MARKETING BOARDS, FERTILIZER SUBSIDIES, PRICES, & SMALLHOLDER BEHAVIOR: MODELING & POLICY IMPLICATIONS FOR ZAMBIA

By

Nicole Marie Mason

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ABSTRACT

MARKETING BOARDS, FERTILIZER SUBSIDIES, PRICES, & SMALLHOLDER BEHAVIOR: MODELING & POLICY IMPLICATIONS FOR ZAMBIA

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Grain marketing boards (GMBs), strategic grain reserves (SGRs), and fertilizer subsidies have experienced a renaissance in eastern and southern Africa over the last decade. Relatively little is known about how the re-emergence of GMBs/SGRs as major players in maize markets in the region is affecting smallholder behavior and maize market prices, and although the revival of fertilizer subsidies has received considerably more attention from researchers and policymakers, knowledge gaps remain. The dissertation consists of four essays and the empirical work focuses on the case of Zambia. The Government of the Republic of Zambia (GRZ) has become increasingly involved in maize marketing in recent years through the Food Reserve Agency (FRA), an SGR/GMB. The FRA buys maize from smallholders at a pan-territorial price that typically exceeds wholesale market prices in major maize-producing areas. The scale of GRZ targeted fertilizer subsidy programs has also increased since the late 1990s.

The first essay develops a conceptual model of crop production decisions in the context of dual maize marketing channels (government and private sector) when there is uncertainty about the prices to be paid by both channels and about whether one of the channels will be available come harvest time. The empirical analysis is based on a three-wave, nationally representative household-level panel data set. Estimation results suggest that increases in past FRA maize purchases in a household's district and in the effective (i.e., farmgate) FRA maize price faced by the household at the previous harvest do not have statistically significant marginal effects on the household's maize quantity harvested or total crop output.

The second essay estimates the effects of FRA maize buying and selling price policies and net maize purchases on equilibrium maize market prices in Zambia using a vector autoregression model (VAR) and monthly data from July 1996 through December 2008. Threshold tests generally favor a linear VAR over a threshold VAR. Simulation reults suggest that FRA activities raised mean wholesale maize prices in Lusaka and Choma by 17% and 19%, respectively, between July 2003 and December 2008. The Agency's activities also reduced the variability of maize market prices throughout the period of analysis.

The third essay uses the household-level panel data and constituency-level election data to estimate the effects of past election outcomes on the allocation of GRZ-subsidized fertilizer. Households in constituencies won by the ruling party (the Movement for Multi-Party Democracy, MMD) in the last presidential election receive an estimated 25.6 kg more subsidized fertilizer than households in constituencies lost by the MMD. Furthermore, households in constituencies won by the MMD receive 0.7 kg more subsidized fertilizer for each percentage point increase in the MMD's margin of victory. The MMD appears to use subsidized fertilizer to reward its supporters, and the reward is greater the stronger the support.

The fourth essay also draws on the household-level panel and estimates the marginal effects of GRZ fertilizer subsidies on smallholder fertilizer purchases from commercial retailers and total fertilizer acquisition. Each additional kg of GRZ-subsidized fertilizer received by a household decreases its fertilizer purchases from commercial retailers by 0.14 kg. As a result of diversion and leakage, only approximately 67% of the fertilizer intended for GRZ subsidy programs reaches smallholders through the government channel. Assuming the remaining 33% is resold through commercial retailers, total fertilizer acquisition is estimated to increase by 0.53 kg for each additional kg of GRZ-subsidized fertilizer injected into the system.

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KEY TO ABBREVIATIONS

ADF	Augmented Dickey-Fuller
ADMARC	Agricultural Development and Market Corporation
AE	average elasticity
AER	agro-ecological region
AMIC	Agriculture Market Information Center
APE	average partial effect
ARCH	autoregressive conditional heteroskedasticity
BIC	Schwarz-Bayesian information criterion
BPP	buy price premium
CDFA	Chipata District Farmers Association
CF	conservation farming
CFS	Crop Forecast Survey
CMA	Crop Marketing Authority
CRE	correlated random effects
CSA	Census Supervisory Area
CSO	Central Statistical Office
CSPR	Civil Society for Poverty Reduction
CV	coefficient of variation
DA	District Administrator
DAC	District Agriculture Committee
DMMU	Disaster Mitigation and Management Unit
DRC	Democratic Republic of Congo
ESA	eastern and southern Africa
FAOSTAT	Food and Agriculture Organization Statistical Database
FCP	Fertilizer Credit Programme
FE	fixed effects
FEWSNET	Famine Early Warning Systems Network
FIQI	Fisher-Ideal Quantity Index
FISP	Farmer Input Support Programme
FRA	Food Reserve Agency
FSP	Fertilizer Support Programme
FSPP	Food Security Pack Programme
FSRP	Food Security Research Project
FTE	full-time equivalent
GMB	grain marketing board
GP	Gonzalo and Pitarakis
GRN	Goods Received Note-Crop Purchases
GRZ	Government of the Republic of Zambia
ha	hectare
HH	household
IV	instrumental variable
K	Kwacha

kg	kilogram
km	kilometer
KPSS	Kwiatkowski, Phillips, Schmidt, and Shin
LQI	Laspeyres Quantity Index
LR	likelihood ratio
MA	moving average
MACO	Ministry of Agriculture and Cooperatives
MLFD	Ministry of Livestock and Fisheries Development
mm	millimeter
MMD	Movement for Multi-Party Democracy
MP	Member of Parliament
MT	metric ton
N/A	not applicable
NAMBOARD	National Agricultural Marketing Board
NCPB	National Cereals and Produce Board
NGO	non-governmental organization
OLS	ordinary least squares
PA	prime-age
PAM	Programme Against Malnutrition
PCO	Programme Coordination Office
PHS	Post-Harvest Survey
POLS	pooled ordinary least squares
PP	Phillips-Perron
PRN	Produce Received Note
PPS	probability proportional to size
PRP	Poverty Reduction Programme
PSA	private sector activity
PQI	Paasche Quantity Index
SAFEX	South African Futures Exchange
SD	standard deviation
SEA	Standard Enumeration Area
SEM	structural simultaneous equations model
SFR	strategic food reserve
SGR	strategic grain reserve
SPP	sell price premium
SS	Supplemental Survey
SSA	sub-Saharan Africa
TNH	truncated normal hurdle
TVAR	threshold vector autoregression model
VAR	vector autoregression model
WFP	World Food Programme
ZMK	Zambian Kwacha

CHAPTER 1: INTRODUCTION

Over the last decade there has been a resurgence in direct government participation in agricultural input and output marketing in eastern and southern Africa (ESA). After being scaled back or eliminated during the market reforms of the 1980s and 1990s, fertilizer subsidies, parastatal grain marketing boards (GMBs), and strategic grain reserves (SGRs) are once again en vogue in the region (Jayne and Jones, 1997; Jayne et al., 2002; Jayne et al., 2007).[1] Maize, the main staple grain in ESA, is important both economically and politically. The majority of small farmers grow the crop and maize is the foundation of many governments' implicit or explicit 'social contracts' with constituents. Under these social contracts, the government's role is to support smallholder incomes while keeping food prices low for urban consumers (Jayne and Jones, 1997; Jayne et al., 2007). For example, Tembo et al. (2009: 1) argue that the Government of the Republic of Zambia (GRZ) "sees as its moral mandate to ensure that … producers and consumers alike are not solely at the mercy of unpredictable market forces".

The pendulum shift back toward more direct state involvement in agricultural marketing has been driven by political pressure to deliver on the social contract and facilitated by donors' transition from highly conditional to direct budget support (Jayne et al., 2007). GMBs/SGRs and fertilizer subsidies account for large shares of government spending in several countries in the region. In Malawi, the fertilizer subsidy program accounted for 5% to 15% of the national budget

[1] A marketing board is a state-controlled or state-sanctioned entity established to direct the market and marketing of specific commodities within a given country or other geographic area (Staatz, 2006; Barrett and Mutambatsere, 2008). An SGR is a "public stock of grain used to meet emergency food requirements, to stabilize food prices, and [or] to relieve temporary shortages while commercial imports or food aid are being arranged" (Minot, 2010). Some entities that refer to themselves as SGRs, e.g., the Zambian Food Reserve Agency, have functions, such as grain marketing and market facilitation, that are more characteristic of GMBs.

between 2005 and 2008 (Ricker-Gilbert et al., 2011). In Zambia, from fiscal years 2006 to 2011, budget allocations to the main fertilizer subsidy program and the strategic food reserve accounted for 46% to 71% of the total allocations to the ministries responsible for agriculture, livestock, and fisheries, and at least 90% of the budget allocation for Poverty Reduction Programmes.

Little is currently known about how the revival of GMBs and SGRs as major players in maize markets in ESA has affected smallholder behavior and maize market outcomes. There is a large literature on the effects of GMBs prior to structural adjustment as well as on the effects of their dismantling during the agricultural market reforms of the 1980s and 1990s. However, few studies have examined the effects of the resurgence of GMBs and SGRs in recent years. The main goal of this dissertation is to re-examine the effects of GMBs/SGRs on smallholder behavior and maize market outcomes in light of recent events and modern conditions, and to provide empirical evidence to inform grain marketing policy debates in ESA and elsewhere.

The renaissance of fertilizer subsidies in ESA over the last decade has generally received more attention from researchers, policy makers, and the popular press than has the resurgence of GMBs and SGRs (see, for example, Denning et al., 2009; Duflo et al., 2009; Ricker-Gilbert et al., 2011; Dugger, 2007; Kapekele, 2010). However, knowledge gaps remain. A secondary goal of the dissertation is to contribute to the literature on the targeting and impacts of fertilizer subsidies in the region.

More specifically, the dissertation focuses on Zambia and studies the effects of the Food Reserve Agency (FRA), a parastatal SGR/GMB, on smallholder behavior and maize market prices. The role of past election outcomes in the targeting of GRZ-subsidized fertilizer and the effects of these fertilizer subsidy programs on smallholder behavior are also examined.

Established in 1996, the FRA began buying maize directly from smallholders during the 2002/03 agricultural marketing year and has set a pan-territorial price for maize every year since 2003/04.[2] The FRA buy price typically exceeds wholesale maize market prices in major maize producing areas. During both the 2006/07 and 2007/08 marketing years, the FRA purchased nearly 400,000 MT of maize (more than 50% of the maize marketed by smallholders). This marked a sharp increase in the level of FRA purchases: between its establishment in 1996 and the 2005/06 marketing year, FRA's annual maize purchases only once exceeded 100,000 MT. Following the 2010 harvest, the Agency's market share was 83%, having purchased 878,570 MT of the bumper maize crop. The cost of the 2010 FRA maize purchase exercise is estimated at K1.5 trillion or approximately 9% of the GRZ national budget for 2010 (K16.7 trillion) (Nkonde et al., 2011).

GRZ fertilizer subsidy programs have also expanded since the late 1990s. Fertilizer marketing and pricing were liberalized and direct subsidies to farmers were eliminated as part of the market reforms initiated in 1991. Then, beginning in the 1997/98 agricultural season, GRZ ran a Fertilizer Credit Programme through the FRA (FRA-FCP) that provided fertilizer on credit to targeted smallholder farmers. 15,495 MT of fertilizer were distributed through the program in 1997/98 and during its five years in existence, a yearly average of 30,541 MT were distributed. GRZ moved to a cash-only targeted fertilizer subsidy program for smallholders with the establishment of the Fertilizer Support Programme (FSP) in 2002/03. FSP was renamed the Farmer Input Support Programme (FISP) in 2009/10. FRA-FCP fertilizer was not subsidized *per se* but FSP/FISP fertilizer is subsidized and the subsidy rate has increased over time (e.g., from

[2] The agricultural marketing year in Zambia, henceforth referred to as "marketing year", is from May to April. The agricultural year is from October through September.

50% in 2002/03 to 75% or higher in recent years). The scale of FSP/FISP has also grown (e.g., from 48,000 MT in 2002/03 to 106,000 MT in 2009/10).

The dissertation consists of four essays. The first essay (Chapter 2) is entitled "Smallholder Behavioral Responses to Marketing Board Activities in a Dual Channel Marketing System: The Case of Maize in Zambia". In this essay, I use nationally-representative household-level panel survey data to estimate the marginal effects of changes in the FRA's past maize purchase price and quantities purchased on smallholder fertilizer use and crop production, while controlling for the effects of GRZ fertilizer programs and other factors. The panel data set captures years before and during the recent scale-up of FRA's domestic maize purchases. The specific outcome variables examined are fertilizer use on maize (kg/ha) and total, maize, and non-maize area planted, crop output per hectare, and crop output. The analysis also generates estimates of the marginal effects of changes in the quantity of GRZ-subsidized fertilizer acquired by a household on these outcome variables.

Beyond these empirical contributions, I also develop a conceptual framework that models production decisions in the presence of dual marketing channels (e.g., government and private sector) when there is uncertainty about the prices to be paid by one or both of the channels, and possibly uncertainty about whether one of the channels will be available come harvest time. These are situations that exist in many agricultural settings throughout the world. Maize prices offered by private sector buyers and by the FRA at harvest are not known to households at the time that land preparation, planting, and other input use decisions are made. Furthermore, the FRA does not announce its planned maize purchase quantities or buying depot locations until harvest time. Households' decisions must therefore be based on their *expectations* of the FRA's purchase price and buying presence in their locality, and of prices to be offered by private buyers. In the essay, I develop a conceptual model to capture these elements of the decision-making environment, and then operationalize the model and apply it to the FRA/Zambia case. The conceptual framework and empirical strategy should have wide applicability beyond the FRA/Zambia context.

The second essay (Chapter 3) is entitled "The Effects of the Food Reserve Agency on Maize Market Prices in Zambia: Are There Threshold Nonlinearities?". In this essay, I use monthly data from July 1996 through December 2008 to estimate the impacts of the FRA's buying and selling price decisions and net maize purchases on the level and variability of wholesale maize prices in Zambia. The general perception is that the FRA's activities have raised the level of maize prices and one of the Agency's goals is to stabilize maize market prices (Govereh et al., 2008; FRA, n.d.). The essay builds on the vector autoregression (VAR) model used by Jayne et al. (2008) to estimate the effects of the activities of the National Cereals and Produce Board on wholesale maize prices in Kenya. I extend the Jayne et al. (2008) framework to allow for threshold nonlinearities in the underlying dynamic relationships among FRA policy variables and market prices in Zambia. Testing for threshold effects and estimating a threshold VAR if such nonlinearities are detected is important because if thresholds exist but the system is constrained to be linear (no thresholds), then the inferences drawn and resultant conclusions and policy implications may be incorrect. The threshold VAR approach used in this paper is readily applicable to estimating the effects of SGR and/or GMB activities on market prices in other countries.

An additional contribution of the paper is that I consider multiple potential threshold variables and use the Gonzalo and Pitarakis (GP, 2002) sequential procedure to test for the existence and number of thresholds. Past applications of threshold VARs in the agricultural economics literature have typically considered only one potential threshold variable and relied on the multivariate version of Hansen's bootstrap p-value procedure to test for threshold effects (Hansen, 1996; Lo and Zivot, 2001; Hansen and Seo, 2002). I consider four candidate threshold variables and use both the Hansen and GP threshold testing approaches. To my knowledge, this is the first application of the GP procedure in a VAR setting. The advantage of the GP approach is that it is valid for selecting between a linear model and a threshold model, and for discriminating among threshold models with different numbers of regimes. While the Hansen approach has also been used in this way, its validity has only been demonstrated for testing a linear model against a threshold model (Hansen, 1999; Gonzalo and Pitarakis, 2002).

The third essay (Chapter 4) is entitled "Rewarding Loyalty: Election Outcomes and Government-Subsidized Fertilizer Allocation in Zambia". Although fertilizer subsidy programs in sub-Saharan Africa generally have widespread popular support, there have also been accusations of mismanagement and politically driven targeting. The research question in this essay is to what extent are allegations that electoral politics influence subsidized fertilizer allocation supported by empirical evidence from Zambia? The analysis draws on nationally representative panel survey data covering more than 5,000 smallholder households and collected by the Zambia Central Statistical Office, Ministry of Agriculture and Cooperatives, and Food Security Research Project in conjunction with constituency-level presidential and parliamentary election data from the Electoral Commission of Zambia. I estimate the *ceteris paribus* effects of several election outcome-related variables on the quantity of government-subsidized fertilizer received by a household. The paper builds on and complements a recent study by Banful (2011) that examines the effects of presidential election outcomes on the allocation of subsidized fertilizer vouchers at the district level in Ghana in 2008. The essay differs from Banful (2011) in that it: (i) examines the impacts of past election outcomes on household-level allocation of subsidized fertilizer as opposed to district-level allocation; (ii) uses panel data instead of cross-sectional data and so can better control for time-invariant unobserved heterogeneity that may otherwise render the econometric estimates biased and inconsistent; and (iii) explores the effects of parliamentary election outcomes in addition to presidential election outcomes as in Banful (2011). The results in this essay should be of considerable interest to policymakers, donors, and Zambian citizens.

