoretical model of competitive equilibrium with storage used in this study. The model is an extension of the model developed by Williams and Wright (1991) and suggests that agricultural price volatility will follow stock level variations. The original model considers firms' (storers) storage behavior, but the model used here includes an additional economic agent (the government) through its storage behavior (stocks). Williams and Wright (1991) benefit from the pioneering works of Gustafson (1958) who shows that negative aggregate stocks are impossible in that sense that harvests cannot be consumed in advance. According to Deaton and Laroque (1992), this implies a non-negativity restriction to the storage optimization problem. The model also builds on the work of Muth (1961) who includes the assumption of forward-looking rational expectations in the model. For (Muth, 1961), naïve models are less precise than averages of expectations in an industry which are as accurate as elaborate systems of equation. Expectations are fundamentally identical to the predictions of the economic model.

The central hypothesis of this study is that stock levels affect commodity price volatility. According to Shively (1996), contemporary higher prices diminish present stocks and induce more volatility in prices for the following period. Storers' speculative behavior and a government stock program will lead to variations in stocks affecting prices volatility.

The model considers individual price taking firms, i, in a competitive storage industry. For the firm, the cost of storage for a quantity, s_t, of stock from one period to the next (i.e., t to t+1) is:

$$K^i[s_t] = ks_t \tag{1}$$

A constant margin, $k > 0$, captures average physical storage cost such as warehousing cost, drying cost, and handling cost. All firms are assumed to have the same technology over time, so the aggregated industry level relation is:

$$K[S_t] = kS_t \tag{2}$$

With S_t being the aggregate decision of competitive firms in the storage industry about carrying their individual stock levels, s_t, from period t to period t+1.

Storers are assumed to be risk neutral and to have access to a perfect capital market where they borrow and lend at a constant rate r per period. The expected price at time t+1 conditional on information available at time t is $E_t[P_{t+1}]$, so the expected profit of the firm is:

$$E_t[\Pi^i_{t+1}] = E_t[P_{t+1}]s^i_t/(1+r) - P_t s^i_t - ks^i_t \tag{3}$$

The maximization problem yields:

$\partial E_t\left[\Pi_{t+1}^i\right]/\partial s_t^i = 0$ which leads to (4)

$E_t\left[P_{t+1}\right]/(1+r) = P_t + k$ (5)

From equation (5) we derive the following results of the competitive equilibrium with storage model:

If $E_t\left[P_{t+1}\right]/(1+r) < P_t + k$ then $s_t^i = 0$ (6)

If $E_t\left[P_{t+1}\right]/(1+r) \geq P_t + k$ then $s_t^i \geq 0$ (7)

Equation (7) shows that if the discounted expected price in period t+1 is greater than the current price by more than the storage cost, then individual storers will increase their current stock that will be carried over to the following period. Equation (6) suggests the opposite effect.

We include in this model the government stock at time t, G_t, which represents the stocks held by the national office of food security (ONASA) from period t to t+1. Even though this stock is costly for the government, the cost is not included in the decision function of the ONASA since this office doesn't have a profit maximization objective. The interest rate is not relevant either because the ONASA is not concerned with that cost. The benefit to ONASA comes from the positive welfare effect on producers and consumers the government expects by affecting price levels and volatility through its storage mechanism.

From equation (5) the firm choice of stock s_t^i doesn't affect its current price P_t and its expected future price $E_t\left[P_{t+1}\right]$ but we expect that the industry stock level S_t does, as well as the government stock level G_t (if this stock represents a significant share of the private/industry aggregate stock).

According to Deaton and Laroque (1992) higher current prices cause storers to sell, lowering the stock that will be carried to the following period and leading to more price volatility in the next period:

$$\partial v(P_{t+1} \mid P_t) / \partial P_t \geq 0 \qquad (8)$$

with $v(P_{t+1} \mid P_t)$ being the price variance conditional on past prices. The conditional forecast variance at time t+1 is a random variable, but it depends on information at t (Engle and Bollerslev, 1986). Lower current prices cause storers to hold/increase their current stocks increasing the stock that will be carried to the following period and leading to less price volatility in the next period.

Contrary when prices are low, the government buys from producers, increasing its current stock and also current prices and making current prices more volatile. When current prices are high, the government releases its stock, decreasing current prices and making current prices less volatile.

In summary, if current prices are high, storers sell, lowering the current stock that will be carried out to the next period, the government releases their current stock on the market to reduce the current high prices. The low stock carried by storers to the next period tends to increase price volatility in the next period. If prices are high next period, government stock will be released decreasing prices levels and volatility. But if prices are low next period, the government will increase its stock, increasing price levels and volatility.

$$\uparrow P_t \Rightarrow \begin{cases} \downarrow S_t \Rightarrow \uparrow v(P_{t+1} \mid P_t) \\ \downarrow G_t \Rightarrow \downarrow v(P_t \mid P_t) \end{cases} \qquad (9)$$

$$\downarrow P_t \Rightarrow \begin{cases} \uparrow S_t \Rightarrow \downarrow v(P_{t+1}) \\ \uparrow G_t \Rightarrow \uparrow v(P_t \mid P_t) \end{cases} \tag{10}$$

Overall, government behavior tends to reduce price volatility while storers behavior can reduce or increase prices volatility. According to equations 9 and 10, government and storers behaviors work in opposite directions. The resulting effect on price volatility will depend on the size and impact of each action on price volatility.

