Effects of Stock-holding Policy on Maize Prices: Evidence from Zambia

Yujun Zhou, Kathy Baylis*

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 a substantial subsidy. Despite the substantial costs of these stockholding programs, little is known about their effectiveness in mitigating the retail price swings. This paper estimates the effects of the purchase and sales activities of the Zambian Food Reserve Agency (FRA) on maize market prices across more than thirty markets in Zambia using monthly price data 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 in place, we find evidence that FRA activities stabilize retail prices in the major district markets within the cropping year. Results show that FRA purchases raise local prices for surplus maize producers for about 5% on average during the time of harvest and FRA sales help to lower the price during the lean season up to 7%. On the other hand, we are only able to find evidence of the FRA reducing price volatility between years in a few district markets.

JEL classifications: Q11, Q18

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

* Yujun Zhou is a Ph.D. student in the Department of Agricultural and Consumer Economics at the University of Illinois at Urbana-Champaign. Kathy Baylis is a Professor in the Department of Agricultural and Consumer Economics at the University of Illinois at Urbana-Champaign.

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1. Introduction

Public stockholding is widely used by developing countries to stabilize staple food prices. Subsidized grain purchases are combined with often subsidized consumer sales to raise prices to farmers and lower them to consumers, while attempting to lower price volatility. These programs are often large and expensive. India's combined stock-holding 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 markets average to build public stocks in an attempt to control rice prices (Deuss 2015). In Africa, stockholding has become increasingly popular among governments over the past two decades, and government marketing boards have become major players in African food markets (Jayne, 2012). Despite their popularity, it is unclear how well these policies work to stabilize price across space, within or across years.

Volatile food prices endanger the food security of households and can lead to social unrest and civil conflict (Bellemare 2015; Fjelde 2014). Sharp price increases are associated with a low stock to use ratio, suggesting that increasing stocks may mitigate against these price spikes (Wright, 2012). Numerous papers develop theoretical models that demonstrate the role of public storage in reducing fluctuations in food prices (Scheinkman and Schechtman (1983); Wright and Williams (1982), among others). Gouel and Jean (2012) propose a theoretically optimal policy for stabilizing food prices in a developing country by maintaining a public stock along with a subsidy on

agricultural production. Stock holding and agricultural subsidies are precisely the policy

combination used in Zambia, where we focus our research.

Equipped with ample storage facilities in various district markets, the Food

Reserve Agency (FRA) in Zambia purchases a substantial amount of maize from farmers

in maize surplus regions. The FRA started to buy maize in the 1996/1997 marketing year,

but purchases were limited to five district markets. Due to a lack of funding, it suspended

purchases during 1998/1999 – 2001/2002. It was not until 2003/04 that the agency

expanded purchases to more than thirty markets across the country (Mason and Myers

2013). The FRA sets a national purchase price every year, typically announced in May

(the beginning of the harvest season). Due to the volumes purchased, the FRA has

become the dominant buyer in the market. In the 2006/2007 marketing year, the FRA

bought approximately 85% of the maize sold by smallholder farmers (Ricker-Gilbert et

al. 2013), bringing national maize stocks to historic highs in 2009 and continue to reach

higher levels. Figure 1 shows changes in annual maize production, maize yield and maize

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).

To support the high FRA purchase price, along with 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; IMF, 2012).

In this paper, we ask whether the FRA stockholding policy was effective in

stabilizing prices. Price stabilization has several dimensions. In countries like Zambia

with predominantly rainfed agricultural production and one rainy season per year, prices

often vary greatly within the year, hitting lows right after harvest and highs during the

agricultural season. If market participants face credit constraints and/or costly storage, or markets are thin, these seasonal patterns may not be arbitraged away. If markets are not fully integrated across space, one might worry that production shortfalls in one location may generate local price spikes. Similarly, if markets are not well integrated over space, consuming areas may face much higher grain prices than farmers. Last, price volatility may be largest across seasons, where information failures and storage capacity constraints may limit market participant's ability to store sufficient amount of grain from surplus seasons to limit price increases in seasons with a production shortfall. We explore all of these dimensions in this paper. Specifically, we ask: do FRA purchases increase the price that farmers receive during the time of harvest? Second, do FRA sales lower retail prices during the lean season? Third, 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 et al. (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. The NCPB's operation increases maize price on average by 20% in Kitale and Nairob between 1995-2004. Pierre et al. (2018) use a vector error correction model (VECM) to explore the effect of the National Food Reserve Agency on maizes prices in Tanzania. They do not find a significant price stablization effect, except for a small price decrease in some markets. Despite the similarities in the policy between countries, the FRA in Zambia operates on a larger scale both financially and geographically and has a focus on smallholder farmers. Chapoto and Jayne (2009)

find evidence that FRA sales reduce market prices but find no significant effect on price stabilization over time measured in Coefficient of Variation. Like our study, they estimate a reduced form model on four wholesale markets and regard FRA activities as demand and supply shifters. 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 the FRA had a stabilizing effect on the prices over time, and approximately increased prices by 20% between 2003-2008. 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 countries, Intal et al. (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 the previous literature, we use a panel regression approach to explore the spatial variation across thirty-two 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 (detailed results presented in Table A1). This finding is in line with Mason and Myers (2013), as they rejected the possibility of cointegration between the two districts prices and the FRA purchase price. Instead of using government purchase and sales directly as in Chapoto and Jayne (2009), we instrument for the purchases and sales by using their administrative targets averaged over time to avoid the potentially unobserved correlation between annual changes in purchases or sales in a district driven by unexpected local price shocks. 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.

We are faced with three potential sources of endogeneity when identifying the effects of the stockholding policy on maize prices. First, since the FRA explicitly targets locations its purchases to areas that are 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. Second, the 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 market price, again underestimating the price smoothing effect. To tackle with these two issues, we use 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.

The third threat to identification is that 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 policy makers aiming at improving food security. As a demonstration of the effects, this paper contrasts the actual prices with simulated prices without the policy interventions. Considering the substantial spending supporting the high purchase prices and building the facilities for grain storage, stockholding policies would 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 sixty percent of its population below the poverty line and almost fifty percent malnourished, the country suffers from widespread poverty and food insecurity (Sitko et al. 2011).

The agricultural sector in the country is comprised of roughly 1.5 million smallholders and 2,000 large-scale farmers. More than ninety percent of maize production and eighty percent of maize sales come from smallholder farms (Tembo et al. 2009). Even so, maize production is not evenly distributed across farms. Around two percent of the small and medium farmers generate roughly half of maize output. A large number of small farm households are still net buyers of maize (Sitko et al. 2011).

The dependence on volatile rainfall and a lack of irrigation make the agricultural output extremely unstable. Years of production shocks from droughts and floods which occur an average of one year out of three, 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. I most years, Zambia is a net exporter, and its price tends to be below the price in South Africa (Sitko, Kuteya and Chisanga 2014). Only in years of substantial production shortages will the domestic Zambian maize price rise to the Republic of South Africa's maize import parity (Myers and Jayne 2012).