The fourth essay (Chapter 5) is entitled "Fertilizer Subsidies and Smallholder Fertilizer Purchases: Crowding Out, Leakage, and Policy Implications for Zambia". The essay uses the same conceptual framework and empirical strategy developed in Chapter 2 but focuses on the impacts of an increase in the quantity of GRZ-subsidized fertilizer received by a household on its demand for fertilizer from commercial retailers at market prices. The change in total fertilizer use resulting from a government fertilizer subsidy program will depend on, *inter alia*, the extent to which the program "crowd outs" or "displaces" commercial fertilizer purchases.

Two studies have estimated the displacement effect of fertilizer subsidies: Xu et al. (2009) for Zambia and Ricker-Gilbert et al. (2011) for Malawi. The essay revisits the issue of displacement and builds on these previous studies in a number of ways. I extend the conceptual framework used by Xu et al. (2009) and Ricker-Gilbert et al. (2011) to incorporate leakage of government-subsidized fertilizer into commercial channels, a problem reflected in empirical and anecdotal evidence from Zambia. I then apply the framework to the Zambia case and use nationally representative panel household survey data covering the 1999/2000, 2002/03, and 2006/07 agricultural seasons to produce updated estimates of the marginal effects of GRZ fertilizer subsidies on total and commercial fertilizer demand by smallholders. (The 2006/07 data did not become available until after the publication of Xu et al. (2009).) The estimation strategy deals with the potential endogeneity of subsidized fertilizer in a commercial fertilizer demand equation using an instrumental variables (IV)/control function approach as in Ricker-Gilbert et al. (2011). Past election outcome-related variables are used as IVs for the quantity of subsidized fertilizer received by a household. The econometric models also control for the potentially confounding effects of past FRA activities on smallholder fertilizer demand.

The final chapter of the dissertation (Chapter 6) summarizes the main empirical findings and policy implications that emerge from the four essays.

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CHAPTER 2: SMALLHOLDER BEHAVIORAL RESPONSES TO MARKETING BOARD ACTIVITIES IN A DUAL CHANNEL MARKETING SYSTEM – THE CASE OF MAIZE IN ZAMBIA

2.1 Introduction

More than two decades after the initiation of agricultural market reforms in eastern and southern Africa (ESA), which entailed the abolishment or restructuring of parastatal agricultural marketing boards and the liberalization of agricultural input and output markets, several governments in the region continue to be directly engaged in staple food marketing (Jayne and Jones, 1997; Jayne et al., 2002; Jayne et al., 2007). While the recent re-introduction or scaling-up of fertilizer subsidy programs, particularly in Malawi, has received much attention in the popular press and from policy makers and researchers (see, for example, Denning et al., 2009; Duflo et al., 2009; Ricker-Gilbert et al., 2011; Dugger, 2007; Kapekele, 2010), governments in ESA are also increasingly using parastatal grain marketing boards (GMBs) and/or strategic grain reserves (SGRs) to directly influence the prices faced by farmers and consumers.[3]

Zambia is a key example. The Government of the Republic of Zambia (GRZ) distributed a total of 528,000 MT of subsidized fertilizer between the 2002/03 and 2009/10 agricultural seasons through its Fertilizer Support Programme, which was renamed the Farmer Input Support Programme in 2009 (FSP/FISP). The GRZ strategic food reserve, the Food Reserve Agency (FRA), purchased nearly 400,000 MT of maize from smallholders, or more than 50% of the

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[3] A marketing board is a state-controlled or state-sanctioned entity established to direct the market and marketing of specific commodities within a given country or other geographic area (Staatz, 2006; Barrett and Mutambatsere, 2008). A strategic grain reserve is a “public stock of grain used to meet emergency food requirements, to stabilize food prices, and [or] to relieve temporary shortages while commercial imports or food aid are being arranged” (Minot, 2010). Some entities that refer to themselves as SGRs, e.g., the Zambian Food Reserve Agency, have functions, such as grain marketing and market facilitation, that are more characteristic of GMBs.

maize marketed by this group, in both the 2006/07 and 2007/08 agricultural marketing years.[4] This marked a sharp increase in the level of FRA purchases: between its establishment in 1996 and the 2005/06 marketing year, FRA's annual maize purchases only once exceeded 100,000 MT. The new high water mark is the 2010/11 marketing year, during which the FRA purchased 878,570 MT of maize (83% of expected smallholder maize sales). The FRA buys maize at a pan-territorial price that often exceeds market price levels; private trade is legal and private buyers are allowed to buy maize at prices above or below the FRA price. Together, FRA and FSP/FISP accounted for over 90% of the GRZ budget allocation to Poverty Reduction Programmes in the 2006 through 2011 budget years.

Despite the re-emergence or continuation of GMBs/SGRs as important players in grain markets in ESA, little is known about how these agencies' scaled-up activities are affecting fertilizer use and crop production by smallholder farming households. The large existing literature on the impacts of GMBs in eastern and southern Africa focuses mainly on the decades prior to the initiation of agricultural market reforms, and on the effects of the dismantling or downsizing of these entities during the 1980s and 1990s (e.g., Jansen, 1991; Krueger, 1991; Schiff and Valdés, 1991; Masters and Nuppenau, 1993; Krueger, 1996). The current paper revisits the impacts of GMBs/SGRs on smallholder behavior in light of recent events, modern conditions, and new, more detailed and disaggregated data.

For example, previous studies on this topic are based mainly on aggregate, often national-level, data. Few studies have used household-level survey data to investigate the micro-level processes through which GMBs or SGRs affect smallholder behavior. Nor has there been an

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[4] Smallholder households are those cultivating less than 20 ha. The agricultural marketing year in Zambia, henceforth referred to as "marketing year", is from May to April. The agricultural year is from October through September.

investigation of how these entities' operations differentially affect smallholder farmers with varying levels of land and other productive assets, despite the widespread understanding that African farmers are highly heterogeneous. An exception is the study by Kutengule et al. (2006), which uses household-level data from Malawi to estimate the effects of proximity to Agricultural Development and Market Corporation (ADMARC, a GMB) facilities on household per capita expenditures. Distance to ADMARC facilities is used as a proxy for access to ADMARC services. The data used in Kutengule et al. (2006) are essentially cross-sectional and so time invariant unobserved household-level heterogeneity, which could have important effects on household expenditures, could not be adequately controlled for.

A second household level study that is somewhat related to the effects of GMBs/SGRs on smallholder behavior is Mghenyi et al. (2010), which estimates the effects of a 25% maize price increase on the welfare of smallholder households in rural Kenya in 2004. The magnitude of this maize price shock is roughly comparable to the estimated change in wholesale maize prices as a result of Kenya National Cereals and Produce Board (NCPB, a GMB) activities between 1995 and 2004 per Jayne et al. (2008). Unlike the FRA, which sources its maize mainly from smallholder farmers, the NCPB buys maize mainly from large-scale, commercial farmers. Mghenyi et al. (2010) do not explicitly model the effects of NCPB activities on smallholder behavior.

Another feature that distinguishes grain markets in ESA today from those in the pre-structural adjustment period is that today, private grain trade is usually legal even in countries with GMBs/SGRs. Prior to agricultural market reforms, parallel grain markets often existed in countries with GMBs but private grain trade was usually illegal. Hence, further analysis is needed to understand the effects of GMBs/SGRs in the context of dual legal marketing channels.

In this paper, I use nationally-representative household-level panel survey data from Zambia to estimate the marginal effects of changes in the FRA's past maize purchase price and quantities purchased on smallholder fertilizer use and crop production, while controlling for the effects of GRZ fertilizer programs and other factors. The panel data cover the 1999/2000, 2002/03, and 2006/07 agricultural seasons and therefore capture years before and during the recent scale-up of FRA's domestic maize purchases. The specific outcome variables examined in the study are fertilizer use on maize (kg/ha) and total, maize, and non-maize area planted, crop output per hectare, and crop output.

Modeling and estimating the marginal effects of changes in past FRA policies and in GRZ fertilizer programs on smallholder factor demand and output supply present three main challenges. First, like most other GMBs/SGRs in the region, the FRA does not announce its maize buy price or intended purchase quantities and buying depot locations until harvest time, so FRA plans are not known to households at the time they make land preparation, fertilizer use, and planting decisions. Prices offered by private sector buyers at the next harvest are also not known at this time. Households' decisions must therefore be based on their *expectations* of the FRA's purchase price and buying presence in their locality, and of prices to be offered by private buyers. The price expectations process is further complicated by the fact that FRA pricing decisions may affect price expectations in private maize markets. In this paper, I develop a conceptual model to capture these features of the decision-making environment. This framework should have wide applicability beyond the Zambia/FRA context. It models production decisions in the presence of dual marketing channels when there is uncertainty about the prices to be paid by one or both of the channels, and possibly uncertainty about whether one of the channels will even be available come harvest time. These are situations that exist in many agricultural settings throughout the world.

A second challenge relates to the empirical application of the conceptual framework. Under a set of assumptions to be made explicit in section 2.3, factor demand and output supply decision rules derived from the conceptual model are a function of the agent's subjective expected values, variances, and covariance of the harvest time (logged) maize prices in the two marketing channels (private sector and FRA) as well as his/her subjective probability of the FRA channel being available to him/her at harvest. These subjective values must be based on information observed by the agent at the time input use and crop production decisions are made but the agent's subjective assessments are unobserved to the researcher. I use an approach somewhat similar to quasi-rational expectations (Nerlove and Fornari, 1998) to estimate the subjective values. For example, to obtain an estimate of the agent's subjective expected maize market price, I regress the harvest time maize market price on the planting time price and other relevant information that would likely be known to the agent at planting time and potentially influence his/her subjective value. The predicted value from this regression is then used as the agent's subjective expected value. Theil's inequality coefficients suggest that such price predictions have greater forecasting accuracy than a "no change" forecast, i.e., the naïve expectation (Theil, 1966). The approach is less data intensive and arguably more realistic than rational expectations, particularly in the developing country context.

The third challenge is testing and controlling for the potential endogeneity of the quantity of GRZ fertilizer received to households' fertilizer use and crop production decisions. Although GRZ fertilizer programs are not the main focus of this study, it is necessary to control for households' participation in these programs in order to accurately estimate the marginal effects of changes in FRA domestic maize purchase policies on smallholder behavior. Participants in GRZ fertilizer programs are not randomly selected and it is possible that unobserved time-varying factors that affect a household's participation in these programs also influence their fertilizer use and crop production decisions (Ricker-Gilbert et al., 2011). Participation in GRZ fertilizer programs is a corner solution variable (most households do not participate and the quantity of subsidized fertilizer received among participants is an approximately continuous variable), so the control function approach is used to test and control for endogeneity (Rivers and Vuong, 1988; Vella 1993; Ricker-Gilbert et al., 2011). The estimates of the marginal effects of government fertilizer programs on smallholder fertilizer use on maize and crop production derived here are the first of their kind for Zambia. The analysis complements previous empirical work on the effects of input subsidy programs on smallholders in Zambia and other countries in ESA (e.g., Dorward et al., 2008; Xu et al., 2009a, 2009b; Chibwana, 2010; Ricker-Gilbert et al., 2011; Ricker-Gilbert, 2011; Chibwana et al., 2011).

The paper has four objectives. The first is to develop a conceptual model of how households' expectations of private sector and FRA maize prices and of the FRA's buying presence during the next post-harvest period affect their factor demand and crop output supply. The second objective is to develop an empirical model based on the conceptual framework and to use it to estimate the marginal effects of changes in FRA's maize pricing and purchases on Zambian smallholder fertilizer use on maize and on crop area planted, output per hectare, and output. The third objective is to estimate the marginal effects of an increase in the quantity of GRZ fertilizer received by a household on these outcome variables while, if necessary, controlling for the endogeneity of GRZ fertilizer. The fourth objective is to identify the policy implications of the findings.

The remainder of the paper is organized as follows. In section 2.2, I provide an overview of the FRA's domestic maize purchases and a summary of the GRZ fertilizer programs in place in the agricultural years captured in the household panel data set (1999/2000, 2002/03, and 2006/07). In section 2.3, I develop the conceptual framework used in the study. In section 2.4, I describe the data used in the empirical analysis, and in section 2.5, I outline the empirical models and estimation strategy. Results are presented in section 2.6, and the conclusions and policy implications are discussed in section 2.7.

2.2 The Food Reserve Agency & government fertilizer programs in Zambia

2.2.1 The Food Reserve Agency

The Food Reserve Agency, a parastatal, was established in 1996 with the enactment of the Food Reserve Act of 1995. The FRA's original primary functions were to establish and administer a national food reserve. The Agency did not have an explicit crop marketing mandate; it was to be involved in crop marketing only as necessary to administer the national food reserve (GRZ, 1995). Nonetheless, the FRA began buying maize directly from smallholders during the 2002/03 marketing year and has continued to do so to date. Direct participation in crop marketing and market facilitation were added to the FRA's official functions when the Food Reserve Act was amended in 2005 (GRZ, 2005).

Raising rural incomes and improving national food security are core FRA objectives. The Agency's "strategic mission" is "to be an organization that efficiently manages sustainable national strategic food reserves, ensuring national food security and income through the provision of complementary and high quality marketing and storage services, in line with international standards" (FRA, n.d.). The FRA's "strategic goal" is "to significantly contribute to the stabilization of national food security and market prices of designated crops through the establishment and sustenance of a sizable and diverse national strategic food reserve in Zambia by 2010" (ibid). Although the Food Reserve Act does not constrain the national food reserve to be comprised of maize only, maize is the most important crop in Zambia and the FRA's emphasis has been almost exclusively on maize. For example, in the 2005/06 marketing year, 95% of the FRA's budget allocation for crop purchases was for maize. The remaining 5% was for the purchase of rice, cassava, groundnuts, soybeans, and sugar beans (FRA, 2005).

The household panel survey data used in this paper cover the 1999/2000, 2002/03, and 2006/07 agricultural years and subsequent marketing years (2000/01, 2003/04, and 2007/08). In this section, I focus on the FRA's activities from its establishment in 1996 through the 2007/08 marketing year. Table 2.1 summarizes the tonnage of maize purchased on the domestic market by the FRA each year during this period, as well as the number of districts from which maize was purchased, the price at which it was purchased, and the estimated tonnage of maize produced and sold by smallholders in each year.

During its first two marketing years in operation (1996/97 and 1997/98), the FRA contracted small-scale traders to buy maize from smallholders on its behalf. The quantities purchased were small and only made in four to five districts. The price paid by the Agency to contracted traders varied across districts to reflect different market price levels (Kabaghe, 2010). The FRA did not purchase maize in Zambia from 1998/99 to 2001/02 due to lack of funding. Therefore, at the time that land preparation, planting, and input use decisions were made by smallholders in the 1999/2000 agricultural year (decisions that are captured in the first wave of the panel survey data used in this study), the FRA had not purchased maize in Zambia in two years and had no plans to do so for the foreseeable future.

Table 2.1. FRA maize prices and purchases, and estimated smallholder maize production and sales, 1996/97-2010/11 marketing years

Marketing year	FRA pan-territorial price (ZMK/50 kg)	# of districts in which FRA purchased maize[d]	FRA domestic maize purchases (MT)	Estimated smallholder maize:[e] Production (MT)	Estimated smallholder maize:[e] Sales (MT)	FRA purchases as % of smallholder maize sales	Production & sales data source
1996/1997	11,800[a]	5	10,500	1,117,955	280,955	3.7	PHS
1997/1998	7,880[a]	4	4,989	804,626	206,557	2.4	PHS
1998/1999	N/A	0	0	724,024	175,515	0	PHS
1999/2000	N/A	0	0	929,304	242,753	0	PHS
2000/2001	N/A	0	0	1,253,722	303,738	0	PHS
				1,282,352	323,387	0	SS
2001/2002	N/A	0	0	957,437	209,326	0	CFS
				938,539	197,915	0	PHS
2002/2003	40,000[b]	10	23,535	673,673	143,453	16.4	CFS
				947,825	195,407	12.0	PHS
2003/2004	30,000	36	54,847	970,317	260,885	21.0	CFS
				1,126,316	291,462	18.8	PHS
				1,365,538	370,332	14.8	SS
2004/2005	36,000	46	105,279	1,364,841	331,006	31.8	CFS
				1,216,943	356,750	29.5	PHS
2005/2006	36,000	50	78,667	652,414	151,514	51.9	CFS
				800,574	206,092	38.2	PHS
2006/2007	38,000	53	389,510	1,339,479	454,676	85.7	CFS
				1,388,311	674,020	57.8	PHS
2007/2008	38,000	58	396,450	1,419,545	533,632	74.3	CFS
				1,960,692	762,093	52.0	SS
2008/2009	45,000[c]	58	73,876	1,392,180	522,033	14.2	CFS
2009/2010	65,000	59	198,630	1,657,117	613,356	32.4	CFS
2010/2011	65,000	62	878,570	2,463,523	1,062,010	82.7	CFS

Notes: [a]Not a pan-territorial price but the average price paid by FRA to private traders, who procured from smallholders. [b]Not a pan-territorial price but the price paid by FRA directly to smallholder farmers in the districts where it was purchasing; initial FRA price of K30,000 was raised to K40,000 in August 2002. [c]FRA price increased to 55,000 in September 2008. [d]There are 72 districts in Zambia. [e]Smallholder maize production and sales based on CFS data are expected, not realized, levels.
Sources: FRA; CSO/MACO Crop Forecast Surveys (CFS); CSO/MACO Post-Harvest Surveys (PHS); CSO/MACO/FSRP Supplemental Surveys (SS).

