Effects of Stockholding Policy on Maize Prices: Evidence from Zambia

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Abstract

Many countries, particularly in the developing world, use public stockholding programs to stabilize price for both farmers and consumers. Governments directly purchase and store staple grains, and then sell them to processors or consumers, often at heavily subsidized prices. Despite the substantial costs of these stockholding programs, little is known about their effectiveness in mitigating retail price swings. This paper estimates the effects of purchase and sales activities of the Zambian Food Reserve Agency (FRA) on monthly maize market prices across more than thirty markets in Zambia from 2003 to 2008. To deal with the endogeneity in purchases and sales, we use predicted FRA purchase and sales targets as instrumental variables. Controlling for other policies, we find evidence that FRA activities stabilize retail prices in major district markets within the cropping year. Results show that FRA purchases raise local prices for surplus maize producers about 5% on average at the time of harvest and FRA sales help lower the price to consumers during the lean season up to 7%. However, we find limited evidence that the FRA is able to reduce price volatility between years.

JEL classifications: Q11, Q18

Keywords: Public stockholding; Maize marketing board; Price shocks; Zambia

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1. Introduction

Public stockholding is widely used by developing countries to stabilize staple food prices. Subsidized grain purchases are frequently combined with consumer sales to raise prices to farmers and lower prices to consumers, while attempting to reduce price volatility. These programs are often large and expensive. India's combined stockholding and food subsidy program is the largest social safety net in the world, costing 6% of the government budget. Thailand, one of the largest rice exporters, bought rice from the farmers at a price 40% higher than the market average to build public stocks in an attempt to control rice prices (Deuss 2015). In Africa, stockholding has become increasingly popular among governments, and government marketing boards are major players in African food markets (Jayne 2012). Despite their popularity, it is unclear how well these policies work to stabilize prices across space, within or across years.

Volatile food prices endanger food security and can lead to social unrest (Bellemare, 2015; Fjelde, 2015). Sharp price increases are associated with a low stock to use ratio, suggesting that increasing stocks may mitigate against price spikes. Theoretical models demonstrate the role of public storage in reducing fluctuations in food prices (Wright and Williams 1982, among others). Gouel and Jean (2015) propose a theoretically optimal policy for stabilizing food prices by maintaining public stocks and subsidizing agricultural production. Stockholding and agricultural subsidies are precisely the policy combination used in Zambia, where we focus our research.

The Food Reserve Agency of Zambia (FRA) began purchasing maize in the 1996/97 marketing year in five district markets, expanding to 37 markets in 2003/04

(Mason and Myers 2013). The FRA targets markets expected to be in surplus and uses survey information on local harvest expectations to set a national purchase price every year, typically announced in May (the beginning of the harvest season). Due to the volumes purchased, FRA has become the dominant buyer in the maize market (Ricker-Gilbert et al. 2013).

Figure 1 illustrates changes in annual maize production, yield, and stocks from 1990 to 2015. These buffer stocks are intended to reduce variability in grain prices and to provide liquidity in the maize market (Govereh, Jayne, and Chapoto 2008). Along with purchase subsidies, storage, and logistics costs, the estimated total cost of FRA activities consists of 7% of the entire government budget in Zambia (Nkonde et al. 2011).

[Insert Figure 1]

In this paper, we ask whether the FRA stockholding policy was effective in stabilizing prices across several dimensions. In countries like Zambia with predominantly rainfed agricultural production and one rainy season per year, prices often vary significantly within the year, hitting lows right after harvest and highs during the agricultural season. If market participants face credit constraints, costly storage, or markets are thin, these seasonal patterns may not be easily arbitraged away.

Along with within-year variation, if markets are not fully integrated across space, production shortfalls in one location may generate local price spikes, and consumption areas may face much higher grain prices than those received by farmers. However, most concerns about price spikes are about those that occur across seasons, where information failures and storage capacity constraints may limit market participants' ability to store grain from surplus seasons to cover seasons with a production shortfall. We explore all of these dimensions of price variation in this paper: Do FRA purchases increase the price that farmers receive during the time of harvest? Do FRA sales lower retail prices during the lean season? Can FRA activities stabilize prices across years to mitigate price increases associated with production shocks?