Past maize price fluctuations and consequent social unrest have led the government of Zambia to believe food prices are far too strategically and politically important to leave to the market (Chapoto 2012). The government mistrusts private traders' ability to bring in enough maize during production shortfalls to ensure availability and stabilize market prices (Myers and Jayne 2012). The government has argued that uncertainties in imports and the transmission of shocks from other countries make trade an unreliable tool to address domestic food shortages. Further, storage is needed to supply the market throughout the year, and in periods of shortfalls before

imports arrive. Consequently, the government has pursued national grain storage policy to secure domestic food security (Dorosh 2009).

The Food Reserve Agency (FRA) was established in 1996 to build and manage national grain stocks (Govereh, Jayne, and Chapoto 2008). The FRA started by purchasing small quantities in five out of a total of 72 districts in 1996. In May 2003, the agency expanded the purchase 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. Figure 2 shows a map of the average FRA purchase by district between 2002/03 -2009/10. During the marketing year 2006/07, the FRA buy price was set at 38,000 ZMK (for a 50-kg bag), which was substantially higher than the average wholesale price of 23,000–31,000 ZMK (Mason and Myers, 2013). The FRA usually announce the purchase price in May and continue to purchase maize from smallholders throughout the harvest season until October. According to the estimates in Mason, Jayne, and Myers (2015), more than half of the smallholder maize sales were made to the FRA for five consecutive years since the 2002/03 marketing year.

The purchased maize is stored in more than 400 facilities across the country, maintained by the FRA. These stocks are intended to stabilize maize prices and provide available maize supply to the market during the time of maize shortage in the market. The FRA cooperates with large scale millers and sell the stored maize at subsidized prices. There are 78 milling operations in Zambia, only 20 of them are large scale, and most of them are in Lusaka and Copperbelt provinces. The rest of the medium and large-scale millers are primarily located in urban areas in Northern and Central province, with some

in Southern, according to the Millers Association in Zambia. Thus, we would anticipate that the price effect of FRA sales would be largest in those areas that have, or are near, commercial millers. A map of the location of the district markets and the location of the millers is presented in Figure 3.

In part to protect the dominant market position of the FRA, the government implemented a series of policies including export bans, import tariffs, and imports through the FRA (Tschirley and Jayne 2010). Most of the stored maize is sold to large industrial processors and trading companies that cooperate with the FRA through a tender process, often at below-market prices (Mason and Myers, 2013).

3. Method

In this article, we focus on the effects of the FRA's purchase and sales activities on local maize prices. We evaluate the effectiveness of the policy by analyzing maize prices in 32 markets in Zambia from 2003 to 2008, where we have data on local FRA purchases. To help explain how FRA purchases and sales affect retail maize prices, we set up the following model of demand and supply of maize in Zambia. Consider a system of demand and supply of maize as specified in equation (1) and (2):

$$Q_{it}^S = f(P_{i,t-1}^{input}, W_{i,t-1}, E(P_{it}^{output}), P_t^{border}, P_i^d) \qquad (1)$$

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

where Q_{it}^S is the supply of maize at district i at time t, P_{it}^{border} is the maize price 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 P_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.

FRA activities are intended to smooth price both over time and over space. Most of the FRA purchases are made during the harvest season between July to October from smallholdings in surplus maize areas, then stored in the storage facilities in the major districts. Most of the sales are made from December to March, at a subsidized price to commercial millers in cooperation with the FRA (Mason and Myers, 2013). The monthly shares of FRA purchase and sales are presented in Figure 4.

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

$$\text{FRA}_{mt}^S = h(P_{mt}, month) \qquad (3)$$

$$\text{FRA}_{it}^S = h(D_i \; x \; P_i^d \; x \; \text{FRA}_{mt}^S) \qquad (4)$$

$$\text{FRA}_{it}^D = v(\overline{P}_t, E(Q_{it}^S - Q_{it}^D), \text{FRA}_{i,t-1}^D) \qquad (5)$$

where FRA_{mt}^S is the quantity of FRA sales of at time t at districts with miller and is strongly determined by local prices at time t, P_{mt} 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 lcoal 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 and farmers consequently 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 $\text{FRA}^D_{i,t-1}$ and estimated

current excess harvest $E\left(Q^S_{it} - Q^D_{it}\right)$ 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.

$$P_{it} = f(Q^S_{it} + \text{FRA}^S_{it}, Q^D_{it} + \text{FRA}^D_{it}) \qquad (6)$$

Without the FRA, the 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 transport cost up to a maximum of the price of South

African maize plus transport price. But 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 prices

difference between lean seasons and harvest seasons. In other words, they have a

smoothing effect over time. Figure 5 shows the spatial distribution of the average price

during the lean season and harvest season. The average price in Lusaka during the harvest

season was around 608 ZMK for the study period and in a district in the production

region, Chipata, the average during the harvest season is 587 ZMK. The gap between the

two regions are widened during the lean season as the price in Lusaka rises to around 738

when the price in Chipata is at 651.

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 covers a broad range of markets in different geospatial areas and are updated at a monthly frequency. Given the data limitation, we follow the approach used in Chapoto and Jayne (2009) and start with a reduced form framework with demand and supply shifters as regressors subject to the availability of data.

We identify the effect of FRA purchases by the assumption that they will have the most substantial effect in those locations where they buy, and that the effect of FRA sales will be largest at the mills where they are made, and that effect will dissipate over space. Due to the incomplete infrastructure and a lack of market information system, the prices are not perfectly integrated between the primary district markets. Table A1 presents results on price integration analysis. For the six selected district markets from different geographic regions in Zambia, we see at most two cointegration relationships among them from the result of Johansen Co-Integration Trace Test. The trace test is conducted on the original price data since the unit root test presented in Table A2 suggest the price series of six selected markets are stationary in levels. The test results 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. Thus, we expect that local supply and demand shocks such as instituted through FRA sales and purchases, will have strong local price effects.

We apply a vector of weather measures in the previous growing season as exogenous supply shifters to the maize harvested by smaller holder farmers, since the

actual quantity of maize supplied is endogenous to maize prices. We use local market weather as controls in the main specification and use weather shocks in the production region and the average weather shocks in the entire country as part of the robustness checks. 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.

With all these factors considered, we estimate a reduced form model (equation 6) to evaluate the effects of FRA purchase and FRA sales on price levels and price stability. Using a standard panel approach, we control for unobserved or unmeasurable heterogeneity within each district market that do not vary over time.

$$Y_{it} = \text{FRA\_buy}_{it}\alpha + \text{FRA\_sale}_{it}\beta + W_{i,t-1}\gamma + X_{it} + \text{month}_t + \text{mkt}_i + \varepsilon_{it} \qquad (6)$$

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 (usually they do not occur at the same time), $W_{i,t-1}$ is a vector of weather variables from the previous growing season, X_{it} is a vector of other covariates of demand and supply shifters, and ε_{it} is a random error term. The coefficient of interest throughout the paper is α, the effect of FRA purchase on the prices and β for the effects of FRA sales. The price deviations variable is generated by the squared term of the deviation from the long-term average price of each district. We employ district fixed effects models to control for unobserved time-invariant factors that might affect food production and food prices such as the geographical location and climate associated with it. We control for seasonal effects by adding month dummies in the model.