In July 2002, following the drought-related failed harvest in large swathes of the country, GRZ allocated K12 billion to the FRA to buy 15,000 MT of maize directly from smallholders in eight surplus districts in Zambia (FEWSNET and WFP, 2002). Note that the FRA's buying maize directly from smallholders in 2002/03 marked a distinct change in its procurement practices. In 1996/97 and 1997/98, the only two previous years in which the Agency purchased maize on the domestic market, it had contracted private traders to buy maize from smallholders on its behalf.

In order to sell to the FRA, smallholders were required to be members of a cooperative or other farmer group; beneficiaries of FSP were also targeted. Smallholders were encouraged to sell to the FRA through their farmer organizations and, according to FRA guidelines, the minimum quantity of maize accepted from a given farmer or farmer group was 500 kg (FRA, various years). Smallholder sellers delivered their maize to satellite depots set up by the FRA in targeted districts and were to be paid for their maize within ten days.

By the end of October 2002, the FRA had purchased 9,059 MT in eight districts. FRA 2002/03 marketing year purchases continued through March 2003, and purchases for the marketing year totaled 23,535 MT from 10 districts. Thus, at the time that land preparation, planting, and input use decisions were made by smallholders in the 2002/03 agricultural year (decisions that are captured in the second wave of the panel survey data used in this study), the FRA was buying maize directly from smallholders for the first time since its establishment, but the Agency's buying presence was limited to eight of Zambia's 72 districts. The Agency's purchase price, target quantities, and satellite depot locations for the 2003 harvest were not known at planting time in 2002.

In May 2003, the FRA announced its 2003/04 marketing year plans to purchase 205,700 MT of maize directly from smallholders in 37 districts at a pan-territorial price of K30,000 per 50-kg bag; this was the first time since liberalization in 1992 that the government announced a pan-territorial price for maize (FEWSNET, 2003a; FEWSNET, 2003b). Although the Agency only managed to purchase approximately 55,000 MT (15-19% of smallholder maize sales) in 2003/04 due to funding shortfalls, its ambitious purchase plans signaled that the FRA intended to become a major player in the Zambian maize market.

The FRA increased its market share the next two years, accounting for 30% and 38% of smallholder maize sales in the 2004/05 and 2005/06 marketing years, respectively (Table 2.1). At harvest time in 2006, the FRA announced plans to purchase 80,000 MT of maize in 55 districts at K38,000 per bag. Following a surge of sales from smallholders, FRA's purchase target was increased to 200,000 MT in July. By the time it closed its purchase exercise on September 30, 2006 (two days after presidential and parliamentary elections were held), the FRA had bought nearly 360,000 MT of maize. The Agency re-entered the market in November and December, and total FRA maize purchases for the 2006/07 marketing year were 389,510 MT or approximately 58% of smallholder maize sales.

Therefore, at the time that land preparation, planting, and input use decisions were made by smallholders in the 2006/07 agricultural year (decisions that are captured in the third wave of the panel survey data used in this study), the FRA was the dominant buyer of smallholder maize in Zambia and had been buying maize directly from smallholders for five consecutive years. The Agency's purchase plans and price for the 2007/08 marketing year were not yet known but at K38,000 per 50-kg bag, the FRA buy price in the 2006/07 marketing year was well above wholesale maize market prices, which ranged from K23,000 to K31,000 per 50-kg bag. The

FRA's buying presence had increased over time from 10 districts in 2002/03 to 53 districts in the 2006/07 marketing year. The Agency purchased nearly 400,000 MT again in the 2007/08 marketing year.

On the sales side, FRA maize sales are typically done through a tender process. The Agency occasionally sells maize on the market at a pan-territorial price set in consultation with stakeholders such as the Zambia National Farmers Union, the Grain Traders Association of Zambia, and the Millers Association of Zambia. Beginning in October 2010, the FRA also sold small quantities of maize (20,000 MT) through an auction-like mechanism on the Zambia Agricultural Commodity Exchange. The FRA also uses imports and exports to manage its stocks; imported maize is often sold to millers at subsidized prices (Govereh et al., 2008). (See Appendix F for additional details on the FRA.) This paper focuses on the marginal effects of changes in the FRA's domestic maize purchase policies on smallholder factor demand and output supply. The Agency's maize imports, exports, and domestic maize sales may also affect smallholder behavior but such effects are not examined here. Effects of the FRA on smallholder maize sales and consumer behavior are also beyond the scope of this paper.

2.2.2 Government fertilizer programs in Zambia

Three major GRZ fertilizer programs were implemented during the period covered by the panel survey data used in this paper. All three programs are targeted, not universal, fertilizer subsidies. The FRA Fertilizer Credit Programme (FRA-FCP), which ran from 1997/98-2001/02, was in place during the first wave of the panel survey (1999/2000). The loan-based FRA-FCP was replaced by the cash-based Fertilizer Support Programme (FSP) in 2002/03. FSP ran through 2008/09 and so was in place during the second and third waves of the panel survey (2002/03 and

2006/07). The main objectives of FSP were (i) "improving household and national food security, incomes, [and] accessibility to agricultural inputs by small-scale farmers through a subsidy", (ii) "building the capacity of the private sector to participate in the supply of agricultural inputs", and (iii) "rebuilding the resource base of smallholder farmers and instilling their sense of self-reliance" (MACO, 2008: 3). The third GRZ-funded fertilizer subsidy program is the grant-based Food Security Pack Programme (FSPP/PAM), which was implemented by the Programme Against Malnutrition, a Zambian NGO, during the study period. FSPP/PAM has been in place since 2000/01 and so ran during the second and third waves of the panel survey. The main objectives of FSPP/PAM are to (i) "promote crop diversification for increased food production"; (ii) "promote farming methods that help restore soil fertility and productivity"; and (iii) "encourage adoption of conservation farming (CF) technologies" (Tembo, 2007: 1).

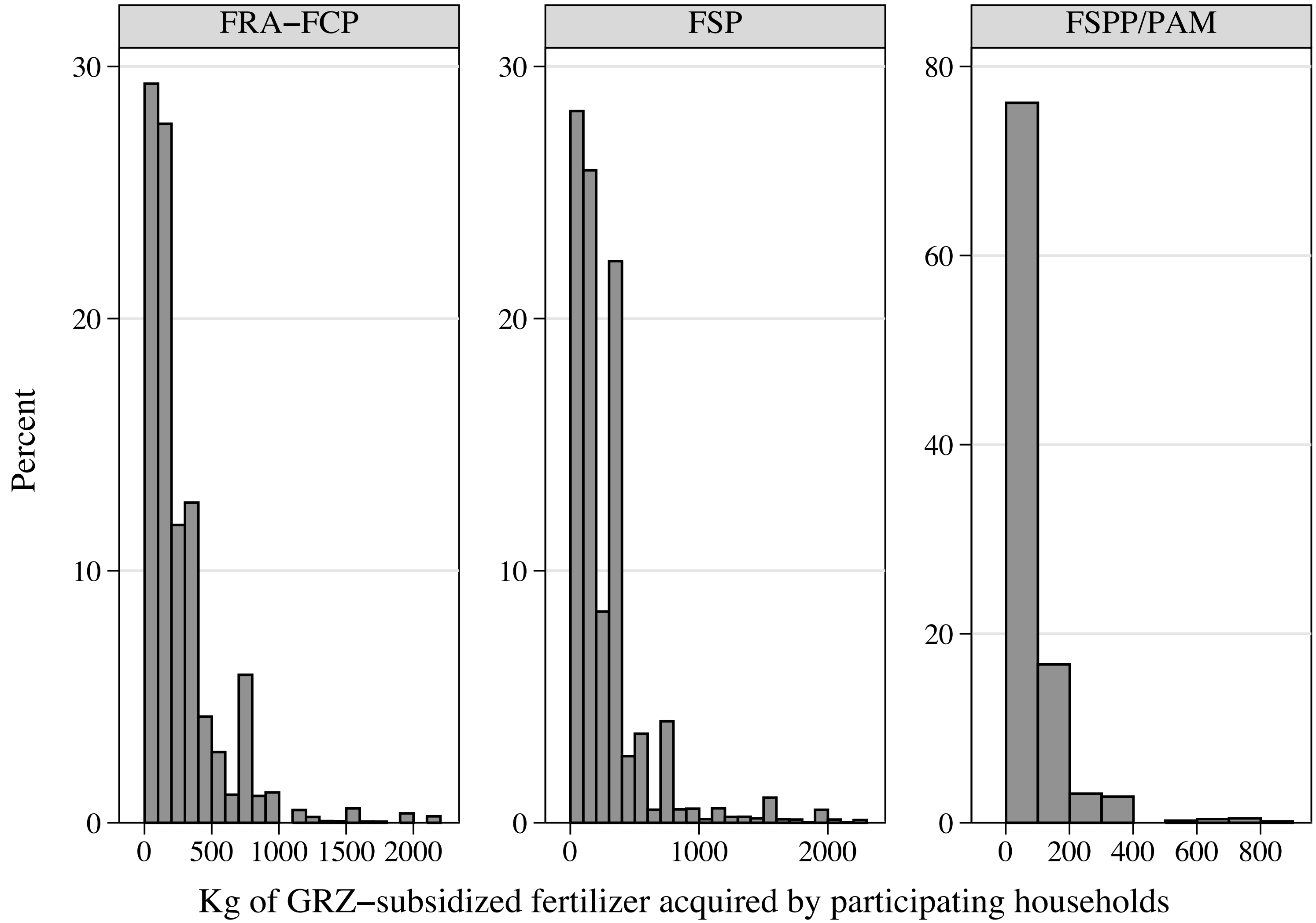
Table 2.2 summarizes the key features of FRA-FCP, FSP, and FSPP/PAM. (See Appendix F for additional details on these programs.) Figure 2.1 shows the quantities of fertilizer acquired by participants in each program based on the panel survey data (which will be described in detail in section 2.4). According to FRA-FCP guidelines, farmers could apply for 200 kg to 800 kg of fertilizer; however, many participants received less than 200 kg and some received more than 800 kg (Figure 2.1). The 'official' subsidy pack size was 400 kg for FSP and 100 kg for FSPP/PAM but the actual quantities received varied greatly. The fact that GRZ fertilizer subsidy program beneficiaries receive different quantities of subsidized fertilizer is taken into consideration in the econometric models estimated in the paper.

Table 2.2. Key features of the GRZ fertilizer subsidy programs in place during the study period

<table>
<tr><th></th><th>FRA Fertilizer Credit Programme (FRA-FCP)</th><th>Fertilizer Support Programme (FSP)</th><th>Food Security Pack Programme (FSPP/PAM)</th></tr>
<tr><td>Agricultural years</td><td>1997/98-2001/02</td><td>2002/03-2008/09</td><td>2000/01-present</td></tr>
<tr><td>Waves of panel survey</td><td>Wave 1</td><td>Waves 2 & 3</td><td>Waves 2 & 3</td></tr>
<tr><td>Fertilizer on credit/cash/grant?</td><td>Credit (≈10% cash down payment at planting; ≈90% due in cash/kind at harvest)</td><td>Cash</td><td>Grant</td></tr>
<tr><td>Subsidy level</td><td>0% but high default rate (e.g., 34.5% recovery rate for 1999/2000 seasonal loans)</td><td>2002/03-2005/06: 50%
2006/07-2007/08: 60%
2008/09: 75%</td><td>100%</td></tr>
<tr><td>Fertilizer pack size</td><td>100 kg</td><td>400 kg</td><td>100 kg</td></tr>
<tr><td>Packs per participating HH</td><td>2-8 (officially)</td><td>1 (officially)</td><td>1 (officially)</td></tr>
<tr><td rowspan="2">Eligibility criteria</td><td colspan="2">(1) In pre-selected coop (coops selected by FRA for FRA-FCP; by District Ag. Committee w/ input from MPs, District Administrator, village headmen, NGOs, local leaders for FSP)
(2) Smallholder (cultivating < 20 ha), farming in coop area
(3) No outstanding FRA-FCP debts</td><td rowspan="2">(1) Cultivate < 1 ha
(2) ‘Vulnerable but viable’ (female-/child-headed, unemployed youth, orphans, disabled)</td></tr>
<tr><td>(4) Can repay loan</td><td>(4) Can pay farmer share
(5) Can plant 1-5 ha of maize
(6) No FSPP/PAM</td></tr>
<tr><td>Selection of beneficiaries</td><td colspan="2">MACO extension agents, Cooperative Boards, Village Farmers’ Committees, village headmen, other local leaders</td><td>Community-level Satellite Food Security Committees</td></tr>
<tr><td>MT fertilizer distributed (mean)</td><td>15,000-50,000 (30,500)</td><td>48,000-84,000 (60,286)</td><td>Data not available</td></tr>
<tr><td># of districts covered (of 72)</td><td>16-45</td><td>67-72</td><td>72 (officially)</td></tr>
<tr><td>Mean (median) kg acquired among participating HHs:</td><td></td><td></td><td></td></tr>
<tr><td>1999/2000</td><td>338 (200)</td><td>N/A</td><td>N/A</td></tr>
<tr><td>2002/2003</td><td>N/A</td><td>300 (200)</td><td>131 (100)</td></tr>
<tr><td>2006/2007</td><td>N/A</td><td>356 (300)</td><td>131 (100)</td></tr>
</table>

Sources: FRA Agro Support Department (1999), MACO et al. (2002), MACO (various years), Tembo (2007), CSO/MACO/FSRP 2001, 2004, and 2008 Supplemental Surveys.

Figure 2.1. Histograms of kg of fertilizer acquired through FRA-FCP, FSP, and FSPP/PAM by participating households



Note: Quantities are for 1999/2000 for FRA-FCP and for 2002/03 and 2006/07 for FSP and FSPP/PAM.
Sources: CSO/MACO/FSRP 2001, 2004, and 2008 Supplemental Surveys.

2.2.3 Participation in GRZ fertilizer programs and maize sales to FRA in survey years

Approximately 6.5% of Zambian smallholder households received FRA-FCP fertilizer in the first survey year, 1999/2000 (CSO/MACO/FSRP 2001 Supplemental Survey). FSP and FSPP/PAM did not yet exist nor did the FRA buy maize in Zambia in the corresponding marketing year. FSPP/PAM participation rates among smallholder households were 4.5% and 1.1%, respectively, in the second and third panel survey years (2002/03 and 2006/07) (CSO/MACO/FSRP 2004 & 2008 Supplemental Surveys). FSP and maize purchases by the FRA were the two major agricultural sector programs in place in these years. Table 2.3 summarizes smallholder participation rates as well as households' socioeconomic characteristics by their involvement in the two programs.

Less than 1% of smallholder households sold maize to the FRA in the 2003/04 marketing year; this percentage rose to nearly 10% in 2007/08 as the FRA scaled up its activities. On average, participating households sold more than 2 MT of maize to the FRA (Table 2.3). FSP participation rates were somewhat higher in 2006/07 (11.2%) than in 2002/03 (8.8%). Among FSP recipients, slightly more than half sold maize to the FRA. The vast majority of smallholder households (84-91%) does not receive subsidized fertilizer from FSP nor sell maize to the FRA.

Households that received FSP, sold maize to the FRA, or both had considerably larger landholdings, more farm assets, and heads with higher educational attainment than did households not participating in either program (Table 2.3). Sellers to FRA also tended to have more land and farm assets than households that received FSP. Households that did not participate in FSP or FRA were more likely to be female-headed. Based on the panel data, FRA-FCP and FSP households are similar in terms of the socioeconomic characteristics in Table 2.3; this is also the case for FSPP/PAM households and those that did not receive FSP nor sell maize to the FRA.