Evidence of how effective stockholding policies are at stabilizing prices is relatively scarce, and what exists shows mixed findings. Using a vector autoregression (VAR) model, Jayne, Myers, and Nyoro (2008) find the National Cereals and Produce Board (NCPB) in Kenya had a stabilizing effect by increasing prices during years of surplus and decreasing prices during years of deficit. Chapoto and Jayne (2009) find evidence that FRA sales reduce market prices but find no significant effect on price stabilization over time measured by the Coefficient of Variation. Mason and Myers (2013) apply a VAR-based approach to analyze price dynamics in the two cities of Lusaka and Choma (representing regions of maize consumption and production, respectively). Simulation results from their model suggest that FRA had a stabilizing effect on prices over time, and increased prices by approximately 20% between 2003 and 2008. The authors note that the welfare gains for smallholder net maize sellers from this policy seem rather small compared to the considerable financial cost to build and maintain the buffer stock. In other regions, Intal, Cu, and Illescas (2012) show that the National Food Authority (NFA) in the Philippines stabilized domestic prices when there was a price shock in the international markets in the 1990s and early 2000s. McCreary (2012) finds evidence that the Food Corporation of India (FCI) has a stabilizing effect on wheat and rice prices.

This paper makes several contributions to previous studies on stockholding policies and FRA in Zambia. In contrast to the time series analysis commonly applied in prior literature, we use a panel regression approach to explore the spatial variation across 32 district markets that vary in geography and economic status. This approach allows us to consider price stabilization over both space and time. The purchases and sales are made locally, and we would expect the effect of the program to be the largest in those areas and times where the FRA actively buys and sells. For this assumption to hold, prices cannot be perfectly integrated throughout the country. We test for cointegration in several markets in our data and find that the prices in different district markets are not fully integrated in terms of long-run price movement. This finding is consistent with findings by Mason and Myers (2013), who reject the possibility of cointegration between prices in Lusaka and Choma, and the FRA purchase price. Instead of using government purchase and sales directly as in Chapoto and Jayne (2009), we use long-run administrative targets on purchases and sales averaged over time as instruments for actual purchases and sales. The instrumental variables can avoid the potentially unobserved correlation between annual changes in purchases or sales in a district driven by unexpected local supply or demand shocks, which would tend to underestimate any price stabilization effect. To our knowledge, this article is the first among the studies on stockholding policies to use instrumental variables to address the issue of endogeneity on evaluating the price effects of government purchases.

Other policies that affect grain prices are also in place and may be correlated with FRA activities. These policies include but are not limited to temporary export bans, government subsided imported maize from South Africa, and targeted fertilizer subsidy program for smallholder farmers. Without controlling for other policies, we risk attributing stabilizing effects to the FRA stockholding policies, whereas it may be the result of a combination of policies. As most of the policies listed above are set at an annual level, we control for these policies by annual fixed effects and by including monthly dummies when the export bans are in place.

Quantifying the effects of stockholding policy matters to policymakers concerned with improving food security. We use our econometric model to compare actual prices to simulated prices without policy interventions to illustrate the amount, timing, and location of any price stabilization effects. Considering the substantial spending supporting the high purchase prices and building the facilities for grain storage, stockholding policies need to yield high returns to justify their expense. Understanding both the benefits and costs involved in carrying out the stockholding policies can help evaluate policy alternatives in stabilizing the grain market.

2. Background

Zambia ranks 139 out of 188 countries in the 2015 UNDP Human Development Report and is classified as a lower middle-income country by the World Bank (Cammelbeeck 2015). With 60% of its population below the poverty line and almost 50% malnourished, the country suffers from widespread poverty and food insecurity. The agricultural sector in Zambia comprises roughly 1.5 million smallholders, most of whom are still net buyers of maize (Sitko et al. 2011).

The lack of irrigation and dependence on volatile rainfall make agricultural output extremely variable. Years of production shocks from droughts and floods, which occur an average of one year out of three, has led to insufficient maize production to satisfy national food demand (Dorosh, Dradri, and Haggblade 2009). Since weather shocks are localized, specific production regions experience more severe shocks than others. Most years, Zambia is a net maize exporter, and its price tends to be below that in South Africa. Only in years of substantial production shortfalls is the domestic Zambian maize price rise to the Republic of South Africa's maize import parity (Myers and Jayne 2012).

Past maize price fluctuations led the government of Zambia to believe food prices are far too strategically and politically important to leave to the market (Myers and Jayne 2012). Further, they believe storage is needed to supply the market throughout the year, and in periods of shortfalls before imports arrive. Consequently, the government has pursued a national grain storage policy to secure domestic food security (Dorosh, Dradri, and Haggblade 2009).