The potential problem with the above regression is that the current FRA purchases and FRA sales are endogenous to current local prices, P_{it}. As is discussed earlier, the OLS estimator of the coefficient of FRA purchase would underestimate since the purchases are typically made in places of surplus maize and price tend to be more stable. At an extreme, the estimated coefficient on FRA sales might be the opposite of what we expect them to be, if not attenuated to zero.

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 2010/2011 marketing year), the Central Statistics Office of Zambia surveys during in the spring before harvest, to get an estimate of the local production for the major districts. The CFS collects a nationally representative sample to get an estimate of national harvest and are used as references for setting goals for FRA purchases quantity and FRA purchase price. By analyzing the CFS data, we get an estimate of the harvest before the actual harvest for each year.

We use an instrument for FRA purchases by using the 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 behaviors, but not the instrument does not affect prices in a particular year directly. Since we are interacting the production with long-run averages shares, the instrument is not strongly correlated to a specific year's harvest and hence not impacting the current local supply of maize directly.

We instrument for distance-weighted FRA sales at a district by using predicted FRA stock, weighted by the number of millers in each district and by the distance to the nearby districts with millers. The validity of this instrument lies in that the estimated FRA stock is dependent on long term shares and are not strongly associated with shocks to food prices in a specific year. Distance to districts with milling companies are also relatively exogenous and tend to stay the same during the 5-year study period. Figure 6 is a map of predicted FRA purchase and sales in each district markets.

4. **Data and Variables**

Our estimation is based on the following data. First, we use monthly Zambia maize prices observed from Jan. 2003 to Dec. 2008 from 32 different markets that spread out in different geolocations in Zambia (a map of markets shown in Figure 3). There is considerable variation among the markets, including food demand, population, food production and cost of transportation. 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 as the main specification. The deviations are calculated by the squared term of the difference between the price in a certain district and the national average maize price of that month. We also compare the Coefficient of Variation (CV) between the historical prices and

In terms of explanatory variables, we use annual Zambia FRA purchases from 2002 to 2009 from different local district markets and monthly national aggregated FRA sales from the Food Reserve Agency and the Central Statistics Office of Zambia. Since Zambia relies on maize imports from South Africa in times of food shortage and that

South Africa is the major producer of excess maize in Southern Africa (Myers and Jayne 2012), it makes sense to include the South African maize price as a control variable. The South African maize price (SAFEX) data are monthly average spot prices from the Johannesburg Stock Exchange. The SAFEX price is 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 import tariff from the Zambia Revenue Authority. The names and location of the larger commercial millers working with the FRA come from the Central Statistical Office (CSO) of Zambia.

We generate measures of agriculturally-relevant precipitation from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) dataset (Funk et al., 2015). The CHIRPS dataset is a combination of satellite imagery and station weather data since there are few public station weather data exist in Zambia. To measure the effects of weather on agriculture more accurately, we use the total amount of rainfall that fell during the October–April growing season. To capture the nonlinearity in the effect of rainfall on agricultural production, the regressions also includes a squared term of rainfall following Schlenker and Roberts (2006). For the same season, we define the length of the longest dry spell as the number of days with no rain in the entire growing season. To measure the beginning of the rainy season, we calculate the number of days after October 1st in which rainfall more significant than 10 mm fell three days out of 5. These three variables are taken from the prior agricultural season to predict food availability for the June/July maize harvest. Temperature data are from the Princeton Global Forcing (PGF) dataset (Sheffield et al., 2013), also limited to the maize growing season. We created average temperature during the growing season. Using 5km-daily resolution data, the

weather measures used in this paper are more accurate and complete compared to only using precipitation as in Dorosh (2009) and Chaopoto and Jayne (2009). All the weather variables are averaged among the districts in the production region to reflect the total effect of weather on the maize production in the entire country in that year.

Table 1 presents the summary statistics of the key variables used in the analysis.

5. Results

This paper tries to address three types of price variation: over time within the year (seasonal), over space within the year (spatial) and between years (annual). Our main model address the first two kinds of price variation through a panel regression, taking advantage of the variations in the timing and location of FRA intervetions.

For both of the outcome variable, we estimate four specifications as follows. Model (1) is a fixed effect model, assuming all the regressors are exogenous. Model (2) is a fixed-effects model with instrumental variables and the estimated coefficient on the variables of interest (FRA purchase and FRA sales) are obtained through a two-stage least squares (2SLS). Model (2) is our main specification and the preferred model because it controls for the endogeneity of various explanatory variables as described above. Models (3) and (4) use the same estimation method on the key variables but are using different specifications for robustness checks. Model (3) includes year dummies instead of the weather variables. Model (4) explores monthly variations in the model by including the price of the same district from the previous month in the model. In this specification, most of the annual level control variables are removed by comparing prices

from one month to another. All of the four specifications include the month fixed effect

and market fixed effect to control for seasonal effects and time-invariant unobservables.

In all the instrumental variables 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.

Table 2 presents the regression results of the maize price regressions. As

expected, we can see the FRA purchases increases maize price during the harvest month,

and FRA sales decrease maize prices during the lean across four different model

specifications. All the estimates are that the variables of interest are statistically

significant. By comparing the OLS estimates (Model (1)) and the IV estimates (Model

(2)), we notice the sharp contrast in the scale of the estimated coefficient on the FRA

sales variable. When we fail to account for the endogeneity in the sales behavior, the

estimated coefficients of the FRA sales variable are attenuated toward zero or even

positive with a marginal effect of only -0.458. The 2SLS estimate of the marginal effect

on the FRA sales on price is as large as -7.908. In other words, the FE model risks

underestimating the true underlying effects of FRA sales in decrease price swings by

proving liquidity to the maize market through releasing stocks and subsidizing the price

that the farmers are getting. The 2SLS estimates of the marginal effect of the FRA

purchase on prices are similar to the OLS estimate, and both are showing a statistically

positive effect on the maize prices. To put numbers in perspective, for an averaged

purchase quantity of 1000 MT 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, as our FRA sales variable are distance-weighted.

We find that, all else equal, the average amount FRA sales help to lower the mean price of maize during the lean seasons by as much as 7% in Lusaka, 3% in Kitwe and the effect decreases towards 0 as the distance to districts with commercial millers increases.

The estimates from the model provide important insights on the spatial variation of the effects of FRA activities have on prices in different regions. On the purchase side, the amount of FRA purchases varies from one location to another. On the sales side, the distance from the major distribution centers matters. We demonstrate the different effects of FRA activities in different local markets by plotting the simulated prices without FRA activity against the actual prices in Figure 7. 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 north-eastern production region, we mainly observe the effects of FRA purchases on increasing prices during the harvest months. In Lusaka, the country's capital city and a net consumption region, the effect of FRA sales during the lean season are much stronger.

Comparing the estimation results from model (3) and model (4) with our main specification model (2), we see that the estimates are consistent in signs and significance. Model (3) uses yearly dummies as a proxy for weather variables, and the estimated coefficient are slightly bigger than the ones in the model (2). This shows that the omitted variable of weather is positively correlated with the prices by reducing maize supply. Model (4) is essentially a price difference regression by having the lagged price in the regression and the variables measured at the annual level are removed. While the interpretation of the marginal effects of the model (4) and model (2) are slightly different,

the coefficients are mostly consistent with our main specification, suggesting that the relationship between FRA sales and FRA purchase also exists in short term variables between months.