Table 2.3. Socioeconomic characteristics of households by participation in FRA & FSP

Descriptive result	Agricul-tural year	Sold maize to FRA	Received FSP fertilizer	Both	Neither
Share of households, unweighted	2002/2003	0.9%	9.5%	0.4%	90.0%
(N=4,286 households each year)	2006/2007	11.2%	12.8%	6.2%	82.1%
Share of households, weighted	2002/2003	0.8%	8.8%	0.4%	90.9%
(N=597,742 households each year)	2006/2007	9.7%	11.2%	5.1%	84.2%
Weighted descriptive results:					
Mean kg of fertilizer acquired from FSP	2002/2003		300	510	0
	2006/2007		356	434	0
Mean kg of maize sold to FRA	2002/2003	2,315		2,321	0
	2006/2007	2,764		3,016	0
Mean landholding size (ha)	2002/2003	3.65	3.13	4.13	2.02
	2006/2007	3.65	3.13	3.55	1.77
Mean value of farm assets	2002/2003	59.4	48.3	30.4	20.7
(100,000 ZMK, 2007/08=100)	2006/2007	65.7	53.3	71.0	17.4
% female-headed	2002/2003	8.6%	15.7%	6.5%	22.4%
	2006/2007	14.0%	14.3%	14.8%	25.8%
Median education of HH head	2002/2003	8	7	8	5
(highest grade completed)	2006/2007	7	7	7	5

Notes: Five households that received FSPP/PAM in 2002/03 and one household that received it in 2006/07 sold maize to the FRA in the subsequent marketing year. Farm assets are plows, harrows, and ox carts. "Sold maize to FRA" column refers to households that sold maize to FRA during the subsequent marketing year (2003/04 and 2007/08).
Sources: CSO/MACO/FSRP 2001, 2004, and 2008 Supplemental Surveys.

2.3 Conceptual framework

In modeling the marginal effects of changes in the FRA's maize pricing and purchases on smallholder factor demand and crop output supply, four key features of the decision-making environment need to be taken into consideration. First, the price at which the FRA will buy maize and the prices at which private traders will buy maize and other crops during the next post-harvest period are not known to farmers at the time that land preparation, planting, and other input use decisions are made.[5] Second, at this time, households do not know if the FRA will be buying maize in their locality when they wish to sell during the next marketing year. There are two main scenarios under which the FRA channel would not be available when the household wants to sell: (i) the FRA is not buying in the household's area at all during the marketing year in question; or (ii) the FRA is not buying at the time the household wants to sell but the Agency did buy in their area earlier or later in the marketing year. Third, the FRA pan-territorial buy price is not a floor price *per se*. Private sector buyers can legally buy maize at a price above or below the FRA buy price. And fourth, although the FRA pays the same price for maize at all of its satellite depots, the *effective* FRA price (i.e., the FRA pan-territorial price adjusted for transfer costs from a household's homestead to the FRA satellite depot) varies across households.

With these features in mind, consider a risk-neutral, expected profit-maximizing agricultural producer (or a farm household for which production and consumption decisions are

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[5] Maize is usually planted and basal dressing fertilizer applied in November or December; top dressing fertilizer is applied approximately six weeks after planting. The FRA typically announces its buy price, planned satellite depot locations, and maize purchase targets at harvest time in April or May.

separable).[6] Assume that production is deterministic and that the household's implicit production function is $G(q,\boldsymbol{q_o},\boldsymbol{x};\boldsymbol{z}) = 0$, where q is the quantity of maize produced, $\boldsymbol{q_o}$ is a vector of the quantities produced of other crops, $\boldsymbol{x}$ is a vector of variable input quantities, and $\boldsymbol{z}$ is a vector of other production shifters such as quasi-fixed factors of production, rainfall, and household characteristics affecting production.

Suppose there is a single (private sector) marketing channel for non-maize crops and that there are two potential marketing channels for maize: the private sector channel and the FRA channel. Assume that the private sector channel is always available but the FRA channel may or may not be available at the time the household wishes to sell maize after the next harvest. Let γ be a Bernoulli random variable that is equal to one if the FRA channel is available at this time and zero otherwise. At planting time, the farmer does not know the value of γ. (Throughout the rest of the paper, I will use 'planting time' as shorthand for the period during which land preparation, planting, and other input use decisions are made.) Let p_f, p_p, and $\boldsymbol{p_o}$ be, respectively, the effective FRA and private sector maize prices and a vector of other crop prices at the next harvest; these prices are unobserved random variables at planting time. Further assume that the household sells maize to only one marketing channel – the one with the higher effective maize price.[7] Variable input prices ($\boldsymbol{w}$) are assumed known at planting time.

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[6] I acknowledge that separability is a potentially strong assumption but my main interest in this paper is production-side decisions in the context of dual marketing channels where prices in both channels are not known at planting time and it is not known if one of the channels will be available come harvest time. A potential area for future research is to model farm household decisions in this context without assuming separability.

[7] This is consistent with household survey evidence from Zambia. In the 2007/08 and 2009/10 marketing years, only 5% of maize-selling smallholder households sold maize to both private

Under these assumptions, the household solves the following expected profit maximization problem:

$$\max_{q,\boldsymbol{q_o},\boldsymbol{x}} E\left\{\left[\gamma \max(p_f, p_p) + (1-\gamma)p_p\right]q + \boldsymbol{q_o p_o}\right\} - \boldsymbol{xw} \qquad (1a)$$

$$\text{s.t. } G(q, \boldsymbol{q_o}, \boldsymbol{x}; \boldsymbol{z}) = 0 \qquad (1b)$$

Under the additional assumptions that γ is independent of p_f and p_p, but that p_f and p_p are not independent, (1a) can be simplified to:

$$\max_{q,\boldsymbol{q_o},\boldsymbol{x}} \left\{E(\gamma)E[\max(p_f, p_p)] + [1-E(\gamma)]E(p_p)\right\}q + \boldsymbol{q_o}E(\boldsymbol{p_o}) - \boldsymbol{xw} \qquad (1a')$$

The expression in curly brackets is the expected (effective) maize price. As there is no general formula for $E[\max(X,Y)]$ when *X* and *Y* are continuous random variables and not independent, an assumption about the joint distribution of (p_f, p_p) is needed in order to further evaluate (1a′) (Lien, 2010). Two tractable joint distributions that have been used for commodity prices in the literature are bivariate normal and bivariate lognormal (see, for example, Chavas and Holt, 1990; and Myers, 1989). I assume bivariate lognormality as an approximation.

Let $E(\ln p_f) = \mu_f$, $E(\ln p_p) = \mu_p$, $Var(\ln p_f) = \sigma_f^2$, $Var(\ln p_p) = \sigma_p^2$, and $Cov(\ln p_f, \ln p_p) = \sigma_{fp} = \rho\sigma_f\sigma_p$, where ρ is the correlation coefficient between $\ln p_f$ and $\ln p_p$. Under the bivariate lognormal assumption,

sector buyers and to the FRA. More than 80% of maize-selling smallholder households had only one maize sale transaction.

$$E[\max(p_f, p_p)] = \exp[\mu_f + (\sigma_f^2/2)]\left\{1 - \Phi\left[\frac{\mu_p - \mu_f - \sigma_f^2 + \sigma_{fp}}{\sqrt{\sigma_f^2 + \sigma_p^2 - 2\sigma_{fp}}}\right]\right\} + \exp[\mu_p + (\sigma_p^2/2)]\left\{1 - \Phi\left[\frac{\mu_f - \mu_p - \sigma_p^2 + \sigma_{fp}}{\sqrt{\sigma_f^2 + \sigma_p^2 - 2\sigma_{fp}}}\right]\right\} \quad (2)$$

where $\Phi(.)$ is the standard normal cumulative distribution function (Lien, 2005). Equation (2) shows that $E[\max(p_f, p_p)]$ is a function of the means, variances, and covariance of $\ln p_f$ and $\ln p_p$.

Let $\boldsymbol{y} = [q, \boldsymbol{q_o}, \boldsymbol{x}]'$ be the vector of output and variable input quantities and let $p^* \equiv E(\gamma)E[\max(p_f, p_p)] + [1 - E(\gamma)]E(p_p)$ be the expected maize price, where $E[\max(p_f, p_p)]$ is defined as in (2). Solving the expected profit maximization problem defined by (1a′), (1b), and (2) gives factor demand and output supply functions:

$$\boldsymbol{y} = \boldsymbol{y}\left(p^*, E(\boldsymbol{p_o}), \boldsymbol{w}; \boldsymbol{z}\right) \quad (3)$$

Given functional forms, error term structures, measures of ***w*** and ***z*** and of households' subjective values for $E(\boldsymbol{p_o})$, μ_f, μ_p, σ_f^2, σ_p^2, σ_{fp}, and $E(\gamma)$, these factor demand and output supply equations can be empirically estimated.

As will be discussed further in section 2.5, in the empirical models in this paper, the household's subjective values for μ_f, μ_p, σ_f^2, σ_p^2, σ_{fp}, and $E(\gamma)$ are estimated as functions of, *inter alia*, the effective FRA price faced by the household and the quantity of maize purchased by the FRA in the household's area during the past marketing year(s). Let *g* represent one of these FRA-related variables. Of particular interest in the empirical work is the partial effect of *g* on the household's factor demand or output supply (*y*):

$$\frac{\partial y[p^*(g)]}{\partial g} = \frac{\partial y[p^*(g)]}{\partial p^*(g)} \cdot \frac{\partial p^*(g)}{\partial g} \tag{4}$$

2.4 Data

The data used in this paper are drawn mainly from a three-wave, nationally-representative longitudinal study of rural smallholder households in 70 districts in Zambia. The first wave of the study was done in two parts: the 1999/2000 Post-Harvest Survey (PHS9900) conducted by the Zambian Central Statistical Office (CSO) and Ministry of Agriculture and Cooperatives (MACO) in August-September 2000, and the linked CSO/MACO/FSRP (Food Security Research Project) Supplemental Survey conducted in May 2001 (SS01). The second and third waves of the longitudinal study were the Supplemental Surveys conducted in May 2004 (SS04) and June-July 2008 (SS08), respectively. (Henceforth I will refer to PHS9900, SS01, SS04, and SS08 collectively as "SS data" or "Supplemental Survey data".)

PHS9900 covered the 1999/2000 agricultural year and 2000/01 marketing year and was a nationally-representative survey of 7,699 rural households in 70 districts in Zambia. A stratified three-stage sample design was used to select PHS9900 sample households (Megill, 2005). In the first stage, Census Supervisory Areas (CSAs), the primary sampling units in the survey, were selected from within each district with Probability Proportional to Size (PPS) based on the sampling frame from the 1990 Census. In the second stage, one Standard Enumeration Area (SEA) was chosen from each selected CSA, again with PPS. A total of 394 SEAs were selected.

All households in selected SEAs were then listed and stratified into two farm size categories: small-scale (0-4.99 ha) and medium-scale (5-19.99 ha). An SEA contains approximately 150-200 households. In the third stage, 20 households were selected from each SEA: 10 medium-scale households and 10 small-scale households. In many cases, the SEA contained fewer than 10 medium-scale households. In such SEAs, all medium-scale households were selected and then a sufficient number of small-scale households were selected to bring the total number of selected households in the SEA to 20.

PHS9900 included questions on households' cropping patterns and production levels, agricultural input use, crop marketing, livestock production and marketing, and farm equipment ownership. In May 2001, attempts were made to revisit all 7,699 PHS9900 households as part of SS01 to collect additional information on household demographics, recent disease-related deaths among household members, off-farm income and remittances, purchases of select staple foods, and other household details. Like PHS9900, SS01 covered the 1999/2000 agricultural season and 2000/01 marketing year. 6,922 of the 7,699 PHS9900 households were successfully re-interviewed in SS01 (a re-interview rate of 89.9%).

A second attempt was made to revisit the PHS9900 households in May 2004 for SS04. This survey included questions comparable to those on both PHS9900 and SS01, as well as additional questions. 5,358 of the households interviewed in SS01 were successfully re-interviewed in SS04 (a re-interview rate of 77.4%). SS04 covered the 2002/03 agricultural year and 2003/04 marketing year. The third and most recent re-interview of PHS9900 households took place in June-July 2008 for SS08, which covered the 2006/07 agricultural year and 2007/08 marketing year. The questions on this survey were similar to those on SS04. 4,286 SS04 households were successfully revisited in SS08 (a re-interview rate of 80.0%). In the analysis unless otherwise noted, I use the unbalanced panel of households that were interviewed in at least SS01 and SS04, i.e., observations on 5,358 households for the 1999/2000 and 2002/03 agricultural years (SS01 and SS04) and on 4,286 households for the 2006/07 agricultural year (SS08).

Given non-trivial attrition rates between rounds of the SS, attrition bias is a potential problem. However, based on tests for attrition bias as described in Wooldridge (2002: 585), I fail to reject the null hypothesis of no attrition bias in all cases. (p-values range from 0.20 to 0.85.) These tests were conducted for all dependent variables that are observed in all three waves of the panel survey. The test is not feasible with fewer than three time periods when used in conjunction with fixed effects or correlated random effects.

Other data used in the study are: (i) administrative records from the FRA on the Agency's total district-level maize purchases each marketing year from 1996/97 to 2006/07; (ii) dekad (10-day period) rainfall data covering the 1990/91 to 2006/07 growing seasons and collected from 36 stations throughout Zambia by the Zambia Meteorological Department; (iii) maize, groundnut, mixed bean, and sweet potato prices from the MACO/CSO Post-Harvest Surveys for 1998/99, 2001/02, and 2005/06; (iv) constituency-level data on the percentage of votes won by the ruling party and opposition parties during the 1996, 2001, and 2006 presidential elections from the Electoral Commission of Zambia; and (v) monthly maize wholesale prices from trading centers in each of Zambia's nine provinces from MACO's Agriculture Market Information Center.

2.5 Empirical models & estimation

In this section, I first describe the auxiliary models, assumptions, and estimators used to obtain measures of households' subjective values for μ_f, μ_p, σ_f^2, σ_p^2, σ_{fp}, $E(\gamma)$, and

$E(\boldsymbol{p_o})$. (Recall that the first five of these are needed to construct the expected maize price, p^*.)

Next, I present the empirical specifications of and estimation strategy for the factor demand and output supply functions in equation (3). The section concludes with a description of the main partial effects of interest and the hypotheses tested.

2.5.1 Measures of subjective values for μ_f and μ_p

A major challenge in operationalizing the conceptual framework outlined in section 2.3 is obtaining measures of households' subjective values for μ_f, μ_p, σ_f^2, σ_p^2, σ_{fp}, and $E(\gamma)$. Given the primacy of maize in Zambia, it is unlikely that smallholders have naïve expectations of maize prices in the FRA and market channels. While rational expectations is appealing because of its consistency with optimizing behavior, it is unrealistic in the current setting and not feasible to implement given available data. I assume a process of maize price expectations formation similar to quasi-rational expectations except that the expected price is calculated as the predicted value for year *t* rather than the one-step-ahead forecast as in Nerlove and Fornari (1998).

Estimates of households' subjective values for expected log effective maize prices in the FRA and private sector channels ($E(\ln p_j) = \mu_j$, $j = f, p$) are obtained as follows. I first estimate

$$\ln p_{j,i,t} = \boldsymbol{\Omega}_{i,t-1}\boldsymbol{\beta}_j + c_i + \varepsilon_{j,i,t} \text{ for } j = f, p \qquad (5)$$

where $p_{j,i,t}$ is the effective channel *j* maize price received by household *i* in harvest year *t*, $\boldsymbol{\Omega}_{i,t-1}$ is a vector of information observed by the household at planting time, $\boldsymbol{\beta}_j$ is a vector of parameters to be estimated, c_i is time invariant household-level unobserved heterogeneity, and $\varepsilon_{j,i,t} \sim N(0,\sigma^2_{j,i,t})$ is the error term. $\mathbf{\Omega}_{i,t-1}$ includes information hypothesized to influence the maize price received by the household and to inform its subjective expectation of the harvest time maize price in marketing channel *j*.

Variables in $\mathbf{\Omega}_{i,t-1}$ include maize prices in the two marketing channels at the previous harvest; the volume of maize purchased by the FRA in the household's district in the previous marketing year(s); wholesale maize market prices in the household's region in the months prior to planting time; the effective market fertilizer price; variables related to the households' access to markets and market information (e.g., distance to the nearest district town, tarmac road, and feeder road; ownership of a bicycle and other forms of transportation, ownership of a radio or cell phone that could be used to monitor maize prices); age, education, and gender of the household head, which may affect the households' ability to process market information and/or negotiate for a higher maize price; landholding size and number of full-time equivalent prime-age adults (ages 15 to 59) in the household, which are likely to affect the quantity of maize produced and sold by the household and the maize price it receives (larger marketed volumes are expected to fetch a higher price); variables related to agro-ecological conditions in the household's community; and year and province or district dummies. The effective maize price in marketing channel *j* is calculated as the maize price received at the point of sale minus estimated transportation costs from the household's homestead/farm to the point of sale.[8] See Tables A.1 and A.2 in Appendix A for summary statistics for the variables in $\mathbf{\Omega}_{i,t-1}$.