The Food Reserve Agency (FRA) was established in 1996 to build and manage national grain stocks (Govereh, Jayne, and Chapoto 2008). In May 2003, FRA expanded maize purchases to 37 districts and set a pan-territorial purchase price for the first time (Mason, Jayne, and Myers 2015). Most of the purchases are made in production areas predicted to have surplus maize, namely the "maize belt" region. A map of the average FRA purchase by district between 2002/03 and 2009/10 is presented in Appendix Figure A1. During the marketing year 2006/07, the FRA purchase price was set at 38,000 Zambian Kwacha (ZMK) per 50-kilogram (kg) bag of maize, which was substantially higher than the average wholesale price of 23,000–31,000 ZMK (Mason and Myers 2013). FRA usually announces the purchase price in May and continues to purchase maize throughout the harvest season until October. According to the estimates in Mason, Jayne, and Myers (2015), more than half of the smallholder maize sales are made to FRA. To protect FRA purchases, in times of domestic shortfalls, the government implemented a series of policies including export bans (Tschirley and Jayne 2010). The purchased maize is stored in more than 400 facilities across the country, maintained by FRA. These stocks are intended to stabilize maize prices and provide the available maize supply to the market during times of maize shortages in the market. Most of the stored maize is sold to large industrial millers and trading companies that cooperate with FRA through a tender process, often at below-market prices (Mason and Myers 2013). There are 78 commercial milling operations in Zambia, only 20 of them are large scale, and are primarily located in urban regions (a map of districts and large miller location is shown in appendix figure A2). Monthly shares of FRA purchase and sales are presented in Figure 2.

[Insert Figure 2]

3. Method

To help explain how FRA's purchases and sales affect retail maize prices, consider the following model of demand and supply of maize in Zambia as specified in equation (1) and (2):

$$Q_{it}^{S} = \mathrm{f}(\mathrm{P}_{i,t-1}^{input}, W_{i,t-1}, E(P_{it}^{output}), P_{t}^{border}, T_{i}^{d}) \quad (1)$$

$$Q_{it}^{D} = g(Income_{it}, P_{it}^{output}) \quad (2)$$

where Q_{it}^{S} is the supply of maize at district i at time t; P_{it}^{output} is the maize price at district i at time t; $P_{i,t-1}^{input}$ and $W_{i,t-1}$ are the price of inputs and weather at district i in the previous period, respectively; $E\ (P_{it}^{output})$ is farmers' expected farm gate price of maize in the next year; P_{t}^{border} is the maize price at the border; and T_{i}^{d} is the transportation cost of transporting maize to or from the border. Q_{it}^{D} is the demand for maize, affected by the current price of maize and the income of consumers.

Several factors determine the quantity of FRA sales and purchases in district i at time t, as shown in equations (3), (4), and (5):

$$FRA_{mt}^{S} = h(P_{mt}, month) \quad (3)$$

$$FRA_{it}^{S} = h\left(D_i \; x \; P_i^d \; x \; FRA_{mt}^{S}\right) \quad (4)$$

$$FRA_{it}^{D} = v\left(\overline{P}_t, E\left(Q_{it}^{S} - Q_{it}^{D}\right), FRA_{i,t-1}^{D}\right) \quad (5)$$

where FRA_{mt}^{S} is the quantity of FRA sales at time t at districts with millers and is strongly determined by local prices P_{mt} at time t and season, with sales peaking in the lean season. D_i is the distance matrix of district i to the districts where large millers are located. FRA_{it}^{S} is thus determined by the distance to the nearest local miller district where the sales occur and the cost of transportation, P_i^d. On the purchase side, we assume that the local FRA purchases do not affect price over space because the pan-territorial purchase price $\overline{P}_t$ is set to be the same for the entire country, so farmers have no incentive to sell in another district, especially when we account for the transportation cost for the rural households to travel to neighboring districts. The FRA purchase can be modeled as a function of past grain stocks $FRA_{i,t-1}^{D}$ and estimated current excess harvest $E\left(Q_{it}^{S} - Q_{it}^{D}\right)$ or total storage target.

Thus, we anticipate the price in district i at time t to be a function of local supply plus nearby FRA sales and local demand plus local FRA purchases as in equation 6.

$$P_{it} = f(Q_{it}^{S} + FRA_{it}^{S}, Q_{it}^{D} + FRA_{it}^{D}) \quad (6)$$

Without the FRA, prices are likely to be lowest at harvest in surplus production regions, and to increase by the cost of storage throughout the year. Through arbitrage, we would expect the price in the main consumption districts to be the price of maize in producing areas plus a transport cost up to a maximum of the price of South African maize plus transport price. However, with a pan-territorial FRA purchase price, the purchase price of maize tends to increase in production areas at harvest, and we can see a smoothing effect between markets or over space.

Similarly, with the release of FRA stocks during the lean months at subsidized prices, we would expect a smoothing effect price between the consumer region and production region. Also, we would expect that FRA activities would shrink the price difference between lean seasons and harvest seasons, smoothing prices within the year. The spatial distribution of the average price during the lean and harvest seasons is presented in Appendix Figure A3.

Solving a structural model consisting of a system of equations (1) through (6) is difficult both theoretically and empirically. We only observe the quantity of maize harvested once a year on a national level, but our price data cover a broad range of markets in different geospatial areas and are updated at a monthly frequency. We follow the approach used in Chapoto and Jayne (2009) and start with a reduced form framework with demand and supply shifters as regressors.