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 the prices since the marginal effect of precipitation on price is negative after the precipitation is higher than a certain threshold. The later the first day of rain of the growing season comes, higher the maize prices. Mean temperature has a negative and statistically significant effect on maize prices. This shows that higher mean temperature increases grain supplies and decreases maize prices.

Across the three different specifications with instrumental variables in Table 2, the under-identification test and weak instruments test to support the validity of the 2SLS estimates. 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 a 5% significance level. The Anderson canon. Corr. 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 Table 3. The model specification and variables in the model are the same as the price regressions presented in Table 2 but 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 maize price of FRA sales via releasing grain stocks during the lean season. Similar to the marginal effect estimated on the price regressions, the IV estimator is much larger in scale compared to the OLS estimates. This shows the endogeneity involved in the FRA sales and prices drives the estimate of marginal effect towards 0 and underestimates the stabilizing effect of FRA activities. This might help to explain the results in previous literature that stockholding policy has no significant impact on stabilizing the market when we would expect them to.

To show the heterogeneous effects of FRA activities on different districts, Table 4 shows the results of running our main regression on different subsamples. Column 1 is the same result from Table 2, presenting the average effect on the 32 district markets. We split the sample by identifying the wholesale and retail market centers in the Production and Trade Flow Maps by FEWSNET (2018). Market Centers are where maize is assembled or sold collectively, and there are 19 of them out of a total 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 more significant positive effects on the prices and the FRA sales have a smaller negative effect on the 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 travel to the remote markets, the subsidized maize sales that occur in distant markets would be less likely to affect the retail prices in these markets.

The results above focus on the effects of FRA activities smoothing prices in the same year and across space. In order to address the stabilization effect across year, we compare the coefficient of variation over time of the actual and simulated price in Table

5, following Chapoto and Jayne (2009). The results in Table 5 show that the coefficient of variation for maize grain prices in Zambia are higher with FRA for the majority of the thirty-two markets compared to the hypothetical case when all the FRA interventions are removed, and prices are bounded by the import parity price from South Africa. The simulated CVs are slightly lower than the CVs based on historical prices from 0% to 5% for most of the markets. But our estimates are a lot lower than the estimates in Chapoto and Jayne (2009), where the with intervention CV are 10% to 30% higher. For six of the thirty-two markets (mostly consumer regions), the FRA interventions actually had a stabilization over time, by reducing the CV up to 2.15%. In contrast to the sharp effects of smoothing prices between spaces and within year, our findings show much smaller inter-year smoothing effect, by storing maize grains in good harvest years and releasing the stocks in bad years. This is partially due to fact that it is difficult to store enough grains across years and that we do not observe such patterns (bad year after good year in our study period). Unpredictability in policy changes between years may also add to the increase in price variability itself.

6. Conclusion

Among the wide variety of factors that affect price volatility in staple foods, this paper focuses on the effect of stockholding policy on lessening price instability. Following the previous literature on maize price and policy interventions, the model incorporates the influence of weather-induced production shocks, external market price transmission to separate the influence of the FRA activities. By controlling for the endogenity issues, the

model can identify the effect of estimating the effect of FRA purchase and sales on maize price variability and maize price in Zambia.

A few interesting findings are derived from this empirical investigation. First, consistent with Chapoto & Jayne(2009) and Mason and Myers (2013), we find the FRA activities have a signiciant impact on reducing maize prices and maize price volatity during the lean season and help to support the purchase price that the farmers are getting. In other words, we find FRA activities smoothes seasonal variation as well as spatial variation between the consumption and production regions. Second, this study finds that failing to control for the reverse caulity in food prices and FRA sales would lead to biased estimates of the marginal effects of FRA activities. Third, our result show consumers in the consumption regions benefit most from the policy as we are seeing decrease in both price levels and price volatilities within year and between years. However, the FRA's effect on between year price variations seem to be rather small.

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

The result of this paper might be of interest to policymakers in the Southern Africa region and to developing countries that are considering public grain reserves as means to stablize the grain markets. A few things to consider: first, is the fiscal impact of building the public grain stock worth it? 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 other programs such as subsiding farm inputs and develop 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 on stabilizing the market and then more pressure on the budget. Third, international spillovers might be big as leaks the stabilizing effect to neighboring countries. Fourth, management and transparency matters, late payments to farmers are known to influence the effectiveness on getting more maize from the smallholder farmers.

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
Explanatory variables				
Key variables				
FRA Purchase (MT)	257.466	845.530	0.000	10310.930
FRA Sales (MT)	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				
Production Region				
Predicted purchase target (MT)	134.695	432.409	0.000	4595.748
Predicted sales target (MT)	2.017	6.716	0.000	86.699

Table 2: Regression Results of Maize Price

Price	(1) FE	(2) FE+IV	(3) FE+IV	(4) FE+IV
FRA Purchase	0.020***	0.031***	0.031***	0.020***
	(0.002)	(0.009)	(0.009)	(0.006)
FRA Sales	-0.458***	-7.908***	-7.908***	-4.531***
	(0.092)	(1.491)	(1.491)	(1.004)
Days without rain	23.376***	19.813***		
	(3.262)	(3.058)		
Precipitation	299.684***	249.174**		
	(54.551)	(100.651)		
Precipitation Squared	-0.136***	-0.113**		
	(0.025)	(0.046)		
First Day of Rain	5.829*	4.523		
	(2.953)	(5.056)		
Mean Temperature	-16.658	-112.066*		
	(29.484)	(59.867)		
SAFEX Price	-0.309***	-0.354***	-0.354***	-0.113***
	(0.039)	(0.057)	(0.057)	(0.019)
Price Lag				
				0.554***
				(0.026)
N	2304	2304	2304	2232
Cluster	32	32	32	32
Anderson canon. corr. *LM statistic*	-	33.262	33.262	31.851
Cragg-Donald Wald F *statistic*	-	16.501	16.501	15.823
Year Fixed Effect	No	No	Yes	Yes
Month Fixed Effect	Yes	Yes	Yes	Yes
Market Fixed Effect	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Specifications of the models: (1): FE, (2): FE-IV (using weather variables), (3) FE-IV (using year fixed effect), (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: IV Regression of Maize Price Deviation Squared

Price	(1) FE	(2) FE+IV	(3) FE+IV	(4) FE+IV
FRA Purchase	0.004***	0.005**	0.005**	0.002
	(0.001)	(0.002)	(0.002)	(0.002)
FRA Sales	-0.047**	-1.332***	-1.332***	-0.583*
	(0.020)	(0.360)	(0.360)	(0.304)
Days without rain	7.201***	6.586***		
	(1.879)	(0.737)		
Precipitation	121.214***	112.456***		
	(19.270)	(24.276)		
Precipitation Squared	-0.055***	-0.051***		
	(0.009)	(0.011)		
First Day of Rain	3.864***	3.643***		
	(0.869)	(1.220)		
Mean Temperature	41.693***	25.036*		
	(8.244)	(14.439)		
SAFEX Price	-0.035**	-0.043***	-0.043***	0.003
	(0.013)	(0.014)	(0.014)	(0.011)
Price Lag				
				0.140***
				(0.008)
N	2304	2304	2304	2232
Cluster	32	32	32	32
Anderson canon. corr. LM statistic	-	33.262	33.262	27.983
Cragg-Donald Wald F statistic	-	16.501	16.501	13.845
Year Fixed Effect	No	No	Yes	Yes
Month Fixed Effect	Yes	Yes	Yes	Yes
Market Fixed Effect	Yes	Yes	Yes	Yes

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

Table 4. Robustness Checks for Market Center 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 in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. 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, (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.