[8] Insufficient information was collected in SS01 to calculate effective maize prices, hence maize prices used in the analysis for that year are at the point of sale. For SS04 and SS08, the median

Equation (5) is estimated by correlated random effects-pooled ordinary least squares (CRE-POLS) using data from households that sold maize to marketing channel j and for which the effective maize price received is captured in the SS data. CRE-POLS controls for time invariant unobserved heterogeneity (c_i) that may be correlated with $\mathbf{\Omega}_{i,t-1}$. CRE-OLS is used instead of fixed effects (FE) because many households that sold maize to a given marketing channel did so in only one year of the survey or in non-consecutive years. Like CRE-OLS, FE controls for time invariant unobserved heterogeneity. However, FE would only use maize price observations for households that sold maize to marketing channel j in at least two years. CRE-OLS uses maize price observations for households that were interviewed in at least two of the three waves of the panel survey, even if the household only sold maize to marketing channel j in one year. CRE-OLS takes better advantage of available data than FE while still controlling for c_i. See section 2.5.7 for additional details on the CRE approach and FE estimator.

Because the variables in $\mathbf{\Omega}_{i,t-1}$ are observed for all households regardless of if they sold maize to marketing channel j or not, once estimated, equation (5) can be used to obtain predicted values for all households in the sample. These predicted values are used as measures of households' subjective values for μ_f and μ_p. That is,

$$\hat{\mu}_{j,i,t} = \hat{E}(\ln p_{j,i,t}) \equiv \widehat{\ln p_{j,i,t}} = \mathbf{\Omega}_{i,t-1}\hat{\boldsymbol{\beta}}_j \quad \text{for } j = f, p \tag{6}$$

district fertilizer transportation cost per kg per km is used as a proxy for the maize transportation rate. The data suggest that per kilometer transportation costs decrease with distance traveled. To reflect this, different transportation rates are used for maize transported up to 5 km, 5-10 km, 10-15 km, and greater than 15 km. Transportation rates for the different distances are provincial medians, ZMK/kg/km.

By measuring households' subjective values in this way, I am assuming that equation (5) is correctly specified, that households know the information included in $\boldsymbol{\Omega}_{i,t-1}$ and the parameters $\boldsymbol{\beta}_j$, and that these parameters are time invariant.

Approximately 70% of smallholder households in Zambia do not sell maize even though roughly 80% of smallholders grow the crop. An even smaller percentage of households sells maize to the FRA (see Table 2.3). Predicted log maize prices obtained for all smallholder households from parameter estimates based on data for smallholder households that sold maize to marketing channel j could therefore be plagued by selection bias. One might expect systematic differences in price expectations formation between maize sellers and non-sellers. For example, although I am assuming separability here, in non-separable agricultural household models, autarkic households make production and consumption decisions based not on market prices but on shadow prices that equate internal supply and demand.

Wooldridge (2002) refers to the type of sample selection encountered in this paper as 'incidental truncation'. I use the procedure described in Wooldridge (2002: 572) to test for sample selection bias in equation (5). A Tobit selection equation determines whether or not we observe a maize price for marketing channel j for a given household: if the household sells some positive quantity of (zero) maize to that channel, then we do (not) observe the maize price received. The selection bias testing procedure entails estimating a Tobit selection equation for each marketing channel and then including the Tobit residual as a regressor in equation (5) for that channel. If one rejects the null hypothesis that the coefficient on the Tobit residual is equal to zero, then there is evidence of selection bias. In this paper, I fail to reject this null hypothesis in all cases and conclude that there is no evidence of selection bias.

2.5.2 Measures of subjective values for σ_f^2 and σ_p^2

The approach used here is similar to that in section 2.5.1. From equation (5), note that

$$Var(\ln p_{j,i,t} \mid \mathbf{\Omega}_{i,t-1}, c_i) = \sigma_{j,i,t}^2 = Var(\varepsilon_{j,i,t}) = E(\varepsilon_{j,i,t}^2), \text{ for } j = f, p \qquad (7)$$

To obtain a measure of a household's subjective value for $\sigma_{j,i,t}^2$, I first estimate

$$\ln \hat{\varepsilon}_{j,i,t}^2 = \mathbf{\Omega}_{i,t-1}\boldsymbol{\delta}_j + c_i + v_{j,i,t} \qquad (8)$$

using CRE-POLS where $\hat{\varepsilon}_{j,i,t}^2$ are the squared residuals from equation (5), $\boldsymbol{\delta}_j$ is a vector of parameters to be estimated, and $v_{j,i,t}$ is the error term. I obtain predicted values $\widehat{\hat{\varepsilon}_{j,i,t}^2}$ for all households in the sample and use it as the household's subjective value for $\sigma_{j,i,t}^2$, i.e., $\hat{\sigma}_{j,i,t}^2 \equiv \widehat{\hat{\varepsilon}_{j,i,t}^2}$.[9] There is no evidence of selection bias in the estimates of equation (8).

2.5.3 Measure of subjective value for σ_{fp}

The covariance of $\ln p_f$ and $\ln p_p$ is $\sigma_{fp} = \rho\sigma_f\sigma_p$. I assume that the correlation coefficient, ρ, is a constant, and empirically estimate it as the sample correlation between $\hat{\varepsilon}_{f,i,t}$ and $\hat{\varepsilon}_{p,i,t}$, i.e., between the residuals from the log effective maize price equations for the FRA and market channels for households that sold maize to both channels in year *t*. The sample

[9] Since $\widehat{\ln X} \neq \ln(\hat{X})$, I follow the procedure described in Wooldridge (2009: 212, equation 6.43) to obtain the desired values, $\widehat{\hat{\varepsilon}_{j,i,t}^2}$, after estimating equation (8).

correlation based on the 43 observations fitting these criteria is -0.0831 (p=0.596). Using this value as $\bar{\rho}$, the household's subjective value for σ_{fp} is measured as $\hat{\sigma}_{fp,i,t} \equiv \bar{\rho}\hat{\sigma}_{f,i,t}\hat{\sigma}_{p,i,t}$.

2.5.4 Measure of subjective value for $E(\gamma)$

Recall that γ is a Bernoulli random variable equal to one if the FRA channel is available to the household at the next harvest and zero otherwise. The value of γ is not known at planting time. A household's factor demand and output supply are functions of the expected maize price, $p^* \equiv E(\gamma)E[\max(p_f, p_p)] + [1 - E(\gamma)]E(p_p)$. $\hat{E}_{i,t}[\max(p_f, p_p)]$ and $\hat{E}(p_{p,i,t})$ can be constructed using equation (2), the fact that $E(p_j) = \exp[\mu_j + (\sigma_j^2 / 2)]$ under bivariate lognormality, and values for $\hat{\mu}_{f,i,t}$, $\hat{\mu}_{p,i,t}$, $\hat{\sigma}^2_{f,i,t}$, $\hat{\sigma}^2_{p,i,t}$, and $\hat{\sigma}_{fp,i,t}$. To construct $\hat{p}^*_{i,t}$, we also need a measure of a household's subjective value for $E(\gamma) = \Pr(\gamma = 1)$.

SS04 and SS08 did not ask respondents if the FRA channel was available to them when they wished to sell maize during the 2003/04 and 2007/08 marketing years, respectively, but we do know if a given household sold maize to the FRA in these years. In the empirical application, $\gamma_{i,t} = 1$ if the household sold maize to the FRA, and zero otherwise. A household's subjective probability that $\gamma_{i,t} = 1$ (call it $\hat{\gamma}_{i,t}$) is defined as the predicted probability from the following probit model:

$$E(\gamma_{i,t} \mid \mathbf{\Omega}_{i,t-1}) = \Pr(\gamma_{i,t} = 1 \mid \mathbf{\Omega}_{i,t-1}) = \Phi(\mathbf{\Omega}_{i,t-1}\boldsymbol{\omega}) \quad (9)$$

where $\boldsymbol{\omega}$ is a vector of parameters to be estimated. Equation (9) is estimated by CRE probit. There is no incidental truncation because $\gamma_{i,t}$ is observed for all households in the sample. The expected maize price variable is constructed as:

$$\hat{p}^*_{i,t} \equiv \hat{\gamma}_{i,t}\hat{E}_{i,t}[\max(p_f, p_p)] + (1-\hat{\gamma}_{i,t})\hat{E}(p_{p,i,t}) \qquad (10)$$

2.5.5 Expected prices for non-maize crops, $E(\boldsymbol{p_o})$

Non-maize crop prices in harvest year *t-1* are used as proxies for expected harvest year *t* prices. While this is inconsistent with the specification of households' maize price expectations, data are not available to estimate households' non-maize price expectations in a similar way. Lagged non-maize crop prices are drawn from the MACO/CSO PHSs for agricultural years 1998/99, 2001/02, and 2005/06 (marketing years 1999/2000, 2002/03, and 2006/07). Sixteen non-maize crops are captured by all three SSs and are covered in this paper: cassava, sweet potato, sorghum, millet, groundnut, mixed bean, cotton, rice, sunflower, soyabean, Irish potato, ground bean, cowpea, velvet bean, tobacco, and coffee. Lagged prices are not available for all 16. The commonly marketed crops for which price data are available for each year are groundnuts, mixed beans, and sweet potato. These prices (provincial medians in nominal ZMK/kg) are included as regressors in the factor demand and output supply equations.[10] Crop

[10] Seed cotton prices are also available; however, Dunavant, the major buyer of cotton in Zambia, announced its cotton buy price before planting time in each year during the study period. Since the cotton price is observed at planting time, no assumptions regarding households' price expectations are necessary. The announced pre-planting Dunavant price is not included as a regressor in the fertilizer demand and output supply equations because it is essentially a pan-territorial price. It would therefore be perfectly collinear with the year dummies in the regressions. Data are not available to compute an effective (farmgate) Dunavant cotton price.

prices and other monetary variables are specified in nominal terms because under the maintained hypothesis of separability, consumer prices are irrelevant for production-side decisions.

2.5.6 Empirical factor demand and output supply equations

Per equation (3), a household's factor demand and output supply equations are $\boldsymbol{y} = \boldsymbol{y}\left(p^{*}, E(\boldsymbol{p_o}), \boldsymbol{w}; \boldsymbol{z} \right)$. The empirical models are specified as:

$$y_{i,t} = \alpha_0 + \alpha_1 \hat{p}^{*}_{i,t} + \boldsymbol{p}_{\boldsymbol{o},i,t-1}\boldsymbol{\alpha_2} + \alpha_3 w_{i,t} + \boldsymbol{z}_{i,t}\boldsymbol{\alpha_4} + \alpha_5 govtfert_{i,t} + c_i + u_{i,t} \qquad (11)$$

where $\hat{p}^{*}_{i,t}$ is the expected maize price (ZMK/kg); $\boldsymbol{p}_{\boldsymbol{o},i,t-1}$ is a vector of other crop prices at the previous harvest in ZMK/kg; $w_{i,t}$ is the effective fertilizer market price in ZMK/kg paid by households that purchased fertilizer from commercial sources and the district median effective fertilizer market price otherwise; $\boldsymbol{z}_{i,t}$ is a vector of other production shifters such as quasi-fixed factors of production, rainfall, and household characteristics affecting production; $govtfert_{i,t}$ is the kilograms of government-subsidized fertilizer (from FRA-FCP, FSP, and/or FSPP/PAM) acquired by the household; c_i is time invariant household-level unobserved heterogeneity; and $u_{i,t}$ is the error term. Price data on variable inputs other than fertilizer are not available. Following Ricker-Gilbert et al. (2011), the quantity of government-subsidized fertilizer acquired by the household is treated as a quasi-fixed factor. See Tables A.1 and A.2 in Appendix A for summary statistics for the explanatory variables in equation (11).

A factor demand equation is estimated for the intensity of fertilizer use on maize (kg/ha). Fertilizer acquired from both government and commercial channels is included. Data are not available to estimate demand equations for factors other than fertilizer. On the output side, equations are estimated for area planted and crop output per hectare. Partial effects of explanatory variables of interest on crop output are derived using the product rule. Equations are estimated for total, maize, and non-maize output per hectare. For area planted, equations are estimated for total area and maize area, and then partial effects on non-maize area are calculated as the difference of the partial effects on total area and maize area. "Total" refers to maize and the 16 non-maize crops covered by all three SSs. Total crop output and non-maize crop output are Fisher-Ideal Quantity Indexes (FIQI) (Diewert, 1992; Diewert, 1993). The usual FIQI formula is slightly modified to preserve variation in the cross-sectional and time dimensions. See Appendix B for additional details on how the FIQIs are constructed. Total and non-maize crop output per hectare are defined as the associated crop output FIQI divided by hectares planted to the crops included in the FIQI. See Table A.3 in Appendix A for summary statistics for fertilizer use on maize and the dependent variables in the various output supply equations.

2.5.7 Estimation strategy

Time invariant household-level unobserved heterogeneity (c_i) may be correlated with the observed covariates in equation (11) (call them $\boldsymbol{X_{i,t}}$). In order to control for c_i and consistently estimate the parameters in this equation, we first need to assume strict exogeneity of $\boldsymbol{X_{i,t}}$ conditional on c_i, i.e., $E(u_{i,t} \mid \boldsymbol{X_i}, c_i) = 0,\ t = 1,2,...,T$. The fixed effects (FE) estimator is consistent under the assumptions of strict exogeneity and a rank condition (Wooldridge, 2002). FE is used to estimate equation (11) for all dependent variables.

Fertilizer use on maize and maize area planted are equal to zero for 64% and 20% of the observations in the analytical sample, respectively. Equations for these two dependent variables are estimated using CRE Tobit as well as FE. For the CRE approach, if in addition to strict exogeneity we assume that $c_i = \psi + \bar{\boldsymbol{X}}_{\boldsymbol{i}}\xi + a_i$ and $c_i \mid \boldsymbol{X}_{\boldsymbol{i}} \sim Normal(\psi + \bar{\boldsymbol{X}}_{\boldsymbol{i}}\xi,\ \sigma_a^2)$, where $\bar{\boldsymbol{X}}_{\boldsymbol{i}}$ is the average of $\boldsymbol{X}_{\boldsymbol{i,t}}$, t=1,…,T, and σ_a^2 is the variance of a_i, then we can control for c_i by including $\bar{\boldsymbol{X}}_{\boldsymbol{i}}$ as additional explanatory variables (Wooldridge, 2002). With the exception of $govtfert_{i,t}$, all explanatory variables in (11) are assumed to be strictly exogenous.

GRZ fertilizer program participants are not randomly selected and it is possible that unobserved time-varying factors that affect a household's participation in these programs also influence their crop production decisions and commercial fertilizer purchases; i.e., $govtfert_{i,t}$ may be correlated with $u_{i,t}$. $govtfert_{i,t}$ is also a corner solution variable: most households acquire zero government-subsidized fertilizer in a given year, and the quantity acquired by recipients is an approximately continuous variable (see Figure 2.1). I use the control function approach to test and control for the potential endogeneity of $govtfert_{i,t}$ (Rivers and Vuong, 1988; Vella 1993; Ricker-Gilbert et al., 2011).

In this two-step approach, I first estimate a reduced form model using CRE-Tobit where $govtfert_{i,t}$ is the dependent variable and the explanatory variables are all of the right hand side variables in equation (11) and at least one instrumental variable (IV). The reduced form Tobit residuals are then included as an additional regressor in equation (11). If the coefficient on the Tobit residuals is statistically significant, then we reject the null hypothesis that $govtfert_{i,t}$ is exogenous. Including the Tobit residuals in (11) also solves the endogeneity problem (Rivers and Vuong, 1988; Vella 1993).

Three IVs are included in the reduced form Tobit for $govtfert_{i,t}$: (i) a binary variable equal to one if the household's constituency (*k*) was won by the ruling party (the Movement for Multi-Party Democracy, MMD) during the last presidential election, and zero otherwise ($MMD_{k,t}$); (ii) the absolute value of the percentage point spread between the MMD and the lead opposition party in the constituency in the last presidential election ($spread_{k,t}$); and (iii) the interaction term, $MMD_{k,t} \times spread_{k,t}$.[11,12] Banful (2011) uses similar variables to explain district level subsidized fertilizer allocation in Ghana in 2008.