The same magnitude of low current prices and high current prices can lead to different size of more or less price volatility. The size of the effect of higher or lower current prices might be different due to the leverage effect. In other words, we can have asymmetric volatility. Asymmetric volatility occurs when the magnitude of the volatility following an increase of price is different than the magnitude of the volatility following the same size decrease of price. This means that agents respond differently to increase or decrease of price volatility of the same magnitude.

Data, diagnostic tests and estimation method

Data

Our analysis focuses on imported rice price on Cotonou market in Benin. The choice of rice in this research project is justified for several reasons. First, among cereals, rice has a strategic importance. It is a nutrient source for more than half of the world population, and income for millions of farmers (Datta, 2004). Second, because of its strategic importance, it has been targeted by several policy interventions that have made it one of the most distorted of all agricultural commodities (Andreosso-O'Callaghan and Zolin, 2010). Third, even though rice is traded internationally in relatively low volumes, demand and supply for rice are inelastic (Yap, 1997). Following the exports restrictions in India and Vietnam to stabilize rice prices in their domestic markets, rice price on international markets increase because of the inelasticity of supply and demand. These export restrictions, combined with the climatic conditions and the 2007/2008 food crisis (driven by rising oil prices, greater demand for biofuels and trade shocks in the food market), created a panic in world rice markets, especially for importing countries. Since 2008, these countries will have focused their policies on instruments such as food stocks. The role of the food stocks in the importing countries is to reduce the transmission of unwanted variations in world market prices at the domestic level. In light of this development, rice stands as one of the most suitable crops to contribute to the theory of the impacts of food stocks on price stabilization.

In Benin rice is consumed both in urban and rural centers. The country imports vast quantities of rice each year. For the period 2004-08 per capita consumption of rice is estimated at 23kg/year and in 2003-05, rice and rice products accounted for 11% of the total dietary energy supply(2016).

The data used are monthly domestic retail prices of imported rice from the market of Cotonou in Benin. The market of Cotonou is the primary international market in Benin that connects the country to the other markets in the West-African sub-region and beyond. The price series data come from the FAO-GIEWS online platform. The data covers the period from January 2000 to September 2016, the price stabilization program starting in July 2008. We have a total of 201 monthly observations. Table 1 gives the summary statistics of the prices data.

A visual examination of the price data in level, figure 1, shows that the price data seem to follow two different regimes with an increasing trend in the first regime that covers 2000 to 2008, and a relatively less-increasing regime from 2009 to 2016. The food policy program starting in July 2008 may be one of the factors that contribute to the relatively non-increasing prices after 2008. It is not clear if the variance is increasing with time so we proceed to a first difference of the data and plot the data (differentiated). After removing the trend, we observe a larger variability in the second half of the data (after 2007) than in the first half (before 2007). We also observe a volatility clustering.

The theoretical distributions that the data follow are important for inference. From the Q-Q plot of the data, figure 2, we notice that the price data do not follow a normal distribution. If the samples follow a normal distribution, the points should fall on the 45-degree line. From the Q-Q plots, the price data seems to have a fat tail, which is confirmed by the statistics in table 1. Indeed, relative to the normal distribution, rice price is slightly negatively skewed. The kurtosis is less than 3 which indicates that rice price follows a flat distribution (platykurtic) relative to the normal distribution. The Jarque–Bera normality test is rejected at 1% significance. This confirms that rice price data are not normally distributed.

Diagnostic tests

Many economic time-series and prices data, in general, are nonstationary. We need then to evaluate the time series properties of the data before running our estimation. To test for unit roots we use many conventional tests including the Augmented Dickey and Fuller (1979) (ADF), the Phillips and Perron (1988) (PP) and the Kwiatkowski, et al. (1992) (KPSS). To account for structural break, we divide our sample into two sub-samples. One sub-sample covers the period before the stock program (pre-stock program) and the second the period after the stock program (post-stock program). Table 2, presents the results of the unit root tests of the price data in level and first difference.

Results of the unit root tests confirm the presence of unit root in the price data. We can then conclude that the price data is not stationary. The tests also confirmed that the rice price is integrated of order 1 since after taking the first difference, the price data becomes stationary.

Estimation method

In an ideal world, econometric models assume a constant unconditional variance to derive their estimates. But time series data do not always exhibit this feature, and their regressions have conditional variances that may vary over time (Engle and Bollerslev, 1986) . The Autoregressive Conditionally Heteroskedastic (ARCH) model introduced by Engle (1982) and its successor the Generalized Autoregressive Conditional Heteroskedastic process (GARCH) developed by Bollerslev (1986) facilitate the modeling of data that exhibits non-constant unconditional variances. They allow the unconditional variance to change over time as a function of past errors, leaving the conditional variance constant.