Table 5. Coefficient of Variation (%) of Maize Prices in Selected Markets (Historical and Simulated)

Market	Historical Price	Simulated Price	% Difference
Chingola	29.45%	28.70%	0.75%
Chipata	27.23%	24.90%	2.33%
Choma	33.70%	32.13%	1.57%
Isoka	30.01%	26.78%	3.22%
Kabwe	29.58%	26.97%	2.61%
Kalomo	35.46%	31.92%	3.53%
Kalulushi	30.98%	30.98%	0.00%
Kaoma	28.07%	29.13%	-1.05%
Kasama	29.21%	27.97%	1.25%
Kasempa	38.69%	37.41%	1.28%
Kawambwa	30.84%	30.01%	0.83%
Kitwe	28.31%	28.09%	0.22%
Livingstone	36.74%	37.81%	-1.07%
Luangwa	31.69%	31.69%	0.00%
Luanshya	31.01%	31.76%	-0.75%
Lusaka	25.56%	24.30%	1.26%
Luwingu	26.43%	25.76%	0.68%
Mansa	29.67%	29.12%	0.55%
Mazabuka	41.87%	40.84%	1.03%
Mbala	30.21%	25.56%	4.65%
Mkushi	38.72%	35.45%	3.26%
Monze	45.19%	42.91%	2.28%
Mufulira	27.54%	28.17%	-0.63%
Mumbwa	27.41%	25.32%	2.09%
Mwense	28.95%	28.81%	0.14%
Mwinilunga	33.12%	32.59%	0.53%
Nchelenge	29.31%	29.15%	0.17%
Petauke	35.06%	31.55%	3.51%
Samfya	31.15%	30.84%	0.31%
Senanga	34.74%	36.88%	-2.14%
Serenje	32.19%	30.24%	1.95%
Solwezi	26.27%	28.42%	-2.15%

Table A1. Result of Johansen Co-Integration Trace Test on Six Selected Markets in Zambia

Null hypothesis	Alternative hypothesis	Trace statistic	1% Critical value	5% Critical value	Hypothesized No of Cointegrating Equation(s)
r = 0	r = 1	132.98	104.2	90.39	None**
r <= 1	r = 2	89.14	78.87	70.6	At most 1**
r <= 2	r = 3	58.55	55.43	48.28	At most 2**
r <= 3	r = 4	35.09	37.22	31.52	At most 3*
r <= 4	r = 5	17.02	23.52	17.95	At most 4
r <= 5	r = 6	1.95	11.65	8.18	At most 5

Table A2. Augmented Dickey-Fuller Test of Six Selected Markets in Zambia

Market	ADF statistics	p-value	Order of Integration
Lusaka	-4.1233	0.01	Stationary at level, I (0)
Mbala	-3.6429	0.03595	Stationary at level, I (0)
Kaoma	-4.3723	0.01	Stationary at level, I (0)
Solwezi	-3.3507	0.07059	Stationary at level, I (0)
Senanga	-3.7543	0.0264	Stationary at level, I (0)
Kawambwa	-3.9193	0.01831	Stationary at level, I (0)

Table A3. First stage results for Instrumental Variables

	(1)		(2)		(3)	
	FRA Purchase	FRA Sales	FRA Purchase	FRA Sales	FRA Purchase	FRA Sales
Predicted Purchase	1.701***	0.002	1.701***	0.002	1.700***	1.701***
	(0.023)	(0.002)	(0.023)	(0.002)	(0.023)	(0.023)
Predicted Sales	0.380	0.642***	0.380	0.642***	-0.441	0.380
	(1.415)	(0.112)	(1.415)	(0.112)	(1.453)	(1.415)
Days without rain	-0.729	-0.456				
	(4.395)	(0.347)				
Precipitation	-397.965***	-10.717				
	(148.269)	(11.707)				
Precipitation Squared	0.181***	0.005				
	(0.067)	(0.005)				
First Day of Rain	-19.590***	-0.462				
	(7.505)	(0.593)				
Mean Temperature	-236.697***	-12.639*				
	(83.165)	(6.567)				
SAFEX Price	0.084	-0.005	0.084	-0.005	0.048	0.084
	(0.083)	(0.007)	(0.083)	(0.007)	(0.087)	(0.083)
Price Lag					-0.109*	-0.139**
					(0.058)	(0.063)
N	2304	2304	2304	2304	2232	2232
R^2	0.821	0.214	0.823	0.221	0.825	0.218