Reduced form Tobit results indicate that the three candidate IVs are valid in the sense that they are partially correlated with $govtfert_{i,t}$: the average partial effect (APE) of $MMD_{k,t}$ is positive and statistically significant at the 1% level; the APE of $spread_{k,t}$ is negative and statistically significant at the 5% level; and the interaction effect is positive and statistically significant at the 1% level. (See Mason (2011, Chapter 4) for a detailed discussion of the political economy implications of the reduced form Tobit results.) I maintain that the IVs should be uncorrelated with $u_{i,t}$ given the explanatory variables included in equation (11) and the fact that FE or CRE is used to control for time-invariant unobserved heterogeneity. Results of tests

[11] There are 150 total constituencies in Zambia's 72 districts. The number of constituencies per district are: 1 (26 districts), 2 (22 districts), 3 (20 districts), 4 (2 districts), 5 (1 district), and 7 (1 district). A constituency contains multiple villages.

[12] Presidential and parliamentary elections in Zambia take place every five years and the MMD candidate has won all presidential elections since 1991 (i.e., 1991, 1996, 2001, 2006, and the 2008 emergency election following the death of President Levy Mwanawasa).

for over-identifying restrictions, which will be discussed further in the results section, generally support the exogeneity of the two extra IVs. (Only one of the three IVs is needed for the model to be just-identified.)

Two explanatory variables included in equation (11) are 'generated regressors', i.e., they are estimated in first-stage auxiliary models: the expected maize price and the Tobit residuals from the reduced form government fertilizer equation. Bootstrapping is used to compute standard errors that account for the sampling variation inherent in these generated regressors (Wooldridge, 2002).

2.5.8 Main partial effects of interest and hypotheses tested

As discussed in the Introduction, the main objectives for the econometric work in this paper are: (i) to estimate the marginal effects of changes in FRA's maize pricing and purchases on Zambian smallholder fertilizer use on maize and crop output supply; and (ii) to estimate the marginal effects of an increase in the quantity of GRZ fertilizer acquired by a household on these outcome variables. For objective (ii), the estimated marginal effects are simply the APEs with respect to $govtfert_{i,t}$ in equation (11).

For objective (i), recall that a household's fertilizer demand or output supply ($y_{i,t}$) is a function of the expected maize price, $\hat{p}^*_{i,t}$, and per equations (2) and (10), $\hat{p}^*_{i,t}$ is a function of $\hat{\mu}_{f,i,t}$, $\hat{\mu}_{p,i,t}$, $\hat{\sigma}^2_{f,i,t}$, $\hat{\sigma}^2_{p,i,t}$, $\hat{\sigma}_{fp,i,t}$, and $\hat{\gamma}_{i,t}$. These values are all functions of $\mathbf{\Omega}_{i,t-1}$, the information set observed by the household at planting time that is hypothesized to inform its subjective valuations. Included in $\mathbf{\Omega}_{i,t-1}$ are two sets of FRA policy-related variables: the log effective FRA maize price at the previous harvest ($\ln p_{f,i,t-1}$), and the MT of maize purchased by the FRA in the household's district (*d*) in previous marketing year(s) ($QFRA_{d,t-l}$, up to a maximum of *l*=5 lags).[13] Let $\boldsymbol{W}_{i,t-1}$ be the vector of variables in $\boldsymbol{\Omega}_{i,t-1}$ other than $\ln p_{f,i,t-1}$ and $QFRA_{d,t-l}$, *l=1,…,L*. For example, suppose *L=1*. Using the chain rule, the partial effects of interest for objective (i) are

$$\frac{\partial E(y_{i,t} \mid \boldsymbol{X_{i,t}}, c_i)}{\partial g_{i,t-1}} = \frac{\partial E(y_{i,t} \mid \boldsymbol{X_{i,t}}, c_i)}{\partial \hat{p}^*_{i,t}} \cdot \frac{\partial \hat{p}^*(\ln p_{f,i,t-1}, QFRA_{d,t-1}, \boldsymbol{W}_{i,t-1})}{\partial g_{i,t-1}} \qquad (12)$$

where $g_{i,t-1} = p_{f,i,t-1}$ or $QFRA_{d,t-1}$ and $\boldsymbol{X_{i,t}}$ is the vector of observed explanatory variables in (11) including $\hat{p}^*_{i,t}$. The first term on the right hand side of (12) is estimated via equation (11). The second term is derived from the auxiliary models estimated and used to construct $\hat{p}^*_{i,t}$. Standard errors for the APEs corresponding to equation (12) are obtained via bootstrapping to account for the two-step estimation. I test the null hypotheses that the APEs with respect to the FRA-related variables and $govtfert_{i,t}$ are equal to zero against the alternative that they are different from zero.

Before moving on to the results, it is important to re-emphasize that what is estimated in this paper are the *marginal effects* of *changes* in past FRA effective prices and district-level maize purchases, and of *changes* in the quantity of government-subsidized fertilizer acquired on

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[13] For *l*=1, FRA district-level purchases are through November, since planting begins in December in most areas and the variables in $\boldsymbol{\Omega}_{i,t-1}$ should be observed by the household at planting time.

smallholder farm household fertilizer use on maize and output supply. FRA activities and GRZ fertilizer programs may also influence equilibrium maize and fertilizer market prices, which may, in turn, affect smallholder behavior. Such equilibrium effects are not captured in this paper. Some estimated *marginal* effects of changes in past FRA policies reported in the results section are not statistically different from zero. This does not imply that these FRA policies have no *equilibrium* effect on the smallholder behavioral outcome of interest, since the FRA policies may affect smallholder behavior indirectly through their effects on *equilibrium* maize market prices.

2.6 Results

Sections 2.6.1 through 2.6.3 highlight the key findings of the analysis. In section 2.6.1, I discuss the results of the auxiliary regressions used to construct the expected maize price variable. In section 2.6.2, I report the fertilizer use on maize and output supply regression results, and focus on the estimated APEs of the expected maize price and of the past effective FRA maize price and district-level purchases. In section 2.6.3, I discuss the estimated APEs of government-subsidized fertilizer in the fertilizer demand and output supply equations.

2.6.1 Marginal effects of past FRA effective prices & FRA purchases on a household's expected maize price and probability of selling to FRA at next harvest

Table 2.4 reports the results for the log effective FRA and market maize price regressions and those for the associated log squared residuals (per equations (5) and (8)).[14,15] As shown in

[14] For results in this section, if squared terms have been included in the regression, it is supported by an F-test for the joint significance of the level and squared terms (p<0.10).

[15] The analytical sample for the effective maize market price regression excludes the bottom and top one percent of observations in each panel survey year. For the effective FRA price regression, the bottom one percent of observations in each year are excluded.

column A, larger FRA district-level maize purchases at the previous harvest are associated with a higher effective maize market price at the upcoming harvest. For each additional 10,000 MT purchased by the FRA in a household's district, the harvest-time effective market price is expected to increase by 6.67%. This is consistent with *a priori* expectations. Once the FRA begins buying maize in a district, it generally returns to that district to buy maize in subsequent marketing years. Higher FRA purchases in a given area are expected to put upward pressure on market prices there. The elasticity of the harvest-time maize market price with respect to the lagged effective FRA maize price is not statistically different from zero.[16] Theil's inequality coefficient for the regression is less than one, indicating that the predicted prices have greater forecasting accuracy than the naïve expectation. For all four regressions in Table 2.4, I fail to reject the null hypothesis that the predicted log price or squared residuals are unbiased (p=1.00).

Turning to the results in Table 2.4, column B, an increase in district-level FRA maize purchases during the previous harvest has a negative effect on the variance (squared residuals) of maize market prices at the upcoming harvest when those purchases are less than 15,330 MT. At 9,890 MT, the 90th percentile of district-level FRA purchases (t-1) over the three waves of the panel survey is well below this level. An increase in a household's naïve expectation of the effective FRA price has no statistically significant effect on the variance of maize market prices.[17]

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[16] The interaction of the log effective FRA price (t-1) and the 1999/2000 agricultural year dummy is included in the log effective maize market price equation and that for its log squared residuals to allow the effect of the FRA price variable to differ in 1999/2000 versus 2002/03 and 2006/07. The FRA did not buy maize in Zambia in 1999/2000 hence there was no FRA price that year. The effective FRA price is set equal to the market price for 1999/2000.

[17] For both the market and FRA price variance equations, there was no statistical support for additional squared or interaction terms beyond those included in Table 2.4.

Table 2.4. Results from log effective market and FRA maize price and log squared residuals regressions

	Dependent variable											
	(A) Log effective maize market price --------at harvest--------			(B) Log squared --residuals from (A)--			(C) Log effective FRA maize price --------at harvest--------			(D) Log squared --residuals from (C)--		
Explanatory variables	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.
FRA dist. purch. ('000MT, t-1)	6.67E-3	**	0.024	-0.149	***	0.007	-2.06E-3		0.373	0.0153		0.825
FRA district purchases, sqd.				4.85E-3	**	0.033						
Log effective FRA price (t-1)	-0.0221		0.811	1.116		0.101	0.341	***	0.000	-4.021	*	0.074
Log eff. FRA price×1999/2000	0.417	*	0.056	0.0469		0.989						
Log maize producer price (t-1)	-0.0221		0.803	-14.434		0.539	1.68E-3		0.968	-1.499		0.337
Log maize producer price, sqd.				1.0156		0.580						
Log regional wholesale maize price (pre-planting):												
October	0.127		0.365	1.058		0.257						
September	0.0354		0.809	-1.850	*	0.063						
August	0.0854		0.418	-0.884		0.265						
July	0.0637		0.707	-2.596	**	0.034						
June	-0.236		0.187	3.127	**	0.010						
May	-0.0318		0.675	-0.790		0.200						
April	-0.155		0.446	2.306	*	0.055						
March	-0.119		0.546	1.845		0.173						
February	0.0270		0.930	-2.016		0.345						
January	0.0419		0.904	0.886		0.726						
December	-0.723	***	0.005	1.658		0.287						
November	0.377	***	0.005	-2.422	**	0.029						
Log eff. market fertilizer price	-0.0163		0.754	-0.521		0.168	0.0250		0.451	-2.029		0.107
HH owns radio (=1)	0.0289	*	0.079	0.0435		0.729	0.0122		0.137	0.572		0.174
HH owns cell phone (=1)	3.78E-3		0.888	0.195		0.425	7.88E-4		0.925	-7.46E-3		0.984
HH access to cell phone (=1)	3.97E-3		0.861	0.0948		0.682	-1.20E-3		0.884	-0.542		0.139
HH owns bicycle (=1)	0.0220		0.165	-0.120		0.345	-0.0111		0.211	0.0528		0.863
HH owns motorcycle (=1)	5.82E-3		0.922	0.639		0.117	0.0404		0.381	-0.855		0.466

Table 2.4 (cont'd)

Explanatory variables	(A) Log effective maize market price --------at harvest-------- Coef.	Sig.	p-val.	(B) Log squared --residuals from (A)-- Coef.	Sig.	p-val.	(C) Log effective FRA maize price --------at harvest-------- Coef.	Sig.	p-val.	(D) Log squared --residuals from (C)-- Coef.	Sig.	p-val.
HH owns car/truck (=1)	0.0300		0.647	0.401		0.353	0.0135		0.402	-0.753		0.143
HH owns ox-cart (=1)	-3.86E-3		0.891	0.393	*	0.075	-1.38E-3		0.880	-1.15E-3		0.847
Kilometers from center of SEA to nearest (as of 2000):												
District town	8.00E-5		0.840	4.54E-3	*	0.060	2.56E-4		0.239	8.64E-3		0.287
Tarred/main road	-5.07E-4		0.216	-4.95E-4		0.829	5.88E-5		0.535	-1.81E-3		0.634
Feeder road	-5.90E-3	**	0.036	-5.70E-3		0.633	1.07E-3		0.392	-0.0293		0.618
HH head age in 2001	-5.58E-4		0.141	-0.0275		0.106	3.21E-5		0.893	-0.0107		0.293
HH head age, sqd.				1.91E-4		0.259						
Highest level of education completed by HH head (base is no formal education):												
Lower primary (gr1-4) (=1)	0.0371		0.197	0.221		0.364	0.0488	***	0.009	-0.503		0.512
Upper primary (gr5-7) (=1)	0.0548	*	0.052	0.421		0.106	0.0332		0.103	-0.594		0.415
Secondary (gr8-12) (=1)	0.0350		0.362	0.385		0.180	0.0567	***	0.007	-0.451		0.563
Post-secondary (=1)	0.102	*	0.077	0.768		0.139	0.0148		0.531	-2.240	*	0.063
Gender & residence status of HH head (non-resident if <6 months; base is resident male):												
Female, non-res. husb. (=1)	-0.108		0.129	0.608		0.285	-0.0642	**	0.011	0.760		0.628
Female, no husband (=1)	9.54E-04		0.973	0.240		0.409	0.0383	***	0.007	0.354		0.630
Landholding size (ha)	-2.94E-4		0.901	-0.0140		0.476	5.76E-4		0.756	0.0118		0.883
Landholding size, sqd.	-1.06E-5		0.302	1.78E-5		0.837	-1.21E-5		0.731	-6.39E-4		0.691
FTE PA adults	-2.94E-4		0.952	-6.35E-3		0.858	4.90E-4		0.857	-0.0661		0.529
Expected rainfall ('00 mm)	0.229		0.160	-0.0379		0.861	-1.07E-4		0.995	-0.891		0.136
Expected rainfall, sqd.	-0.0145	*	0.083									

Table 2.4 (cont'd)

Explanatory variables	Dependent variable											
	(A) Log effective maize market price --------at harvest--------			(B) Log squared --------residuals from (A) --------			(C) Log effective FRA maize price --------at harvest--------			(D) Log squared --residuals from (C)--		
	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.
Exp. moisture stress	0.0770	*	0.075	0.668	*	0.068	-0.0128		0.716	-1.019		0.381
Rain. variability (%)	-5.38E-4		0.854	-0.0349		0.153	-1.88E-3		0.180	0.0563		0.195
SEA suitable for low input mgt maize (=1)	-1.69E-3		0.923	-0.159	*	0.057	9.71E-3	*	0.069	0.609	**	0.034
Agricultural year (base is 2006/2007):												
1999/2000 (=1)	-3.499	***	0.003	-3.285		0.870						
2002/2003 (=1)	-0.400	***	0.002	1.138		0.180	-0.224	***	0.000	0.699		0.468
Constant	2.069		0.661	45.193		0.693	4.205	***	0.000	9.101		0.674
District dummies	Yes			Yes			No			No		
Prov., AER dummies	No			No			Yes			Yes		
Time averages (CRE)	Yes			Yes			Yes			Yes		
Observations	4,405			4,405			492			492		
R-squared	0.694			0.079			0.608			0.130		
Overall model F-stat.	82.94	***	0.000	7.62	***	0.000	21.34	***	0.000	3.88	***	0.000
Unbiased prediction F	0.00		1.000	0.00		1.000	0.00		1.000	0.00		1.000
Theil inequal. coef.	0.800						0.541					
Turning point 1	7.86 (exp. rain, '00 mm)			393.36 (landholding, ha)								
Turning point 2				15.33 (FRA dist purch ('000MT)								
Turning point 3				7.11 (Log eff. maize price)								
Turning point 4				72.10 (HH head age in 2001)								

Notes: See Tables A.1 and A.2 in Appendix A for more complete explanatory variable descriptions. FTE PA adults = full time equivalent prime age (15-59 years old) adults. AER=agro-ecological region. ***, **, * significant at the 1%, 5%, and 10% levels. Complex survey weights & Huber-White robust variance matrix estimator used in computation of standard errors.

Results from the log effective FRA maize price regression (Table 2.4, column C), indicate a statistically significant elasticity of 0.341 of the harvest time effective FRA price with respect to the household's naïve expectation of this price. This is consistent with *a priori* expectations because from a political standpoint it is virtually impossible for the FRA to lower its pan-territorial buy price from one year to the next. The partial effect with respect to past FRA purchases in the household's district is not statistically different from zero. Like the log effective maize market price results, Theil's inequality coefficient for the log effective FRA price regression (0.608) indicates that its forecasting accuracy exceeds that of the naïve expectation.[18]

The final set of results in Table 2.4 is for the log squared residuals from the log effective FRA price equation, i.e., the (log) variance of the log effective FRA price. The elasticity of this variance with respect to the previous year's effective FRA price is statistically significant, negative, and large in magnitude (-4.021). The coefficient on past FRA purchases in the household's district is not statistically significant.

The last auxiliary regression required to construct the expected maize price variable is the probit to obtain a household's predicted probability of selling maize to the FRA at the next harvest. As reported in Table 2.5, a 1% increase in the previous year's effective FRA price is associated with a small increase (0.003) in the probability that the household will sell to the FRA the following year (where the probability is measured on a [0,1] scale). The long-run average partial effect of a 1,000 MT increase in FRA district-level purchases is a 0.032 increase in the probability that the household will sell to the FRA at the next harvest.