The standard GARCH model can be specified as follows:

$$P_t = \delta_0 + \sum_{i=1}^{k} \delta_i P_{t-i} + \varepsilon_t \qquad 11$$

$$\varepsilon_t \mid \Omega_{t-1} \sim N(0, h_t) \qquad 12$$

$$h_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-1}^2 + \sum_{j=1}^{q} \beta_j h_{t-j}^2 \qquad 13$$

Equation (11) shows that P_t is generated by an autoregressive process. The conditional variance h_t^2 in the GARCH model is a function of its past values and past news ε_{t-1}^2 (equation 13) with $\alpha_0, \alpha_i > 0; \beta_i \geq 0$ and $\sum_{i=1}^{p} \alpha_i + \sum_{j=1}^{q} \beta_j < 1$.

$\sum_{i=1}^{p} \alpha_i + \sum_{j=1}^{q} \beta_j$ measures persistence in conditional volatility.

In practice, for each commodity price, we start by identifying the best ARIMA model that fits the data and test for ARCH effect in the residuals. To account for the increasing variance in our data we transform the series with a logarithm. The autocorrelation functions (ACF) and partial autocorrelation functions (PACF), in figure 3, suggest an ARIMA (1, 0, 1) for the conditional mean estimation for rice price. But to identify formally the best ARIMA model that fits the time series data, we run ARIMA models and use the Akaike Information criteria and the Bayesian information criterion (BIC) or Schwarz criterion as the information criteria for the model selection. Table 3 presents the results of the model comparison based on AIC and BIC. The results show that an ARIMA (2, 0, 2) better fits the rice price data.

Figure 4 provides the diagnostic of the standardized residuals for the ARIMA (2, 0, 2). The time series plot of the standardized residuals doesn't indicate any trend in the residuals. We do observe changing variances over time. The ACF of the residuals do not show any significant autocorrelation in the immediate lags. But we might have some correlations at higher lags. The Q-Q plot of the residuals indicates that the residuals have a heavier tail than a normal distribution. The p-values of the Ljung-Box-Pierce statistics for each lag up to 35 shows that there is no significant autocorrelation in the error terms.

To test for the presence of ARCH effect, we run a series of diagnostic test on the squared residuals of the ARIMA regression. The result is presented in figure 5. From the observation of the residuals squared plot and its ACF and PACF it appears that there may be some dependence in the residuals squared. These results are confirmed by the Ljung-Box and ARCH LM tests in table 4. The tests rejected the absence of an ARCH effect.

The residuals of the ARIMA (2, 0, 2) model have a heavier tail than a Gaussian distribution. This is confirmed by the Jarque-Bera and Shapiro-Wilk tests of normality, table 4, that strongly reject the null hypothesis that the white noise innovation process follows a normal distribution. This result implies that the standard GARCH model with Gaussian errors will not be appropriate to model volatility for rice price on the market considered in this study, a distribution with a heavier tail than the normal distribution will better fit the GARCH model. The standard GARCH model has been applied to model many economic and financial data series with regression errors normally distributed and seems attractive for the type of question this paper wants to answer. This model suggests symmetric errors that follow a normal distribution. The normality tests show that the standard GARCH model will fail to fit our data.

The GARCH model doesn't allow for the presence of leverage effects. Negative shocks can have a different impact on volatility than good news. One of the stylized facts in the finance literature is that volatility is more pronounced when the market experiences crises than when the market is rising. This asymmetric news impact is referred to as the leverage effect (Zivot, 2009). The symmetric property of the standard GARCH model will not capture the asymmetry in the variation of price volatility due to leverage effects. Government and private storers' behavior following bad news might be different from their behavior following good news. To address this problem, we will use the asymmetric Exponential Generalized Autoregressive Conditional

Heteroskedastic (EGARCH) model developed by Nelson (1991). Bollerslev (1987) and (Baillie and Bollerslev, 2002) suggests to use a t distribution to account for the excess kurtosis and when the degree of freedom is greater than 4.

The model used in this study is specified as follows:

$$p_t = \delta_0 + \sum_{i=1}^{2} \delta_{p,i} p_{t-i} + \sum_{i=1}^{2} \delta \, \varepsilon_{e,it-i} + \phi_1 ' S_t + \phi_2 D^f + \phi_3 P_{maize,t-1} + \phi_4 D^f * S_t + \phi_5 I_{t-1} + \phi_6 p_{t-6} + \mu_t \tag{14}$$

$$\mu_t = \sigma_t z_t \tag{15}$$

$$z_t \,|\, \Omega_{t-1} \sim \Psi(0,1,\nu) \tag{16}$$

$$\ln\sigma_t^2 = \omega + \beta_1 \ln(\sigma_{t-1}^2) + \beta_2 \ln(\sigma_{t-1}^2) + \gamma \frac{\varepsilon_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \alpha \left[\frac{|\varepsilon_{t-1}|}{\sqrt{\sigma_{t-1}^2}} - E\left[\frac{|\varepsilon_{t-1}|}{\sigma_{t-1}} \right] \right] + \lambda_1 ' S_t + \lambda_2 D^f + \lambda_3 P_{t-1} + \lambda_3 D^f * P_{t-1} + \lambda_4 P_{maize,t-1} + \lambda_7 D^f * S_t * P_{t-1} + \lambda_8 I_{t-1} + \nu_t \tag{17}$$

Where σ_t^2 is the conditional variance and z_t is the standardized residual. $\psi(.)$ is a conditional density function and ν is a vector of parameters that characterizes the probability distribution. $\omega, \beta, \gamma, \alpha$ and λ are parameters to be estimated. p_t is the rice differentiated log price at time t. $P_{maize,t}$ is maize price. Since maize and rice are two substitutable products, we introduced $P_{maize,t-1}$ to evaluate the impact of the increase of the maize price on rice price level and volatility.