Figure 1. Annual Maize Production, Maize Yield and Maize Stocks from 1990-2015
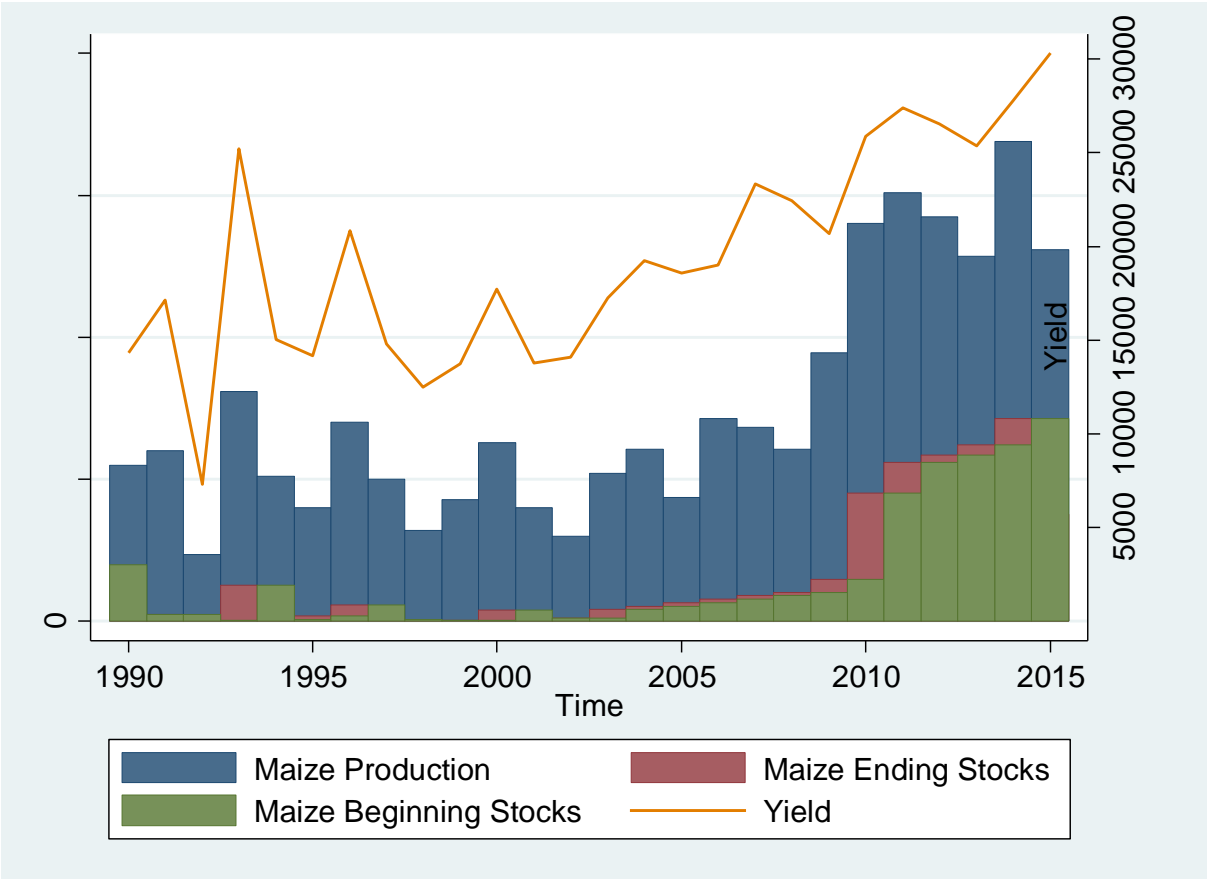
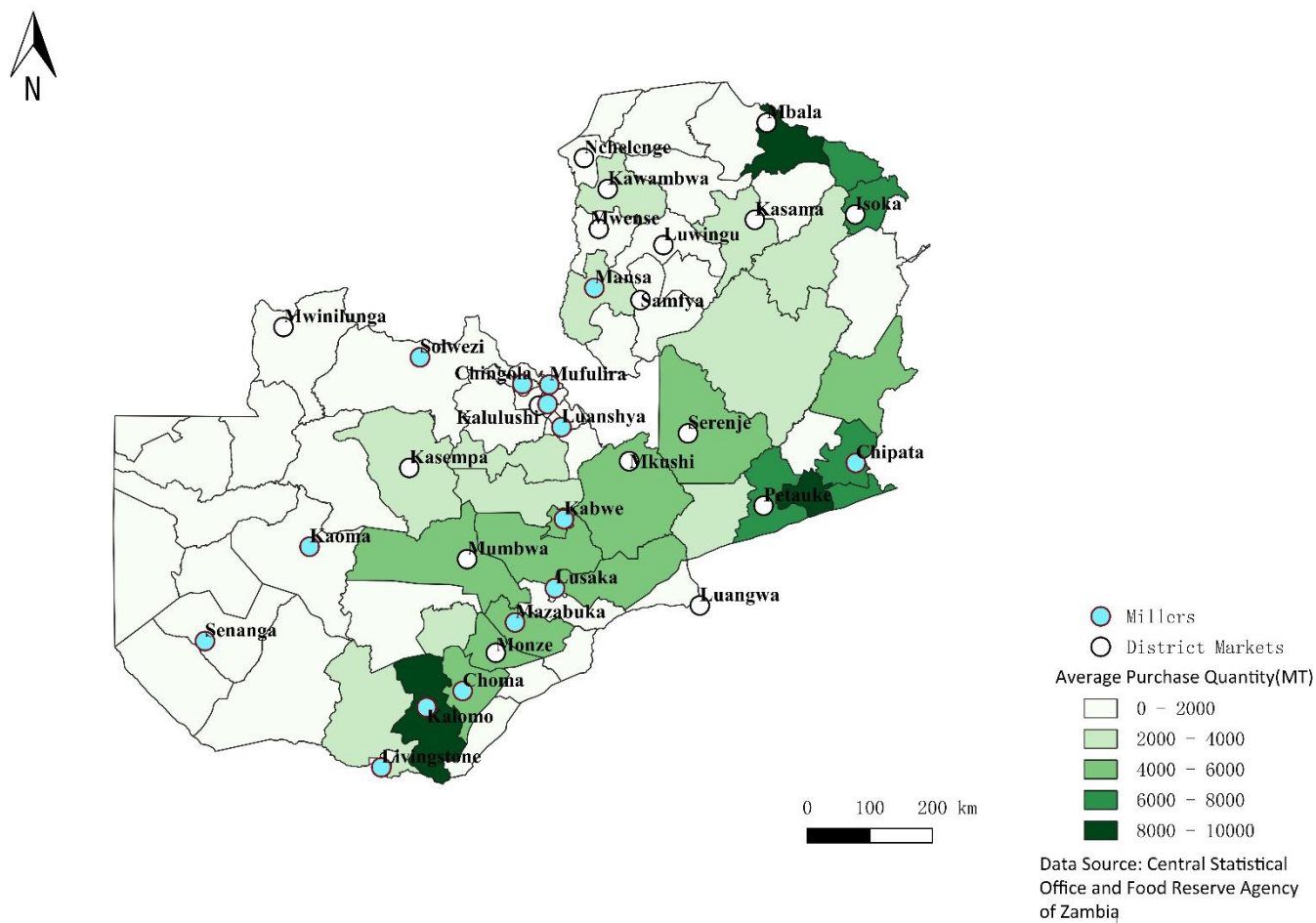**Figure 2. Average FRA Purchase by District from 2002/03 to 2009/10**