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[18] The effective FRA price mean and variance regressions are overparameterized if the vector of pre-planting regional wholesale maize prices is included. This is also the case for the CRE probit to predict the probability that a household will sell to the FRA at the next harvest.

Table 2.5. CRE Probit results: HH sold maize to FRA at harvest =1; =0 otherwise

Explanatory variables	APE	Sig.	p-val.
FRA district-level purchases ('000 MT, t-1)	0.00303		0.427
FRA district-level purchases ('000 MT, t-2)	0.0146		0.158
FRA district-level purchases ('000 MT, t-3)	-0.00670		0.703
FRA district-level purchases ('000 MT, t-4)	0.00784		0.764
FRA district-level purchases ('000 MT, t-5)	0.0128		0.214
Log effective FRA price (t-1)	0.279	***	0.003
Log maize producer price (t-1)	-0.180	***	0.005
Log effective market fertilizer price	-0.0721		0.168
HH owns radio (=1)	0.0146		0.150
HH owns cell phone (=1)	0.0173		0.164
HH does not own but has access to cell phone (=1)	0.0145		0.126
HH owns bicycle (=1)	0.0245	**	0.029
HH owns car/truck (=1)	0.0382		0.440
HH owns ox-cart (=1)	0.0282		0.188
Km from center of SEA to nearest district town (as of 2000)	0.000415		0.187
Km from center of SEA to nearest tarred/main road (as of 2000)	0.000104		0.640
Km from center of SEA to nearest feeder road (as of 2000)	-0.00561	***	0.002
HH head age in 2001	-0.000122		0.631
Highest level of education completed by HH head (base is no formal education):			
Lower primary (grades 1-4) (=1)	-0.0187		0.274
Upper primary (grades 5-7) (=1)	-0.0163		0.353
Secondary (grades 8-12) (=1)	-0.00323		0.883
Post-secondary (=1)	-0.0201		0.500
Female HH head (=1)	-0.0208		0.193
Landholding size (ha)[a]	0.0107	***	0.000
Full-time equivalent prime-age adults (ages 15-59)	0.00209		0.434
Expected growing season rainfall ('00 mm)[b]	0.00678		0.734
Expected moisture stress (# of 20-day periods)	-0.0260		0.502
Rainfall variability (%)	0.00436	*	0.060
SEA suitable for low input mgt rainfed maize production (=1)	0.00514		0.641
2002/2003 agricultural year (=1) (2006/2007 is base year)	-0.0384		0.170
Province and agro-ecological region dummies	Yes		
Time averages (CRE)	Yes		
Observations	5,441		
Number of observations with dependent variable =1	503		
Overall model F-stat.	15.49	***	0.000
Joint significance of lagged FRA district-level purchases (F-stat.)	3.77	***	0.003
Long-run effect of FRA district-level purchases ('000 MT)	0.0315	*	0.058

***, **, * significant at the 1%, 5%, and 10% levels. Complex survey weights & Huber-White robust variance matrix estimator used in computation of standard errors. [a]APE includes effect of squared and cubed terms. [b]APE includes effect of squared term.

Summary statistics for the probability of selling maize to the FRA at the next harvest are reported in Table 2.6. As of planting time in 1999, the FRA had not purchased maize on the domestic market for two years and there was no indication that it planned to do so at the upcoming harvest. All households are thus assigned zero probability of selling to the FRA for 1999/2000. As of planting time in 2002, the FRA had purchased small quantities of maize in just eight districts and there was no indication that the Agency intended to expand to other districts and/or increase its purchase levels at the next harvest. Therefore, for 2002/03, zero probability of selling to the FRA is assigned to all households outside of these eight districts. The remaining 2002/03 households are included in the probit model and are assigned the predicted probability of selling to the FRA from the estimated probit. The FRA increased its level of maize purchases and geographic coverage between 2003 and 2006. As of planting time in 2006, the Agency was in the midst of its largest maize purchase campaign since its creation in 1996. Predicted probabilities from the probit model are assigned to all 2006/07 households. The probability of selling to the FRA is extremely low for the vast majority of households (Table 2.6).

Given the auxiliary regression results, associated predicted values, and probabilities of selling to the FRA, an expected maize price is constructed for each household and agricultural year per equation (10). See Table 2.7 for summary statistics.[19] The overall partial effects of increases in past FRA district-level purchases and in the lagged effective FRA price on a household's expected maize price (i.e., the second term on the right hand side of equation (12)) are summarized in Table 2.8.

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[19] One household has unreasonably high expected maize prices for 2002/03 and 2006/07 (the maximum values for each of those years in Table 2.7). This household is excluded from the fertilizer demand and output supply econometric analysis.

Table 2.6. Probability of selling maize to FRA at the next harvest

Summary statistic	Predicted prob-abilities from probit	Probabilities for all sample HHs: 2002/03 & 2006/07	2002/03	2006/07
N	5,441	9,644	5,358	4,286
Mean	0.0796	0.0448	0.00333	0.0969
Std. deviation	0.126	0.102	0.0172	0.136
Skewness	2.799	3.781	10.556	2.487
Kurtosis	12.3767	20.507	157.331	10.255
Minimum	1.18E-7	0	0	0
1st percentile	8.19E-6	0	0	7.55E-6
5th percentile	0.0000945	0	0	0.000139
10th percentile	0.000414	0	0	0.00141
25th percentile	0.00464	0	0	0.0110
50th percentile	0.0289	0.000575	0	0.0445
75th percentile	0.0977	0.0382	0	0.123
90th percentile	0.226	0.141	0.00395	0.262
95th percentile	0.343	0.247	0.0159	0.386
99th percentile	0.621	0.533	0.0751	0.664
Maximum	0.951	0.951	0.459	0.951
Observed mean	0.0799	0.0473	0.00761	0.0971

Table 2.7. Expected maize price summary statistics

Summary statistic	Agricultural year: 1999/2000	2002/03	2006/07
N	6,922	5,358	4,286
Mean	270	525	654
Standard deviation	62	90	86
Skewness	0.357	1.073	0.810
Kurtosis	2.520	4.505	4.529
Minimum	151	339	427
1st percentile	167	377	500
5th percentile	177	406	539
10th percentile	188	424	555
25th percentile	223	465	590
50th percentile	264	511	643
75th percentile	315	564	705
90th percentile	354	653	761
95th percentile	375	721	807
99th percentile	422	792	920
Maximum	497	1,224	1,387

In 2006/07, the average elasticity of the expected maize price with respect to past FRA district-level purchases is 0.103 (p=0.060). The average elasticity for 2002/03 is not statistically different from zero (Table 2.8). This is expected given that 75% of households had zero probability of selling to the FRA that year, and that the 99th percentile is 0.075 (Table 2.6). The average elasticity of the expected maize price with respect to FRA district-level purchases is positive and statistically significant in 2006/07 for all groups of households except female-headed households with a non-resident husband (which are less than 1% of the sample) (Table 2.8).

The relative size of the elasticity is consistent with *a priori* expectations: it is larger among households that cultivate more land, in areas that are suitable for low-input management rainfed maize production, and among male-headed households. Households in these three groups also have a positive and statistically significant average elasticity of the expected maize price with respect to the lagged effective FRA maize price (Table 2.8). In summary, results suggest that an increase in past FRA district-level maize purchases and, for certain groups of households, an increase in the lagged effective FRA price are associated with increases in the household's expected maize price.

2.6.2 Marginal effects of the expected maize price and past FRA maize purchases and prices on smallholder behavior

The fertilizer demand and crop output supply equations estimated in this paper include as explanatory variables both the expected maize price and the quantity of government-subsidized fertilizer acquired by the household. In this section, I focus on the estimated effects of an increase in the expected maize price and reserve discussion of the subsidized fertilizer results for section 2.6.3. The full regression results are reported in Tables A.4 through A.6 in Appendix A.

Table 2.8. Average elasticities of expected maize price with respect to past FRA effective maize price & district-level purchases

	Average elasticity of expected maize price with respect to:											
	FRA district-level purchases (t-1 to t-5)						Effective FRA maize price (t-1)					
	---2002/03 & 2006/07---			------2006/07 only------			---2002/03 & 2006/07---			------2006/07 only------		
Population	Elasticity	Sig.	p-val.	Elasticity	Sig.	p-val.	Elasticity	Sig.	p-val.	Elasticity	Sig.	p-val.
All households	0.0456	*	0.062	0.103	*	0.060	0.0991		0.130	0.121		0.160
Farm size category:												
< 2 ha cultivated	0.0352	*	0.067	0.0796	*	0.064	0.0872		0.212	0.0962		0.353
>= 2 ha cultivated	0.0749	*	0.071	0.170	*	0.070	0.133	**	0.035	0.191	***	0.002
Suitability of area for low input management, rainfed maize production:												
High/moderate	0.0569	*	0.072	0.128	*	0.070	0.102	*	0.059	0.130	***	0.004
Marginal/unsuitable	0.0311	*	0.071	0.0710	*	0.068	0.0961		0.327	0.109		0.532
Gender & residence status of HH head (non-resident if <6 months):												
Resident male	0.0477	*	0.066	0.109	*	0.064	0.105	*	0.100	0.131		0.102
Female, non-res. husband	0.0206		0.221	0.0849		0.191	0.146		0.225	0.135		0.350
Female, no husband	0.0391	*	0.055	0.0844	*	0.054	0.0783		0.374	0.0875		0.486
Agricultural year:												
2002/2003	-1.82E-4		0.861				0.0819		0.249			
2006/2007	0.103	*	0.060				0.121		0.160			

Notes: ***, **, * significant at the 1%, 5%, and 10% levels. p-values from standard errors based on 500 bootstrap replications.

Average partial effects (APEs) and average elasticities (AEs) with respect to the expected maize price are summarized in Table 2.9. Contrary to *a priori* expectations, an increase in the expected maize price has no statistically significant impact on maize quantity harvested (rows L and M). The APE of the expected maize price is statistically significant and positive for maize area planted (rows D and E) but negative for maize yield (row I). (Maize area and yield average elasticities are both quite large in magnitude, though less than one in absolute value.) The area and yield effects offset each other, the result being no significant change in maize quantity harvested. The APE of the expected maize price on the intensity of fertilizer use on maize (kg/ha) is not statistically different from zero (rows A and B). This result coupled with the positive APE on maize area planted suggests that an increase in the expected maize price is associated with an increase in total fertilizer use on maize (kg).

What could explain the positive maize area effect but negative maize yield effect? Households are expected to try to produce more maize in response to a higher expected maize price. This could be achieved through an increase in maize area planted (holding yield fixed), an increase in maize yield (holding area constant), or increases in both area and yield. Results suggest a maize area expansion but yield declines despite no change in the intensity of fertilizer use. The additional land brought under maize may be poorer quality and/or in areas less suitable for maize production. Even with the same intensity of fertilizer use, maize yields on such land would be expected to be lower. The negative APE on maize yields could be due to constraints on other inputs as well. For example, the household may not have the necessary cash or credit to buy improved seed for the additional maize area; family time or financial resources to hire in labor to successfully weed and otherwise manage the additional acreage of maize could be lacking, etc.

Table 2.9. Summary: Average partial effects and average elasticities with respect to the expected maize price

Row	Outcome variable	Estimator	Average partial effect	Average elasticity	p-value based on ___ standard errors[a] Bootstrap	Robust
A	Fertilizer use on maize (kg/ha)	Fixed effects	0.000230	0.000847	0.995	0.996
B	Fertilizer use on maize (kg/ha)	CRE Tobit	0.0102	0.0509	0.817	0.807
C	**Total area planted (ha)**	**Fixed effects**	**0.00148**	**0.843**	**0.063**	0.000
D	**Maize area planted (ha)**	**Fixed effects**	**0.000881**	**0.970**	**0.044**	0.000
E	**Maize area planted (ha)**	**CRE Tobit**	**0.000626**	**0.639**	**0.063**	0.001
F	Non-maize area planted (ha)	Derived (C-D)	0.000595	0.615	0.158	N/A
G	Non-maize area planted (ha)	Derived (C-E)	0.000850	0.884	0.094[b]	N/A
H	Total output/ha (FIQI/ha)	Fixed effects	-0.000842	-0.037	0.897	0.878
I	**Maize yield (kg/ha)**	**Fixed effects**	**-1.388**	**-0.866**	**0.007**	0.001
J	Non-maize output/ha (FIQI/ha)	Fixed effects	0.0114	0.516	0.327	0.208
K	Total output (FIQI)	Derived [f(C,H)]	0.0298	0.783	0.134	N/A
L	Maize output (kg)	Derived [f(D,I)]	0.0573	0.096	0.935	N/A
M	Maize output (kg)	Derived [f(E,I)]	-0.229	-0.232	0.715	N/A
N	Non-maize output (FIQI)	Derived [f(F,J)]	0.0259	1.106	0.123	N/A
O	Non-maize output (FIQI)	Derived [f(G,J)]	0.0328	1.359	0.080[c]	N/A

Notes: Results in **bold** are statistically significant at the 10% level based on the bootstrap standard errors. [a]Bootstrap standard errors account for the generated regressors (expected maize price and/or Tobit residuals from government fertilizer reduced form) and are based on 500 bootstrap replications. Robust standard errors are Huber-White standard errors clustered at the household-level and do not account for the generated regressors. [b]Not statistically different from zero at the 10% level if estimate directly with CRE Tobit (APE=0.000432, p=0.260). [c]Not statistically different from zero at the 10% level if estimate directly with CRE Tobit (APE=-0.00566, p=0.386) or if derive from directly estimated non-maize area planted (CRE Tobit) and non-maize output/ha (APE=0.0226, p=0.152).

The regression results do not suggest that the additional area planted to maize comes at the expense of area planted to non-maize crops. The APE of the expected maize price on total area planted is positive and significant (Table 2.9, row C), while the APE on non-maize area planted is not statistically different from zero (rows F and G; also see note (b)). Other factors constant, total and non-maize output (per hectare and overall) do not significantly change when the expected maize price increases (rows H, J, K, N, and O; also see note (c)).

Using bootstrapping to obtain standard errors that account for the 'generated regressor' nature of the expected maize price substantially increases the p-value of its APE, particularly in the area planted equations. p-values based on non-bootstrapped (in this case, Huber-White) standard errors are no larger than 0.001 but once the multiple first stage regressions are taken into consideration via bootstrapping, the p-values rise to 0.044 or 0.063 (Table 2.9, rows C through E). Granted, these APEs are still statistically significant at the 5% and 10% levels, respectively, but using non-bootstrapped standard errors would have greatly overstated the precision of the estimates.

What do the expected maize price APEs in Table 2.9 suggest about the marginal effects of past FRA district-level purchases and of the lagged effective FRA price on smallholder behavior? The APEs of these FRA-related variables on fertilizer use on maize (kg/ha), non-maize area planted, total and non-maize output/ha, and total, maize, and non-maize output are not statistically different from zero because the APE of the expected maize price is not statistically significant in the equations (Table 2.9). However, the APE of the expected maize price is statistically significant in the total area planted, maize area planted, and maize yield equations. Changes in past FRA district-level purchases and the lagged effective FRA price affect these outcome variables via their effects on the expected maize price.

Table 2.10 summarizes the APEs and AEs of these FRA-related variables on total and maize area planted and maize yield. The table also includes reduced form estimates of the APEs and AEs. Recall that the "structural" models estimated in this paper entail a set of first stage auxiliary regressions to obtain measures of a household's subjective values for the mean and variance of log effective FRA and market maize prices and of the probability of selling to the FRA at the next harvest. Predicted values from these auxiliary regressions are used to construct a household's expected maize price, which is then included as an explanatory variable in the second stage fertilizer demand and crop output supply regressions. The "reduced form" results reported in Table 2.10 are from a regression of, say, total area planted on all of the explanatory variables from both the first and second stages. Thus past FRA district-level purchases and the lagged effective FRA price are included as explanatory variables in the reduced forms.

The standard errors associated with the structural APE and AE estimates are large due to the multiple first stage regressions, so few of the results in Table 2.10 are statistically significant at the 10% level or lower. However, many of the p-values for the structural APEs and AEs are less than 0.20 so there is some evidence, albeit weak, of significant FRA marginal effects. As expected based on the first and second stage regression results, an increase in past FRA district-level purchases has a weak positive effect on total area planted for most groups of households ($p<0.20$) but the associated reduced form APE and AE are not statistically different from zero. The AE of the lagged effective FRA price on total area planted is weakly positive for all households based on the structural model results ($p<0.22$) and positive and statistically significant at the 10% level based on the reduced form results.