By modeling $\ln(\sigma_t^2)$ we are sure that the conditional variance will be positive even if the parameters are not. The magnitude or the symmetric effect is represented by the parameter α. It is also called the GARCH effect. The asymmetric aspect of the leverage effect will be measured by the parameter γ. For $\gamma = 0$ the model is said to be symmetric. Positive values of γ indicate that positive shocks induce more volatility than negative shocks. Negative values of γ mean that positive shocks create less volatility than negative shocks.

S_t is a matrix of predetermined seasonal crop calendar variables that will affect the price and its variability. It includes seasonal binary indicators that represent rice's crop calendar in Benin. The seasonal calendar affects agricultural product prices. Rice is harvested principally from July to September. S_t =1 for harvest periods and 0 otherwise.

We will also include in the mean and variance equations a dummy variable that will correspond to the period after (D^f) the implementation of the food stock program. $D^f = 1$ for months after the implementation of the program and 0 otherwise. The interaction between D^f and the harvest period S_t ($D^f * S_t$) variable in the mean equation model helps evaluate the impact of the food stock program run by the government on prices level. If the food stock program is effective in reducing prices at non-harvest periods and increasing prices at harvest, the sign of the coefficient associated with the interaction term will be negative in the mean equation. We also expect this coefficient will be negative in the variance regression, if the food stock program decreases price volatility.

The coefficient of the variable P_{t-6} in the variance equation tests equation 8. According to this equation, higher current prices will cause storers to sell, lowering the quantity of stock that will be passed to the following period, and increasing volatility in the following period. A positive coefficient for this variable will confirm this hypothesis. Based on our interviews with stores, they stock their product for an average 6 months before releasing on the market to benefit from higher prices.

From equations 9 and 10, government and storers' behaviors effects on price volatility can work in opposite directions. To test whether government behavior and the storers' behavior reinforce each other, we introduce an interaction term $D^f * S_t * P_{j,t-1}$. The coefficient of this interaction term will inform on which agent behavior, government or storers, most impact price volatility, and if they reinforce each other or not.

The food stock program role is also to reduce the transmission of unwanted food price instability from world market to the domestic market. We then introduce an international market price term, $I_{j,t-1}$, to evaluate the impact of world price on domestic price levels and volatilities. We use the Thai 100% B price as the international price.

Empirical results and discussions

To determine the orders of the EGARCH model to use, we proceed to a model selection using the AIC as a selection criterion. The results are presented in table 5. Results of our model selection show that the EGARCH (1, 2) with conditional errors following a t distribution best fits our data. We estimate three models. Model 1 uses the base EGARCH (1, 2) specification with no external regressors. Model 2 includes the food stock program, the harvest period and their interaction as dummies as the only external regressors. Model 3 is the full model with all the external regressors included as specified by equation 17. The model is estimated in EViews 9.5. Estimates of the three models are presented in table 6.

Results of the estimates show that in the conditional mean equation, the coefficient of the autoregressive term is significant and positive for all the models. This indicates the presence of serially correlated prices. The two-period lag price is also significant but negative. The one-period lag price tends to increase current rice price while the two-period lag price tends to decrease it.

When the dummy representing the implementation of the food stock program is introduced into the conditional mean equation, its coefficient is negative and significant for model 2 and negative but not significant for model 3. The harvest period dummy is not significant in any of the models. The interaction of the food stock program and the harvest period is significant and positive in model 2 but not significant in model 3. If the food stock program was effective in reducing price levels in harvest period, this coefficient should be negative and significant. This result indicates that the government policy is not effective in reducing rice price levels.

The coefficient for maize price is significant and positive showing that high current maize price increases the rice price. High maize price leads to an increase of demand for rice, and consequently, an increase in contemporaneous rice price. The coefficient of rice price on the international market is not significant in our model.

Considering the variance model, the food stock program dummy and the harvest period dummy as well as the interaction between these two variables are significant in model 3 but not significant in model 2. In model 3, the coefficients of the food stock program and harvest period dummies are individually negative but their interaction is not significant. When rice price volatility is reduced during the period of implementation of the food stock program, this result doesn't provide enough evidence to support that the food stock program has been effective in reducing the volatility of rice price as anticipated since the interaction of the food stock program and the harvest dummy is not significant.

The coefficient of the six-period lag price of rice is positive and significant. Past period prices increase current price variance. This result indicates that the theory of competitive commodity storage holds for the rice market in Benin. An increase of current rice price will lead to an increase in price volatility next period as shown in equation 8. The contemporary high prices of maize send a signal to storers to sell their existing stock in order to benefit from the high prices. This diminishes the stock that will be passed to the following period and then lead to an increase in price volatility in that subsequent period. Low contemporaneous prices send the opposite signal to storers. They hold their stock increasing the stock that is carried to the following period and reducing price volatility in that following period.