Millers
District Markets
Average Purchase Quantity(MT)
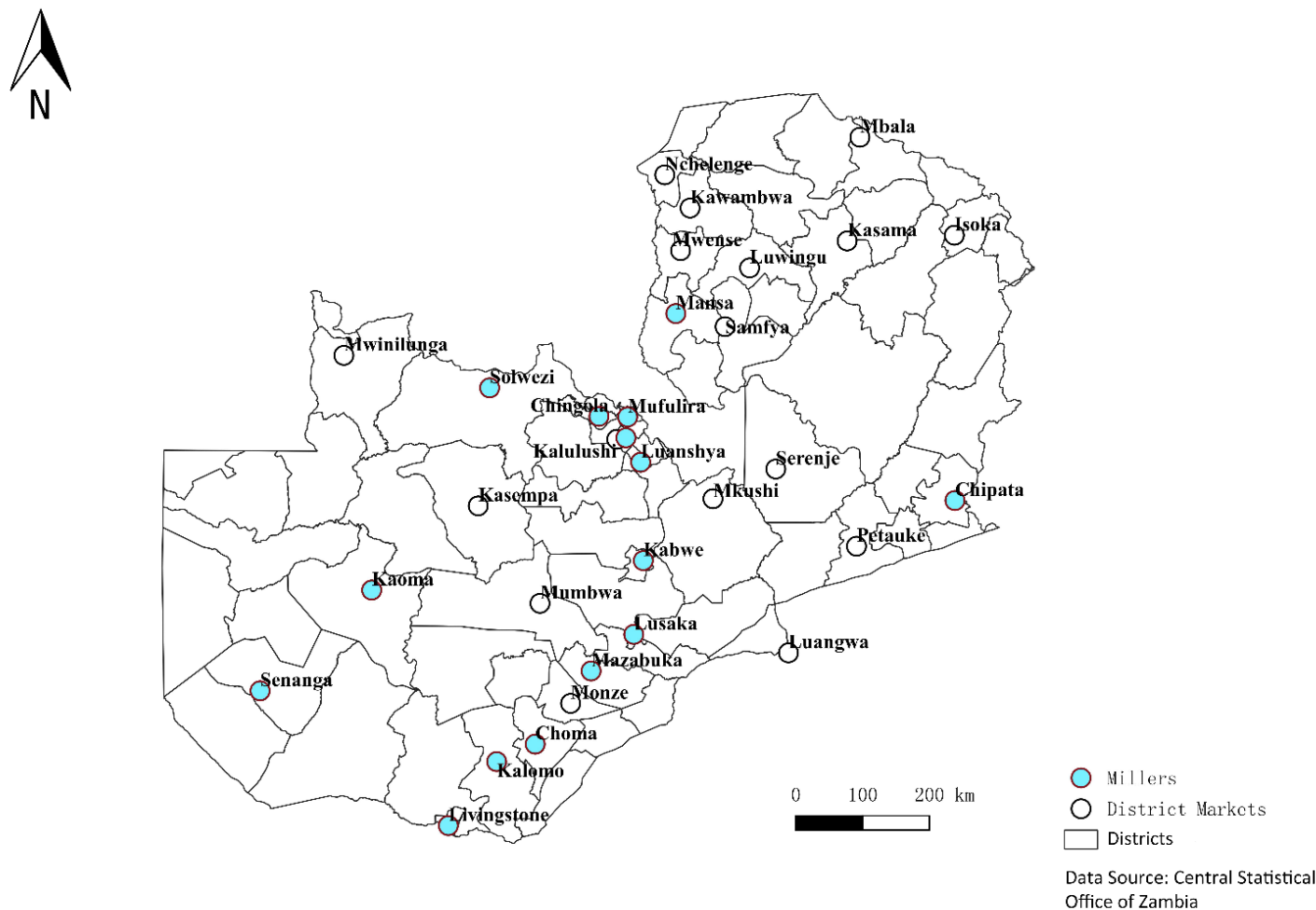
0 – 2000
2000 – 4000
4000 – 6000
6000 – 8000
8000 – 10000

Data Source: Central Statistical Office and Food Reserve Agency of Zambia

Figure 3. Map of Major District Markets in Zambia

Data Source: Central Statistical Office of Zambia

Figure 4. Monthly Shares of FRA Purchase and Sales
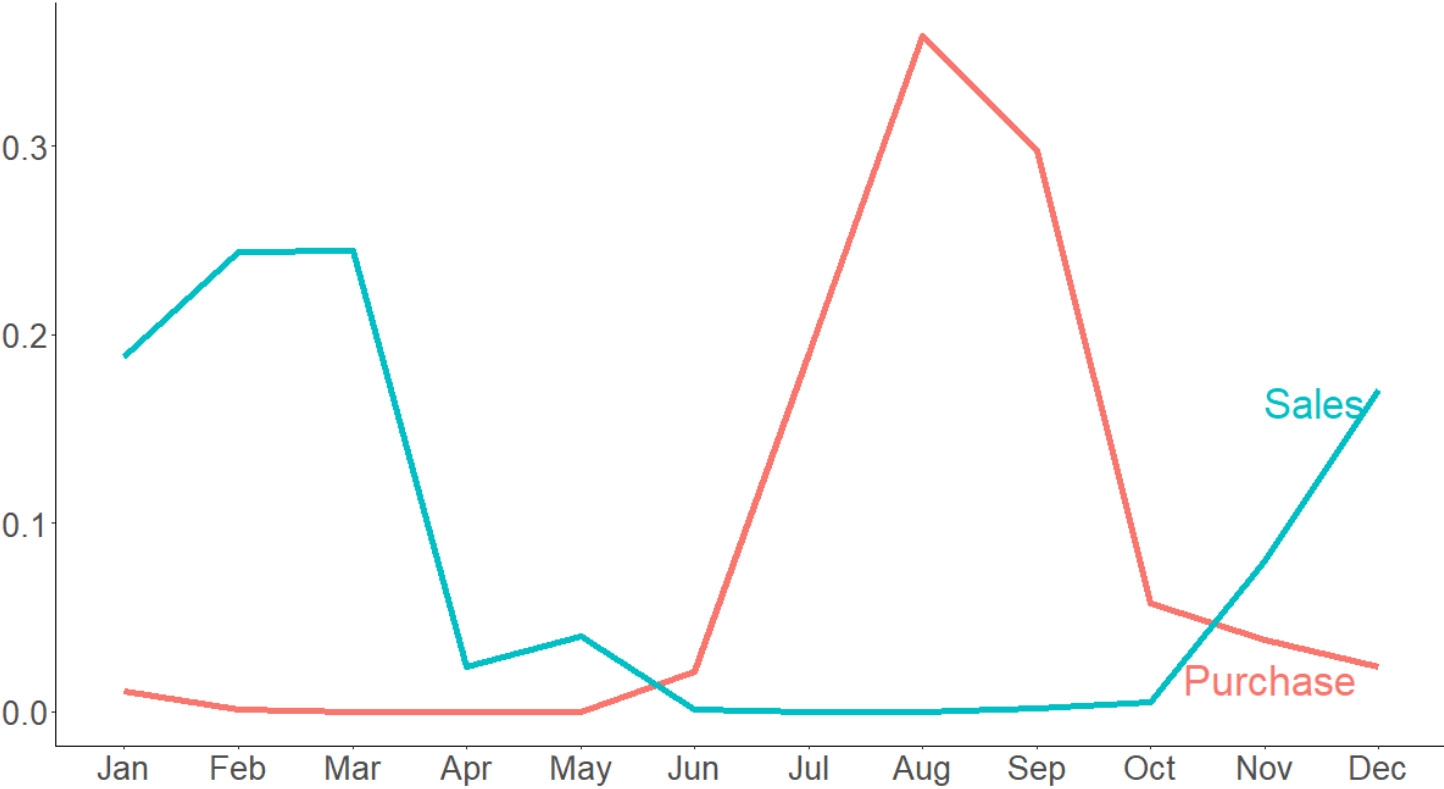
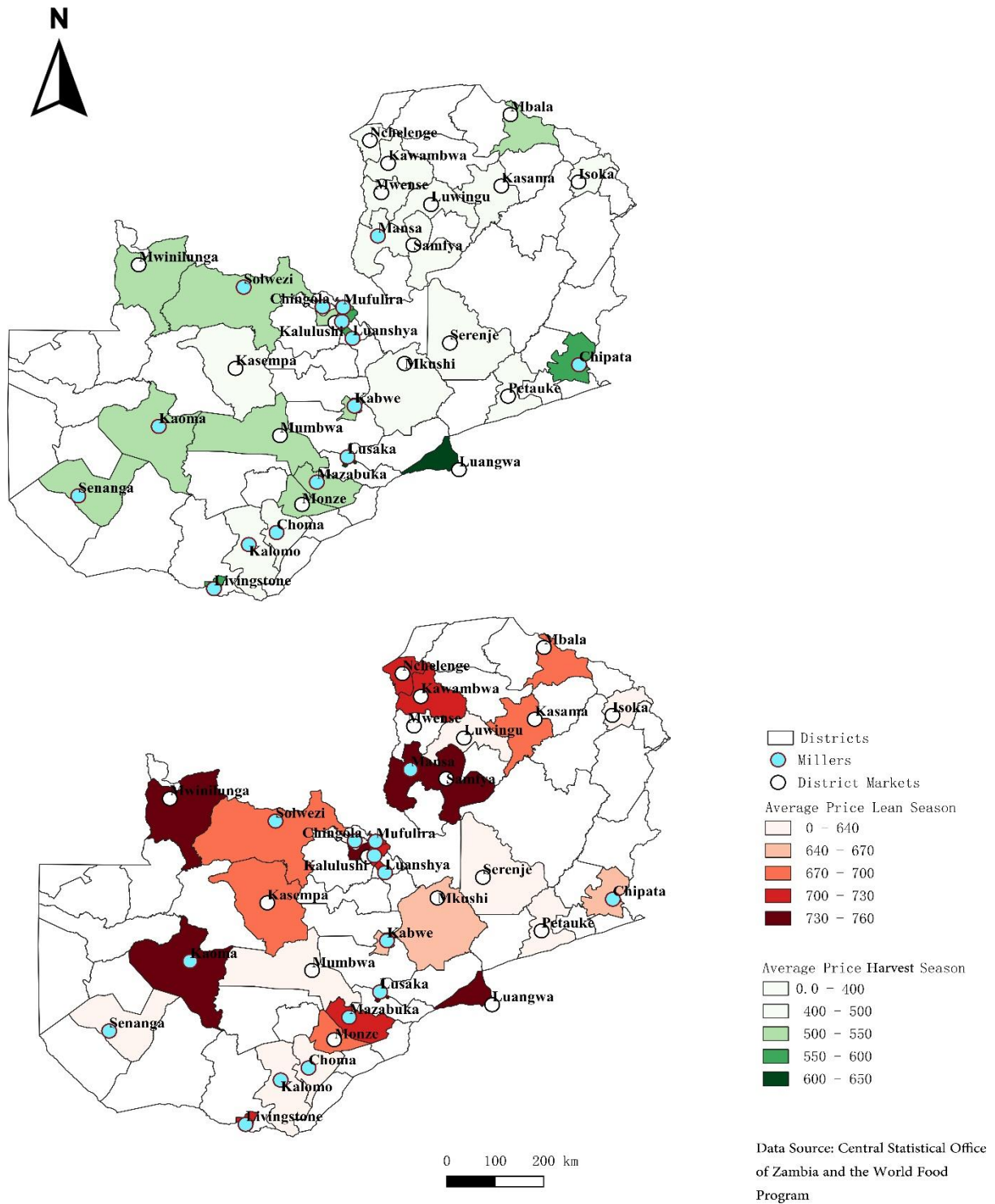**Figure 5. Average Price Distribution by District in Lean Season and Harvest Season**