We identify the effect of FRA purchases by the assumption that they will have the most substantial effect in their purchase locations, and that the effect of FRA sales will be largest at the districts with large mills, and that effect will dissipate over space. Cointegration test results (Appendix Table A1 and unit root tests presented in Table A2) suggest that prices in district markets far away from the primary production and consumer centers are not fully integrated with price movements with other markets, supporting our assumption that the effects of FRA may be somewhat localized.

We apply a vector of weather measures in the previous growing season as exogenous supply shifters to the maize harvested by smallholder farmers, since the actual quantity of maize supplied is endogenous to maize prices. By adding in the market fixed effect and month fixed effect in the model, we can compare regions that are less affected by FRA purchases and sales as controls (both unaffected by price arbitrage or by the FRA purchases) to reflect the effect of stockholding policy.

We estimate a reduced form model (equation 7) to evaluate the effects of FRA purchase and FRA sales on price levels and price stability,

$$Y_{it} = FRA\_buy_{it}\alpha + FRA\_sale_{it}\beta + W_{i,t-1}\gamma + X_{it} + month_t + mkt_i + \varepsilon_{it} \qquad (7)$$

where Y_{it} is price and price deviations at district i at time t, FRA_buy_{it} and FRA_sale_{it} are the quantity bought and sold by the FRA, $W_{i,t-1}$ is a vector of average weather variables of districts in corn growing regions from the previous growing season, X_{it} is a vector of other covariates of demand and supply shifters, month_t are month fixed effects to capture seasonality, mkt_i is a market fixed effects to control for time-invariant unobserved heterogeneity and ε_{it} is a random error term. The coefficient of interest throughout the paper is α, the effect of FRA purchases on prices, and β for the effects of FRA sales. The price deviations variable is the squared deviation from the long-term average price in each district.

We face three potential sources of endogeneity when identifying the effects of the stockholding policy on maize prices using the reduced form equation above. First, since FRA explicitly targets its purchases to areas predicted to be in surplus, we need to control for endogeneity in the amount and location of FRA purchases. Otherwise, we would tend to underestimate the stabilizing effect since places of surplus maize will likely also be the places where prices might be lowest, causing FRA purchases to be spuriously correlated with low prices. Second, FRA tends to target the timing of its sales to those times when the price is higher. If we did not control for this effect, we would likely observe FRA sales as being positively correlated with the market prices, again underestimating the price smoothing effect. Thus, we use long-run predicted FRA purchase and sales targets as instrumental variables for the actual purchases and sales as they are relevant to the stockholding activities but not directly correlated with production shocks or grain prices in that location, in that year.

Inspired by the policy design, we derive instrumental variables for actual purchases and sales by using predicted purchase and sales targets from the Crop Forecast Survey (CFS). Every year (except for the 2010/11 marketing year), the Central Statistics Office of Zambia conducts surveys during the spring before harvest to obtain an estimate of the local production for the major districts. The CFS collects a nationally representative sample to obtain an estimate of the national harvest. The estimates are used as references for setting goals for FRA purchases quantity and target price. By analyzing the CFS data, we get an estimate of the harvest before the actual harvest for each year.

The instrumental variable for FRA purchases is an interaction term of long-run shares of production for each district and the expected total crop harvest to capture the annual purchase targets. The share is calculated as the average share of production in a specific district as a percentage of national harvest from 1999 to 2011. We believe this instrument to be valid because the policy design makes the estimated production relevant to FRA purchase behavior, but the instrument does not affect prices in a particular year directly. Because we are interacting the production with long-run averages shares, the instrument is not strongly correlated to a specific year's harvest and local maize supply.

The instrumental variable for distance-weighted FRA sales in a district uses predicted FRA stock, weighted by the number of millers in each district and by the distance to nearby districts with millers. The estimated FRA stock is dependent on long-term shares and is not strongly associated with shocks to food prices in a specific year. Distance to districts with milling companies is also relatively exogenous and tends to stay the same during the five-year study period. A map of predicted FRA purchase and sales in each district markets is presented in Figure A4.

4. Data and Variables

We use monthly Zambia maize prices observed from January 2003 to December 2008 from 32 different markets that spread out in different locations in Zambia. Price data were collected by the World Food Program and the Central Statistical Office in Zambia. In terms of price volatility measures, we use monthly squared price deviations from the district mean as the main specification.