Equation 9 and 10 suggest that government and price storers behavior may work in opposite directions and the resulting effect will be determined by the actor whose effect is stronger. The coefficients of the interaction term between the six-period lagged price, the food stock program, and the harvest period dummy, in the conditional variance equation, is significant and negative.

The negative sign could be due to the dummies food stock program and harvest period since the price lagged six periods has a positive effect on the variance. But since each of these dummies have negative coefficients individually but a positive coefficient when combined, we do not have robust evidence on the effect of the government food stock program on rice price volatility. We do not have enough evidence to support the implications of equations 9 and 10. As suggested by these equations, high current price would lead storers to sell, decreasing the stock that is carried to the next period and increasing price stability in the next period. Contrary government food stock program behavior would reduce volatility if the prices are high and increase it if the prices are low. These two behaviors would work in opposite direction on price volatility but in our case, we do not have robust evidence to support this claim for rice on the Cotonou market.

The coefficient of the international price is not significant in the variance equation. This indicates that the rice price on the international market doesn't affect its volatility on the domestic market in Benin.

The coefficients of the lag variance β_1 and β_2 in the variance equation are significant in all the models. This confirms the presence of conditional heteroscedasticity in the errors meaning that past volatilities do affect rice price volatility. We found the presence of a leverage effect in model 3. The sign of the leverage parameter γ being negative and significant implies that the variance increases more after negative shocks than after positive ones. We can conclude that bad news produces more volatility than good news. We do not observe a high persistence in the volatility, $\sum_{i=1}^{p}\alpha_i + \sum_{j=1}^{q}\beta_j = 0.23$. This result suggests that after a shock, volatility doesn't persist in the rice market for a long period.

The Jarque-Bera normality tests show that the standardized residuals exhibit strong deviations from the normal distribution. The ACF and PACF of the residuals do not show any serial correlation in the error term.

Conclusion

The objective of this paper is to examine how effective government food reserve program have been in stabilizing prices levels and variability on rice market in Benin. This stabilization policy has been divisive between economists and policy makers because of the cost associated with these programs and their effectiveness to stabilize prices is still empirically unclear. The role of these programs is to moderate price increases in lean periods and raise price levels during the harvest period.

Using the theoretical model of competitive storage, the present research shows that the resulting volatility is the result of the interaction of two agents: government and private storers. Due to the limits of the GARCH model to fit asymmetric and non-normal errors, the research employs the Exponential Generalized Autoregressive Conditional Heteroskedastic (EGARCH) regression model to present evidence that the food reserve program has not been effective in reducing the level and volatility for rice price in the Benin market. The research also shows that low current prices lead storers to sell, lowering the stock that they will pass to the following period and increasing the volatility in that subsequent period. High current price leads to the opposite effect. Finally, the research also shows that there is a leverage effect on the rice market in Benin. Bad news tends to produce more volatility than good news.

The results presented in this paper do not support the positive role food reserve programs are designed to play in reducing price levels and volatilities on domestic markets. This might be related to the relative small size of government stock compared to the private storers stocks.

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Annex

Figure 1: Rice prices, level and first difference on Benin markets ($ US/kg)

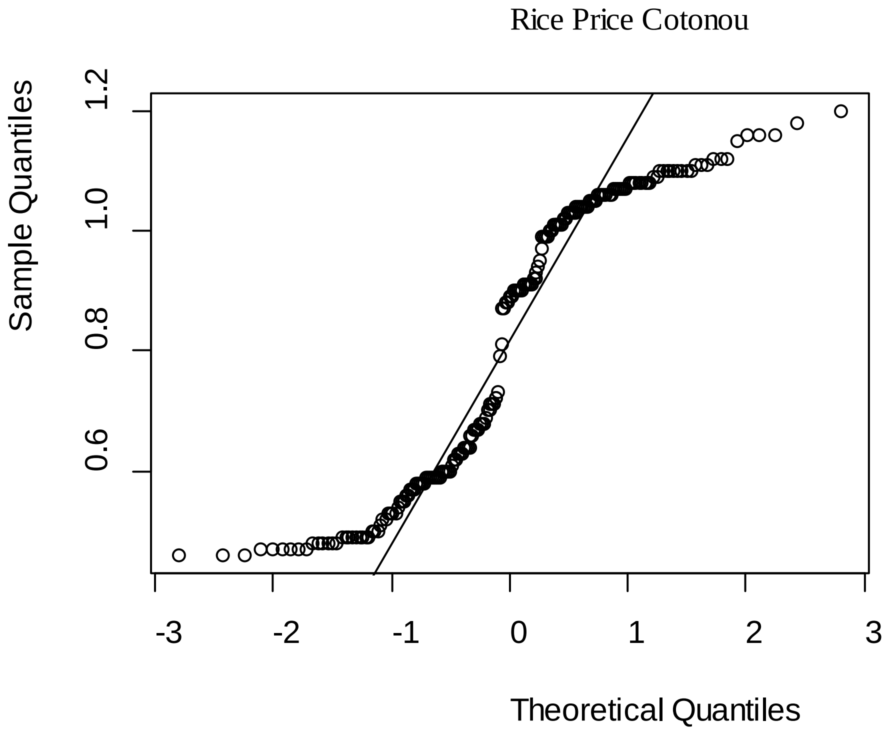

Figure 2: Normal Q-Q plot of price data

Table 1: Results of the unit root tests for rice prices on Cotonou Market.