Data Source: Central Statistical Office
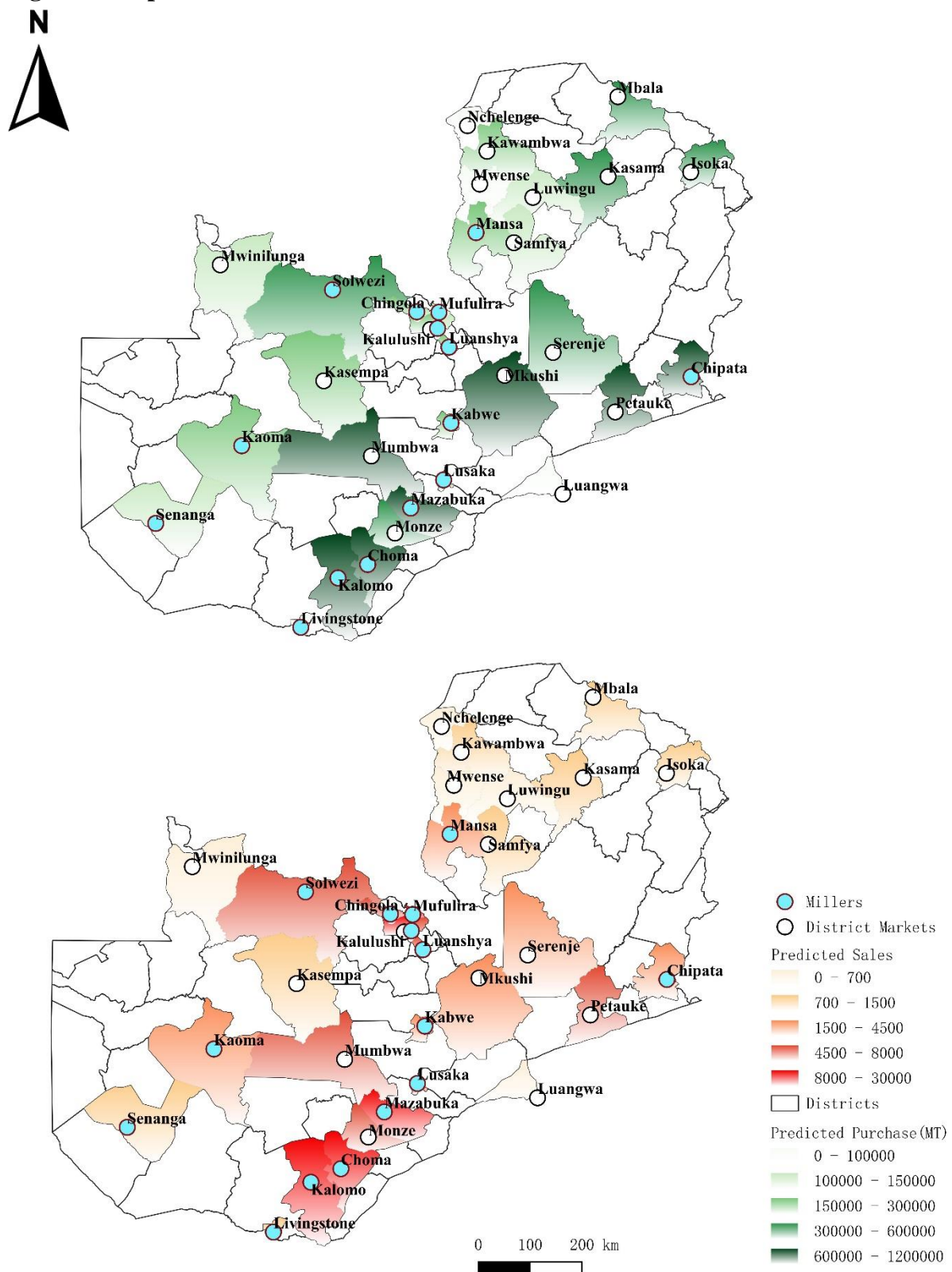of Zambia and the World Food
Program

Figure 6. Map of Predicted FRA Purchase and Sales

Data Source: Central Statistical Office of Zambia and the World Food Program

Figure 7. Historical and Simulated Price in Production and Consumption Region

Historical and simulated maize price in Mbala

Historical and simulated maize price in Lusaka

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