In terms of explanatory variables, we use annual Zambia FRA purchases from 2002 to 2009 from local district markets and monthly national FRA sales from the Food Reserve Agency and the Central Statistics Office (CSO) of Zambia. Because Zambia relies on maize imports from South Africa in times of food shortage (Myers and Jayne 2012), we include the South African monthly average spot maize price from the Johannesburg Stock Exchange, converted to Zambian Kwacha and adjusted by import tariff rates to reflect the maize import parity price. We obtain the exchange rate from the South African Reserve Bank and the import tariff from the Zambia Revenue Authority. Locations of the large commercial millers working with the FRA come from the CSO.

We generate measures of agriculturally relevant precipitation from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) dataset (Funk et al. 2015). We use the total amount of rainfall recorded during the October–April growing season, and its squared term following Schlenker and Roberts (2006). We also include the first day of the rainy season, calculated as the number of days during the maize growing season in which more than 10 millimeters (mm) of rain fell in three out of five days. Temperature data are from the Princeton Global Forcing (PGF) dataset (Sheffield et al. 2014), also limited to the maize growing season. All the weather variables are averaged across the districts in the production region to reflect the total effect of weather on national maize production in that year. Table 1 presents the summary statistics of the key variables used in the analysis.

[Insert Table 1]

5. Results

This paper addresses three types of price variation: over time within the year (seasonal), over space within the year (spatial), and between years (annual). Our main model addresses seasonal and spatial price variation through a panel regression, taking advantage of the variation in the timing and location of FRA interventions.

For both outcome variables, we estimate three specifications as follows. Model (1) is a fixed-effects model, assuming all the regressors are exogenous. Model (2) is a fixed-effects model with instrumental variables for FRA purchase and FRA sales. Model (2) is our main specification and the preferred model because it controls for the endogeneity of various explanatory variables as described above. Model (3) uses the monthly change in price as the dependent variable. In this specification, most of the annual level control variables are dropped. All three specifications include month and market fixed effects to control for seasonal effects and time-invariant unobservables. In all instrumental variable regressions, we use the Anderson-Rubin Wald test to detect under-identification of endogenous variables, and we use the Cragg-Donald Wald F statistic to test whether we have weak instruments.

Columns (1) – (3) in Table 2 present the results of the maize price regressions. As expected, we can see the FRA purchases increase maize prices during the harvest month, and FRA sales decrease maize prices during the lean season across three different model specifications. The variables of interest are statistically significant for all estimates. Note the contrast in the scale of the estimated coefficient on the FRA sales variable from the OLS estimates (Model (1)) and the IV estimates (Model (2)). When we fail to account for the endogeneity in the sales behavior, the estimated coefficients of the FRA sales on price are attenuated toward zero or even positive with a marginal effect of only -0.46, compared to the 2SLS estimate that is as large as -7.91. In contrast, the 2SLS estimates of the marginal effect of FRA purchases on prices are similar to the OLS estimate, both showing a statistically positive effect. To put numbers in perspective, for an averaged purchase quantity of 1000 tonnes at a district market, the estimated FRA purchases effect raises the average local maize prices at 570 ZMK by about 5.4%. The estimated effect of the FRA sales varies across districts. We find that, all else equal, the average amount of

FRA sales help to lower the mean price of maize during the lean seasons by as much as 7% in Lusaka and 3% in Kitwe, and the effect decreases toward zero as the distance to districts with commercial millers increases.

[Insert Table 2]

We plot the simulated prices without FRA activity against the actual prices (Figure 3) to observe the effect of the FRA over space and time. The simulated prices are calculated by removing the average effects of FRA purchases and sales from historical prices. We assume that the simulated price will not go above the import parity of imported South African maize price. In Mbala, a district market in the northeastern production region, we mainly observe the effects of FRA purchases on increasing prices during the harvest season. In Lusaka, the country's capital city and a net consumption region, the effect of FRA sales during the lean season are much stronger. Note that as much as FRA affects prices outside of the areas of sales and purchases and that these effects persist over time, our results may still have understated the effects of the FRA program. Since our identification assumption is that the influence of the purchases and sales are largest locally and dissipates over space, the areas far away from these locations are still affected by the FRA.

[Insert Figure 3]

Comparing the estimation results from model (3) with our main specification model (2), we see that the estimates are consistent in signs and significance. Model (3) is a price difference regression, measuring the effect of FRA activities on price variation from one month to another. While the interpretation of the marginal effects of model (3) and model (2) are slightly different, the coefficients are mostly consistent with our main specification, suggesting that the relationship between FRA sales and FRA purchases also exists in short-term price changes as well as price levels.

For the control variables, the number of days without rain has a positive and statistically significant effect on prices as they negatively impact maize production. Precipitation seems to have a nonlinear effect on prices since the marginal effect of precipitation on price is negative after the precipitation exceeds a certain threshold. The later the first day of rain of the growing season occurs, the higher the maize prices. Mean temperature has a negative and statistically significant effect on maize prices.