		ADF(lags)[1]		PP		KPSS[2]	
Products		Level	First-diff	Level	First-diff	Level	First-diff
Rice	Full sample	-1.01(2)	-12.21(1)***	-1.43	-15.23***	0.26***	0.16
	Pre-Stock Program	-0.49(1)	-11.44(0)***	-0.61	-11.39***	0.13*	0.50
	Post-Stock Program	-2.09(2)	-9.60(1)***	-2.71	-11.72***	0.21***	0.13

The numbers in parentheses indicate the number of lags for the ADF test based on the Akaike Information Criteria (AIC). ***, **. *** indicate significant respectively at 1%, 5% and 10%.

[1] Augmented Dickey-Fuller: $\Delta y_t = \alpha + \beta t + \nu y_{t-1} + \sum_{j=1}^{L} \lambda_j \Delta y_{t-j} + \varepsilon_t$ where y is the time series variable and $\alpha, \beta, \nu, \lambda_j$ are parameters. We test the hypothesis of existence of a unit root with $h_0 : \nu = 0$

[2] KPSS tests the null hypothesis of stationarity

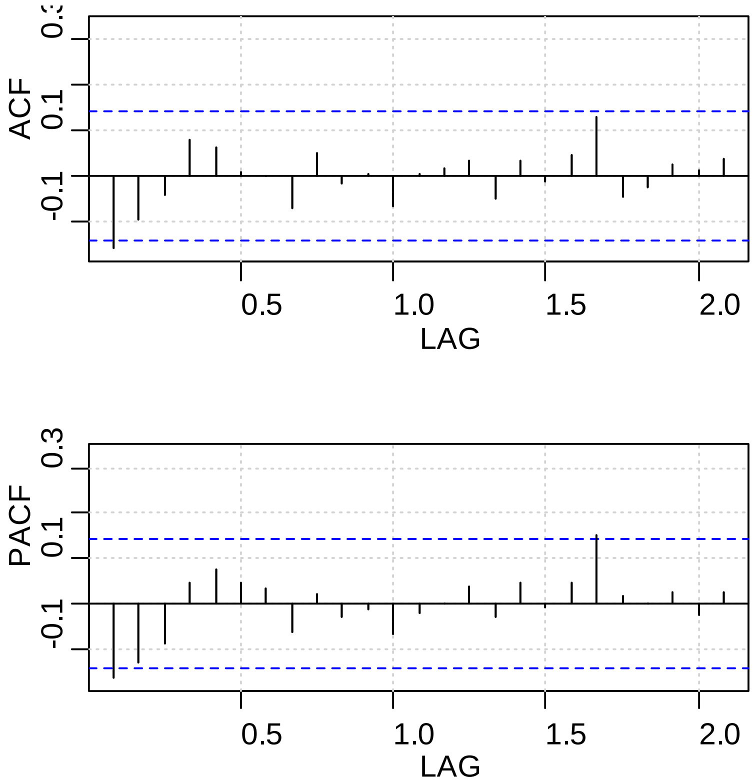

Figure 3: ACF and PACF of Rice price data

Table 2: ARIMA model selection for rice price

Model	AIC	BIC
(1,0,1)	-3.198	-3.132
(2,0,0)	-3.199	-3.133
(2,0,1)	-3.192	-3.110
(2,0,2)	-3.195	-3.096
(0,0,2)	-3.201	-3.135
(1,0,2)	-3.191	-3.108