The under-identification test and weak instruments test support the validity of the 2SLS estimates of the IV regression on the maize prices. The values of Cragg-Donald Wald F statistic are larger than 10, indicating that we can reject the null of no correlation between the endogenous variables and the instrumental variables at the 5% significance level. The Anderson-Canon correlated LM statistic is larger than the critical value at 1%, indicating that we can safely reject the null hypothesis that the instrumental variables are under-identifying the endogenous variables (associated first stage results of the regressions are presented in Appendix Table A3).

Next, we consider the effect of the FRA on price volatility within the year. Results on the squared price deviation are presented in column (4) – (6) in Table 2. The model specification and variables in the model are the same as the price regressions presented in column (1) through (3) but are regressed on price deviations. We see negative and statistically significant effects of FRA sales on price deviations across all three models of IV regressions, suggesting a stabilizing effect on the maize price of FRA sales via releasing grain stocks during the lean seasons. Similar to the marginal effect estimated on the price regressions, the IV estimator is much larger in scale compared to the OLS estimates. This suggests the endogeneity involved in the FRA sales and prices drives the OLS estimate of the marginal effect toward zero and underestimates the stabilizing effect of FRA activities. This might help to explain those prior results that find that stockholding policies have no significant impact on stabilizing the market.

To show the heterogeneous effects of FRA activities on different districts, Table 3 presents the results of our main regression separately on wholesale and retail market centers, defined by the Production and Trade Flow Maps by FEWSNET (2018). Market centers are where maize is assembled or sold collectively (we present 19 of out of 32 markets in our data). Comparing the subsample of market centers and the subsample of remote markets in remote regions, the FRA purchases have a more significant positive effect on prices, while the FRA sales have a smaller negative effect on prices. This makes sense as the local purchases tend to have more substantial effects in regions that are less connected with other markets. Similarly, due to the lack of infrastructure and high transportation cost to remote markets, subsidized maize sales that occur in distant markets would be less likely to affect the retail prices in these markets.

[Insert Table 3]

The above results focus on the effects of FRA activities smoothing prices in the same year and across space. In order to address the stabilization effect across years, following Chapoto and Jayne (2009), we compare the coefficient of variation over time of the actual and simulated price, detailed results shown in Appendix Table A4. For 6 of the 32 markets (mostly consumer regions), the FRA interventions had a stabilization over time, by reducing CVs up to 2.15%. In contrast to the sharp effects of smoothing prices between spaces and within the year, our findings show a much smaller inter-year smoothing effect by storing maize grains in good harvest years and releasing the stocks in bad harvest years. This is partially due to the fact that it is difficult to store enough grains across years and that we do not observe such patterns (a bad year after a good year in our study period). Unpredictability in policy changes between years may also add to the increase in price variability.

6. Conclusion

Among the wide variety of factors that affect price volatility in staple foods, this paper focuses on the effect of a stockholding policy. Following the previous literature on maize price and policy interventions, our model incorporates the influences of weather-induced production shocks, external market price transmission in order to separate the influence of the FRA activities. By controlling for the endogeneity issues, the model can identify the effect of estimating the effect of FRA purchases and sales on maize price variability and maize price in Zambia.

As in Jayne (2009) and Mason and Myers (2013), we find the FRA activities have a significant impact on reducing maize prices and maize price volatility during the lean seasons and helps support the purchase price that the farmers receive. In other words, we find FRA activities smooth both seasonal and spatial variations between the consumption and production regions. Second, this study finds that failing to control for the reverse causality in food prices and FRA sales would lead to biased estimates of the marginal effects of FRA activities. Third, our results show that consumers in the consumption regions benefit most from the policy because there are decreases in both price levels and price volatilities within the year and between years. However, FRA's effect on between year price variations seems to be rather small.

There are limitations to this paper. Due to data limitations, we analyzed retail maize prices rather than wholesale or farmgate maize prices. Because of this limitation, the actual effect on the prices received by smallholder farmers may be slightly lower than our estimates.

The results of this paper might be of interest to policymakers in the southern African region and to developing countries that are considering public grain reserves as a means to stabilize grain markets. A few things need to be considered. First, policymakers must decide whether the fiscal impact of building the public grain stock is worth the cost. We are seeing signs of stabilizing grain prices and increases in the price received by smallholder farmers, but we should not ignore the opportunity cost in investing in other programs, such as subsiding farm inputs, or developing better agricultural practices through education and extension. Second, the public stock may have a crowding out effect on the private sector as private traders have less incentive to build stocks on their own. As a result, governments would face a more prominent role in stabilizing the market and then more pressure on the budget. Third, international spillovers might be large as the stabilizing effect may either be spread to neighboring countries. Fourth, management and transparency concerns, including late payments to farmers are known to influence the effectiveness of getting more maize from the smallholder farmers.

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Table 1. Summary statistics of variables

Variables	Mean	SD	Min	Max
Dependent variables				
Maize Price (ZMK/kg)	573.805	182.059	235.380	1555.600
Price Deviation Squared	26.094	52.641	0.000	674.143
Key variables				
FRA Purchase (tonnes)	257.466	845.530	0.000	10310.930
FRA Sales (tonnes)	5.122	31.832	0.000	655.875
Control variables				
Days without rain (days)	27.453	11.520	1.000	56.000
Precipitation(mm)	1068.551	197.276	550.444	1640.263
Precipitation Squared	1201031	55893.1	1123675	1305399
First Day of rain (days)	33.292	11.703	3.000	70.000
Mean Temperature (°C)	24.918	0.837	23.220	27.064
SAFEX Price (ZMK/kg)	789.909	217.037	468.753	1279.758
Instrumental variables				
Predicted purchase target (tonnes)	134.695	432.409	0.000	4595.748
Predicted sales target (tonnes)	2.017	6.716	0.000	86.699

Table 2. Regression results of maize price and maize price deviation squared

Response Variable:	**Maize Price**			**Maize Price Deviation Squared**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
	FE	**FE+IV**	**FE+IV**	**FE**	**FE+IV**	**FE+IV**
FRA Purchase	0.020^{***}	0.031^{***}	0.020^{***}	0.004^{***}	0.005^{**}	0.002
	(0.002)	(0.009)	(0.006)	(0.001)	(0.002)	(0.002)
FRA Sales	-0.458^{***}	-7.908^{***}	-4.531^{***}	-0.047^{**}	-1.332^{***}	-0.583^{*}
	(0.092)	(1.491)	(1.004)	(0.020)	(0.360)	(0.304)
Days without rain	23.376^{***}	19.813^{***}		7.201^{***}	6.586^{***}	
	(3.262)	(3.058)		(1.879)	(0.737)	
Precipitation	299.684^{***}	249.174^{**}		121.214^{***}	112.456^{***}	
	(54.551)	(100.651)		(19.270)	(24.276)	
Precipitation Squared	-0.136^{***}	-0.113^{**}		-0.055^{***}	-0.051^{***}	
	(0.025)	(0.046)		(0.009)	(0.011)	
First Day of Rain	5.829^{*}	4.523		3.864^{***}	3.643^{***}	
	(2.953)	(5.056)		(0.869)	(1.220)	
Mean Temperature	-16.658	-112.066^{*}		41.693^{***}	25.036^{*}	
	(29.484)	(59.867)		(8.244)	(14.439)	
SAFEX Price	-0.309^{***}	-0.354^{***}	-0.113^{***}	-0.035^{**}	-0.043^{***}	0.003
	(0.039)	(0.057)	(0.019)	(0.013)	(0.014)	(0.011)
Price Lag			0.554^{***}			0.140^{***}
			(0.026)			(0.008)
N	2304	2304	2232	2304	2304	2232
Cluster	32	32	32	32	32	32
Anderson-Canon Corr. LM Statistic	-	33.262	31.851	-	33.262	27.983
Cragg-Donald Wald F Statistic	-	16.501	15.823	-	16.501	13.845
Year Fixed Effect	No	No	Yes	No	No	Yes
Month Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Market Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$. Specifications of the models: (1): FE, (2): FE-IV (using weather variables), (3) FE-IV (using year fixed effect), and (4) FE-IV (difference in month prices). Cragg-Donald Wald statistic and Anderson-Canon correlation statistic are distributed as chi-squared with degrees of freedom of 1.

Table 3. Robustness checks for market center and remote market subsample

Price	(1) Whole Sample	(2) Market Center Subsample	(3) Remote Market Subsample
FRA Purchase	0.031***	0.029**	0.043**
	(0.009)	(0.014)	(0.018)
FRA Sales	-7.908***	-11.258**	-5.612***
	(1.491)	(4.454)	(0.954)
Days without rain	19.813***	16.743***	23.570***
	(3.058)	(5.573)	(3.731)
Precipitation	249.174**	225.325	273.794**
	(100.651)	(178.678)	(124.593)
Precipitation Squared	-0.113**	-0.102	-0.125**
	(0.046)	(0.081)	(0.056)
First Day of Rain	4.523	4.279	4.643
	(5.056)	(8.931)	(6.274)
Mean Temperature	-112.066*	-126.555	-111.760
	(59.867)	(112.897)	(71.529)
SAFEX Price	-0.354***	-0.351***	-0.367***
	(0.057)	(0.101)	(0.070)
N	2304	1368	936
Cluster	32	19	13
Anderson-Canon Corr. LM Statistic	33.262	6.711	53.141
Cragg-Donald Wald F Statistic	16.501	3.279	27.207
Year Fixed Effect	No	No	No
Month Fixed Effect	Yes	Yes	Yes
Market Fixed Effect	Yes	Yes	Yes

Notes: Standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$. Specifications of the models: (1): FE-IV model of the price regression on the entire sample, (2): FE-IV model of the price regression on the market center subsample, and (3) FE-IV model of the price regression on the remote markets subsample. Cragg-Donald Wald statistic and Anderson-Canon correlation statistic are distributed as chi-squared with degrees of freedom of 1.