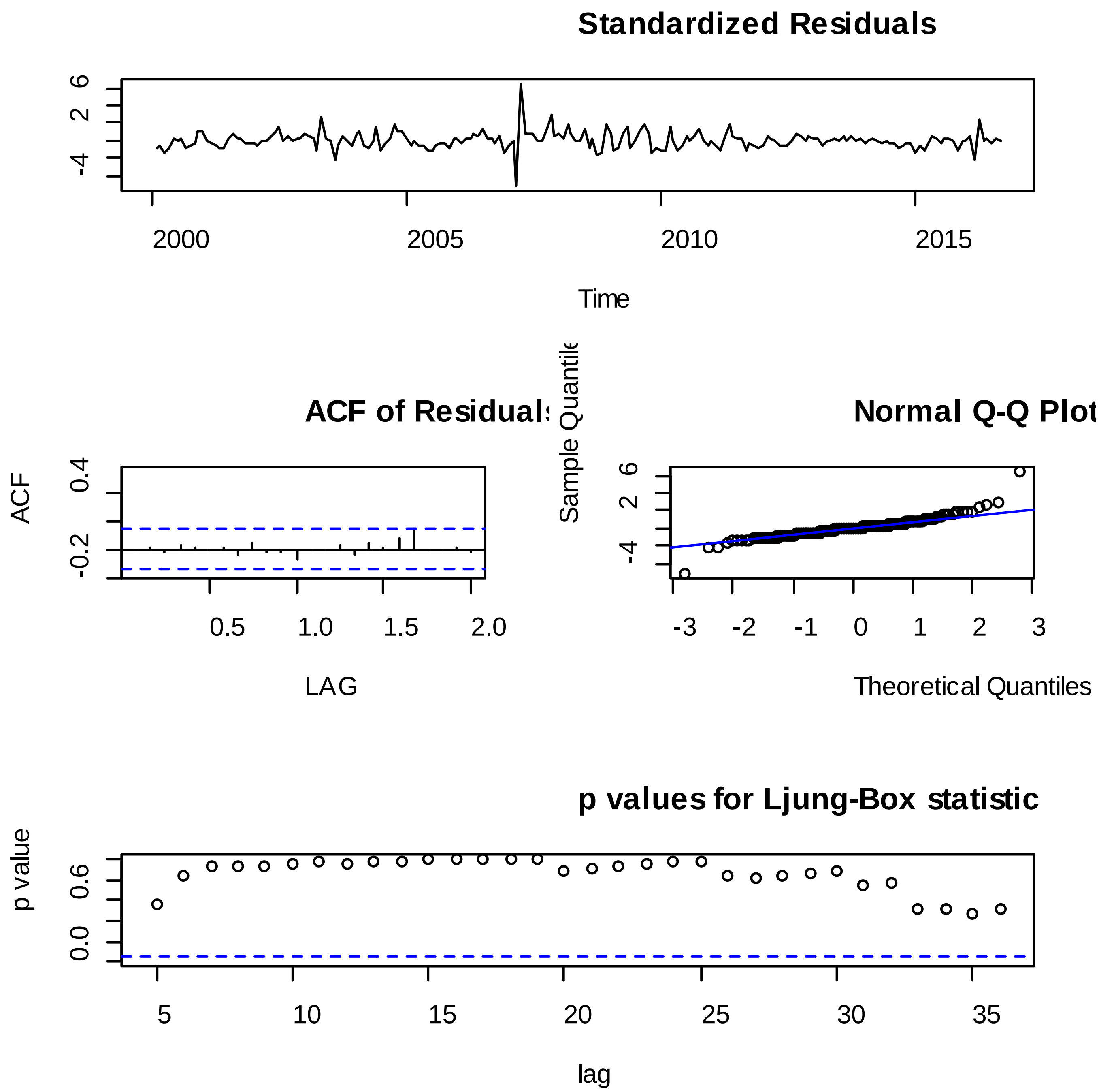

Figure 4: Residuals diagnostic of the ARIMA (2, 0, 2) for rice price data

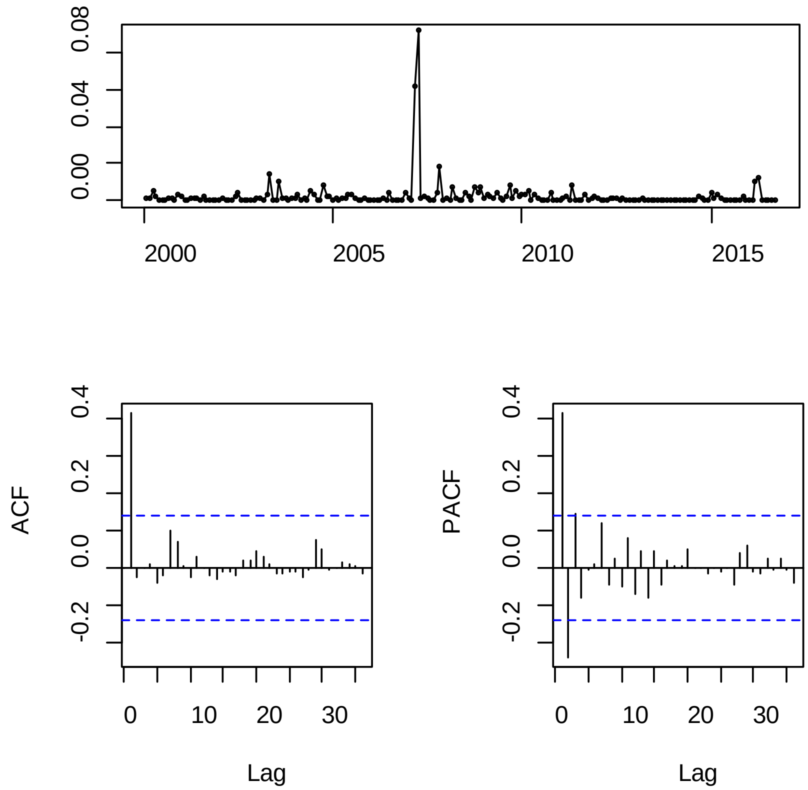

Figure 5: Residuals squared diagnostic of the ARIMA (2, 0, 2) for rice price data

Table 3: ARCH effect test[3] and normality of residuals and residuals squared tests[4]

Residuals		**Residuals squared**			
Jarque-Bera	Shapiro-Wilk	Ljung-Box	ARCH LM-test	Jarque-Bera	Shapiro-Wilk
X-Squared	p-value	X-Squared	Chi-Squared	X-Squared	p-value
1010.7***	0.87***	39.17***	31.96***	68005***	0.23***

*, **, *** significant respectively at 10%, 5% and 1%

[3] Null hypothesis: No ARCH effects
[4] Null hypothesis: Normal distribution

Table 4: EGARCH model selection

Model	AIC	BIC
(1,1)	-3.65	-3.48
(2,1)	-3.63	-3.45
(1,2)	-3.68	-3.50
(2,2)	-3.67	-3.47

Table 5: EGARCH models estimation for imported rice on Cotonou market

Estimates	Rice		
	Model1	Model2	Model3
Conditional mean equation			
Constant	0.00 (0.00)	0.00* (0.00)	0.00 (0.00)
ar(1)	0.53*** (0.02)	0.54*** (0.02)	0.94*** (0.08)
ar(2)	-0.96*** (0.01)	-0.95*** (0.02)	-0.79*** (0.09)
ma(1)	-0.54*** (0.03)	-0.57*** (0.03)	-0.99*** (0.08)
ma(2)	0.94*** (0.02)	0.92*** (0.03)	0.79*** (0.09)
Program_Dummy		-0.01** (0.00)	-0.01 90.00)
Harvest_Period		-0.01 (0.00)	-0.00 (0.00)
Program* Harvest_Period		0.02** (0.00)	0.00 (0.00)
Pt-6			-0.01 (0.05)
Maize_Price			0.04** (0.02)
International_Rice_Price			-0.04 (0.02)
Conditional variance equation			
ω	-13.11*** (1.76)	-14.96*** (1.24)	-0.37** (0.18)
α	0.70*** (0.24)	0.60*** (0.17)	-0.28*** (0.10)
γ	-0.03 (0.12)	0.01 (0.09)	-0.38*** (0.08)
β_1	0.40*** (0.13)	-0.47*** (0.09)	0.59*** (0.00)
β_2	-0.58*** (0.14)	-0.74*** (0.09)	0.30*** (0.01)
Program_Dummy		0.14 (0.70)	-0.31** (0.13)
Harvest_Period		0.34 (0.60)	-0.67* (0.37)
Program* Harvest_Period		-0.78 (0.87)	0.71 (0.52)
Pt-6			10.86*** (2.90)
Pt-6*Program_Dummy* Harvest_Period			-15.70** (7.04)
Maize_Price			-0.36 (0.70)
International_Rice_Price			0.70 (0.65)
Log Likelihood	376.21	381.22	379.98
AIC	-3.68	-3.67	-3.70

BIC	-3.50	-3.39	-3.30
Jarque-Bera	893***	2084***	22.63***
Kurtosis	12.95	18.33	0.31
Skewness	-1.52	-2.09	4.56

*, **, *** significant respectively at 10%, 5% and 1%; standard errors are in parentheses

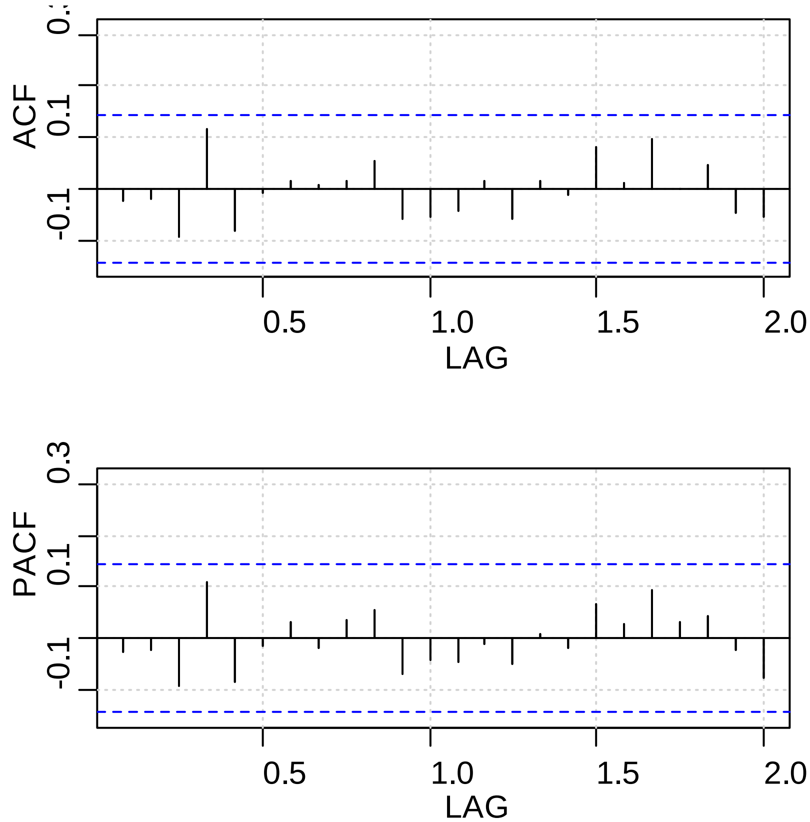

Figure 5: ACF and PACF of residuals from EGARCH estimation