FIGURES

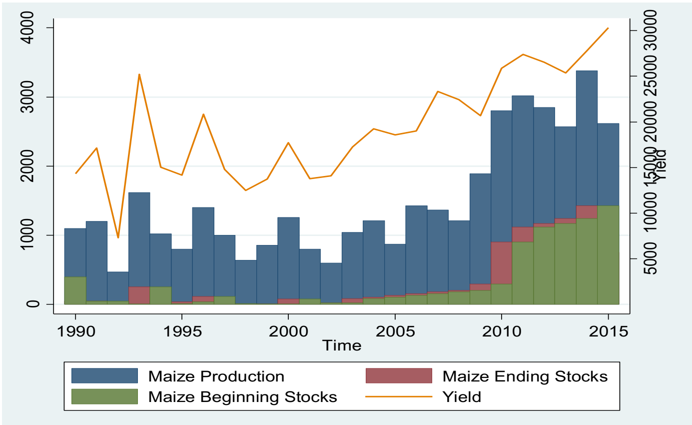

Figure 1. Annual maize production, maize yield, and maize stocks, 1990–2015

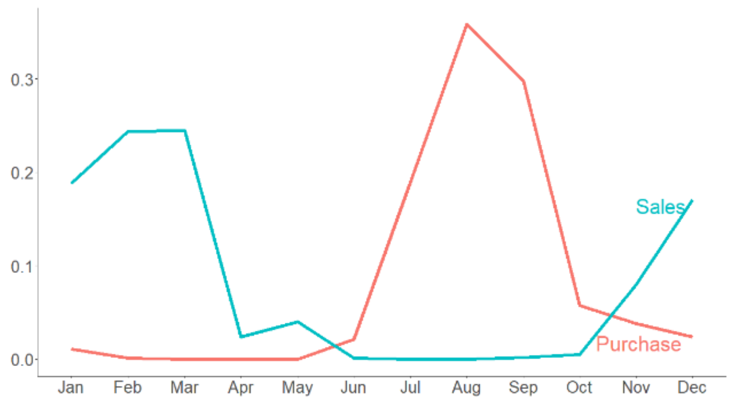

Figure 2. Monthly shares of FRA purchase and sales

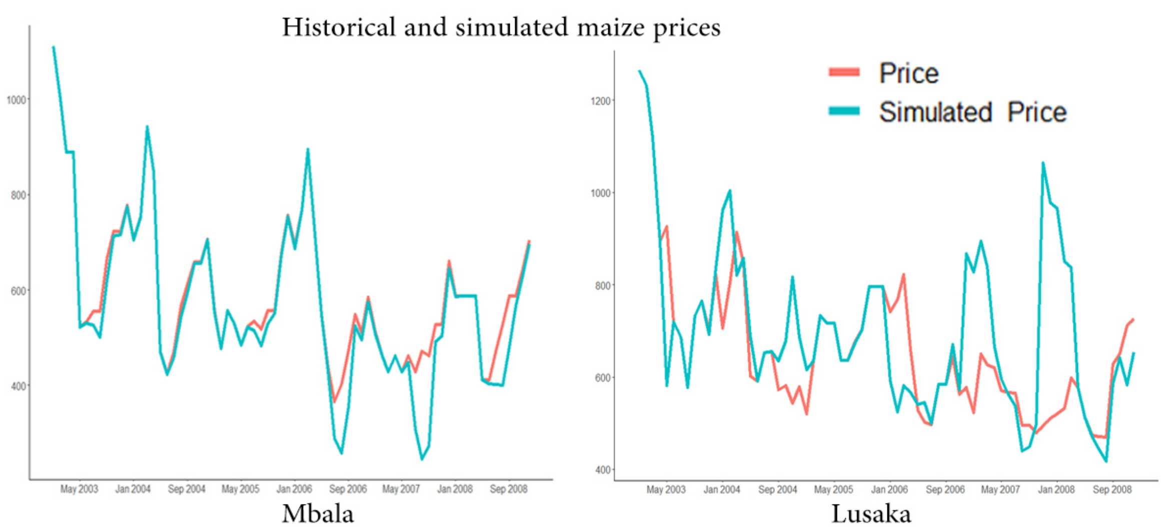

Figure 3. Historical and simulated price in production and consumption region