Table 2.10. Summary: APEs with respect to past effective FRA maize price & district-level purchases, 2006/07 agricultural year

Outcome variable, population	FRA district-level purchases ('000 MT, t-1 to t-5)						(Log) effective FRA maize price (t-1)					
	-Average partial effect-			---Average elasticity---			-Average partial effect-			---Average elasticity---		
	APE	Sig.	p-value	AE	Sig.	p-value	APE[a]	Sig.	p-value	AE	Sig.	p-value
Total area planted (ha)												
All HHs	0.00868		0.166	0.0805		0.182	0.115		0.215	0.104		0.213
All HHs (reduced form)	-0.00162		0.722	-0.0117		0.722	0.216	*	0.094	0.257	*	0.094
Farm size category												
< 2 ha cultivated	0.00699		0.160	0.0905		0.176	0.0920		0.322	0.120		0.247
>= 2 ha cultivated	0.0135		0.186	0.0530		0.221	0.183		0.231	0.0579		0.179
Maize suitability												
High/moderate	0.0110		0.154	0.0996		0.189	0.122		0.349	0.0994		0.408
Marginal/unsuitable	0.00565		0.233	0.0558		0.187	0.106		0.257	0.109		0.155
HH head gender/residence												
Resident male head/spouse	0.00922		0.172	0.0771		0.196	0.126		0.259	0.0998		0.293
Fem. head, non-res. husb.	0.00788		0.218	0.0505		0.222	0.121		0.162	0.154		0.238
Female head, no husband	0.00697		0.145	0.0923		0.151	0.0829		0.298	0.115		0.155
Maize area planted (ha) – Fixed effects												
All HHs	0.00518		0.129	0.0913		0.138	0.0689		0.136	0.121	*	0.069
All HHs (reduced form)	0.00433	*	0.094	0.0562	*	0.094	0.0266		0.733	0.0553		0.733
Farm size category												
< 2 ha cultivated	0.00417		0.123	0.103		0.132	0.0549		0.103	0.137	*	0.070
>= 2 ha cultivated	0.00809		0.151	0.0633		0.172	0.109		0.317	0.0825		0.181
Maize suitability												
High/moderate	0.00658		0.116	0.110		0.142	0.0731		0.133	0.118	*	0.069
Marginal/unsuitable	0.00337		0.205	0.0665		0.151	0.0636		0.339	0.124		0.111
HH head gender/residence												
Resident male head/spouse	0.00550		0.136	0.0887		0.149	0.0750		0.165	0.124	*	0.074
Fem. head, non-res. husb.	0.00471		0.197	0.0778		0.245	0.0722		0.127	0.147		0.231
Female head, no husband	0.00416		0.108	0.101		0.109	0.0495		0.192	0.114	*	0.087

Table 2.10 (cont'd)

Outcome variable, population	FRA district-level purchases ('000 MT, t-1 to t-5)						(Log) effective FRA maize price (t-1)					
	-Average partial effect-			---Average elasticity---			-Average partial effect-			---Average elasticity---		
	APE	Sig.	p-value	AE	Sig.	p-value	APE[a]	Sig.	p-value	AE	Sig.	p-value
Maize area planted (ha) – CRE Tobit												
All HHs	0.00424		0.162	0.0734		0.179	0.0545		0.220	0.0865		0.117
All HHs (reduced form)	0.00347	**	0.027	0.0495	**	0.027	0.0134		0.888	0.0273		0.888
Farm size category												
< 2 ha cultivated	0.00316		0.147	0.0809		0.170	0.0394		0.163	0.0957	*	0.097
>= 2 ha cultivated	0.00733		0.190	0.0559		0.227	0.0977		0.388	0.0647		0.442
Maize suitability												
High/moderate	0.00545		0.154	0.0886		0.186	0.0596		0.250	0.0861		0.154
Marginal/unsuitable	0.00268		0.220	0.0527		0.188	0.0479		0.435	0.0870		0.147
HH head gender/residence												
Resident male head/spouse	0.00463		0.170	0.0731		0.189	0.0610		0.258	0.0901		0.133
Fem. head, non-res. husb.	0.00343		0.228	0.0575		0.291	0.0518		0.156	0.0935		0.236
Female head, no husband	0.00300		0.129	0.0747		0.148	0.0336		0.294	0.0732		0.128
Maize yield (kg/ha)												
All HHs	-8.854		0.989	-0.139		0.894	-113.492		1.000	-0.133		1.000
All HHs (reduced form)	-10.342	***	0.006	-0.113	***	0.006	298.130	*	0.058	0.410	*	0.058
Farm size category												
< 2 ha cultivated	-7.082		0.136	-0.114		0.215	-87.714	*	0.056	-0.110		0.102
>= 2 ha cultivated	-13.032		0.995	-0.196		0.953	-174.239		1.000	-0.189		1.000
Maize suitability												
High/moderate	-11.101		0.943	-0.184		0.775	-121.118		1.000	-0.132		1.000
Marginal/unsuitable	-5.795		0.997	-0.0761		0.965	-103.108	*	0.082	-0.136		0.144
HH head gender/residence												
Resident male head/spouse	-9.290		0.991	-0.132		0.920	-122.289		1.000	-0.136		1.000
Fem. head, non-res. husb.	-7.487		0.483	-0.0822		0.204	-113.752		0.104	-0.141		0.618
Female head, no husband	-7.298		0.115	-0.163		0.298	-81.638		0.579	-0.123		0.267

Notes: ***, **, * significant at the 1%, 5%, and 10% levels. p-values from standard errors based on 500 bootstrap replications to account for generated regressors (expected maize price and/or Tobit residuals from government fertilizer reduced form). [a] "APE" is with respect to log effective FRA price. "APE" divided by 100 is % change in outcome given a 1% increase in effective FRA price.

For maize area planted, structural model results indicate weak positive effects of increases in both past FRA district-level maize purchases and the lagged effective FRA price (Table 2.10). The reduced form APE and AE are positive and significant at the 10% level for past FRA maize purchases but are not statistically significant for the lagged effective FRA price.

For maize yield, the standard errors are very large for several of the structural model APEs and AEs, but there is some evidence of significant negative impacts of increases in past FRA district-level purchases on maize yields among households cultivating less than two hectares. The associated reduced form APE and AE are negative and statistically significant at the 1% level and similar in magnitude to the structural estimates. The structural APEs and AEs of increases in the lagged effective FRA price on maize yield are also negative and marginally significant for smallholders cultivating less than two hectares and for those in areas that are only marginally suitable or unsuitable for low-input rainfed maize production. The latter finding is consistent with the hypothesis that an increase in the expected maize price (due in part to increases in past FRA purchases and effective prices) incentivizes expansion of maize production into areas with agro-ecologies that are not particularly well suited for maize production. The reduced form estimates of the lagged effective FRA price APE and AE on maize yield are inconsistent with the structural estimates.

In summary, the results presented in sections 2.6.1 and 2.6.2 indicate that increases in past FRA district-level maize purchases and the lagged effective FRA price have positive marginal effects on the expected maize price for many households. Through their impact on the expected maize price, increases in these FRA-related variables have a positive effect on total and maize area planted, a negative effect on maize yields, and no significant effect on maize quantity harvested, total and non-maize output and output per hectare, and the intensity of fertilizer use on maize.

2.6.3 Marginal effects of the quantity of government-subsidized fertilizer received by the household on smallholder behavior

Estimates of the marginal effects of an increase in the kilograms of government-subsidized fertilizer received (*govtfert*) on smallholder behavior are summarized in Table 2.11. (See Tables A.4 through A.6 in Appendix A for the full regression results.) The results suggest that an increase in *govtfert* has a positive, statistically significant APE on all outcome variables examined ($p<0.05$). For example, each additional kg of subsidized fertilizer received by a smallholder household is associated with a 2.2-2.6 kg increase in maize output, a 0.74 kg/ha increase in maize yield, and a 0.11-0.21 kg/ha increase in the intensity of fertilizer use on maize.

govtfert is greater than zero for only 10% of the observations in the panel dataset. Average elasticities with respect to *govtfert* among beneficiary households range from 0.132 to 0.489 (Table 2.11). Maize output has the largest average elasticity and the area planted average elasticities are generally larger than those for output/ha.

The positive and significant contemporaneous APEs of *govtfert* on smallholder crop output (total, maize, and non-maize) in Zambia are consistent with the findings of Ricker-Gilbert (2011), which indicate the same for maize and tobacco output and the total value of rainy season crop output among smallholders in Malawi. Chibwana et al. (2011) find positive marginal effects of the Malawi Farm Input Subsidy Program on the share of total area planted to maize and tobacco but negative effects on the share allocated to other crops.

Table 2.11. Summary: APEs and AEs with respect to kg of government-subsidized fertilizer acquired by the household

				Average partial effect			Average elasticity	
Row	Outcome variable	Estimator	Gov't fertilizer	APE	Sig.	p-value	All HHs	Gov't fertilizer recipients
A	Fertilizer use on maize (kg/ha)	Fixed effects	Endog.	0.208	***	0.000	0.116	0.307
B	Fertilizer use on maize (kg/ha)	CRE Tobit	Endog.	0.106	***	0.000	0.121	0.318
C	Total area planted (ha)	Fixed effects	Exog.	0.00147	***	0.000	0.0245	0.231
D	Maize area planted (ha)	Fixed effects	Exog.	0.00122	***	0.000	0.0449	0.347
E	Maize area planted (ha)	CRE Tobit	Exog.	0.000852	***	0.000	0.0379	0.293
F	Non-maize area planted (ha)	Derived (C-D)	--	0.000249	**	0.016	0.0142	0.132
G	Non-maize area planted (ha)	Derived (C-E)	--	0.000617	***	0.000	0.0184	0.171
H	Total output/ha (FIQI/ha)	Fixed effects	Endog.	0.00912	***	0.000	0.0146	0.136
I	Maize yield (kg/ha)	Fixed effects	Endog.	0.739	***	0.000	0.0184	0.141
J	Non-maize output/ha (FIQI/ha)	Fixed effects	Endog.	0.00705	**	0.043	0.0167	0.152
K	Total output (FIQI)	Derived [f(C,H)]	--	0.0454	***	0.000	0.0394	0.368
L	Maize output (kg)	Derived [f(D,I)]	--	2.613	***	0.000	0.0638	0.489
M	Maize output (kg)	Derived [f(E,I)]	--	2.194	***	0.000	0.0566	0.434
N	Non-maize output (FIQI)	Derived [f(F,J)]	--	0.0131	***	0.005	0.0311	0.284
O	Non-maize output (FIQI)	Derived [f(G,J)]	--	0.0231	***	0.000	0.0354	0.322

Notes: ***, **, * significant at the 1%, 5%, and 10% levels. p-values from standard errors based on 500 bootstrap replications to account for generated regressors (expected maize price and/or Tobit residuals from government fertilizer reduced form).

The main econometric challenge with estimating the marginal effects of *govtfert* on factor demand and crop output supply is its potential endogeneity in such regressions. Estimation results suggest that *govtfert* is endogenous in the fertilizer use on maize and output/ha equations but not in the area planted equations (Table 2.11). Three IVs are included in the reduced form Tobits for *govtfert*. With only one suspected endogenous variable (*govtfert*) and three IVs, it is possible to test whether the two 'extra' IVs are uncorrelated with the error term in the structural equation ($u_{i,t}$ in equation (11)). Hansen J test results of the two over-identifying restrictions are included at the bottom of Tables A.4 through A.6 in Appendix A. These results support the validity of the over-identifying restrictions in the fertilizer use on maize, total and maize area planted, and maize yield equations, but reject the validity of these restrictions in the total and non-maize output/ha equations. Since nearly all fertilizer obtained by smallholders in Zambia is applied to maize, the fact that the over-identifying restrictions are supported for all of the maize-related regressions inspires confidence in the validity of the IVs used for *govtfert.*

2.7 Conclusions & policy implications

Over the last decade there has been a resurgence in direct government participation in agricultural input and output marketing in eastern and southern Africa (ESA). After being scaled back or eliminated during the market reforms of the 1980s and 1990s, fertilizer subsidies, parastatal grain marketing boards (GMBs), and strategic grain reserves (SGRs) are once again en vogue in the region (Jayne and Jones, 1997; Jayne et al., 2002; Jayne et al., 2007). Ethiopia, Kenya, Malawi, Tanzania, Zambia, and Zimbabwe all have a GMB and/or SGR, and several of these entities have raised their level of involvement in grain marketing in recent years (Jayne et al., 2007). Private grain trade remains legal in most cases, thus an increasingly important feature of grain markets in ESA is dual marketing channels: government and private sector. Yet little is known about how the re-emergence of GMBs/SGRs is affecting input use and crop production by smallholder farmers in the region.

In this paper, I first develop a conceptual framework to model factor demand and crop output supply in the context of dual grain marketing channels when there is uncertainty about the prices to be paid by one or both of the channels, and possibly uncertainty about whether one of the channels will even be available come harvest time. Farmers in ESA and elsewhere often find themselves in such situations. I then operationalize the conceptual model and apply it to the case of Zambia, where the Food Reserve Agency (FRA), a strategic food reserve, has become a major player in the domestic maize market in recent years. The FRA buys maize from smallholders at a pan-territorial price that is typically well above market prices.

Using nationally-representative panel survey data covering more than 5,000 Zambian smallholder farm households over the 1999/2000, 2002/2003, and 2006/2007 agricultural years, I estimate the average partial effects of increases in past FRA district-level maize purchases and in the lagged effective FRA maize price on household fertilizer use on maize, and total, maize, and non-maize area planted, crop output per hectare, and crop output.

The empirical models are estimated in two stages. In the first stage, I estimate the marginal effects of changes in past FRA maize purchase and pricing policies on the mean and variance of (log) effective maize market and FRA prices at the next harvest and on the probability that a household will sell to the FRA at the next harvest. Predicted values from the first stage regressions are used to construct an expected maize price for each household and agricultural year in the panel survey. The expected maize price is then included as an explanatory variable in the second stage fertilizer demand and output supply regressions.

In addition to its involvement in maize marketing through the FRA, the Zambian government also implemented several large-scale fertilizer subsidy programs during the study period (the FRA Fertilizer Credit Programme, the Fertilizer Support Programme, and the Food Security Pack Programme). The econometric models used to estimate the marginal effects of changes in past FRA behavior on smallholder factor demand and output supply control for the effects of these fertilizer subsidy programs and also provide estimates of their marginal effects. FRA activities and GRZ fertilizer programs may influence equilibrium maize and fertilizer market prices, which may, in turn, affect smallholder behavior. Such general equilibrium effects are not captured in this paper.

The empirical results point to four key findings. First, the first-stage regressions indicate that increases in past FRA maize purchases and effective prices are associated with a higher expected maize price at the next harvest. A 1% increase in past FRA district-level purchases increases households' expected maize price in 2006/07 by 0.10%. The magnitude of this elasticity is larger for households that cultivate two or more hectares of land, are located in areas that are well suited for low input rainfed maize production, or are male-headed. The elasticity of the expected maize price with respect to the lagged effective FRA price is also positive and statistically significant ($p<0.10$) for households in these groups.

Second, the fertilizer demand and output supply regression results suggest that an increase in the expected maize price has a positive effect on total and maize area planted, a negative effect on maize yields, and no statistically significant effect on the intensity of fertilizer use on maize (kg/ha), non-maize area planted, total and non-maize output per hectare, and total, maize, and non-maize output. The marginal effects of an increase in the expected maize price on maize area planted and maize yield offset each other, the result being no significant change in maize quantity harvested. The additional area brought under maize production in response to an increase in the expected maize price may be of poorer quality and/or not well suited for maize production, hence the decline in maize yields even with the same intensity of fertilizer use.

Third, together, the first- and second-stage results imply that for 2006/07, increases in past FRA district-level maize purchases and in the lagged effective FRA price are associated with increases in total and maize area planted, a decrease in maize yield, and no significant change in maize quantity harvested or the other outcome variables examined. Recall that part of the FRA's "strategic mission" is to ensure national food security and income, and that part of its "strategic goal" is stabilizing national food security (FRA, n.d.). Although this study does not estimate the effects of past FRA behavior on food security or incomes *per se*, the finding of no statistically significant impact of FRA activities on maize or total crop output is not suggestive of major improvements in food security or incomes. Keep in mind, however, that effects of the FRA on smallholder behavior via general equilibrium effects on maize, fertilizer, or other prices are not captured in this study. Furthermore, the FRA continued to ramp up its level of participation in maize marketing after 2006/07, the most recent year of the panel. As the FRA became a more permanent fixture of the maize marketing landscape, smallholders may have become more responsive to its activities. Thus the effects of the FRA on smallholder behavior after the study period may be more substantial.

And fourth, estimation results suggest that an increase in the quantity of government-subsidized fertilizer acquired by a household has a statistically significant, positive effect on contemporaneous intensity of fertilizer use on maize as well as total, maize, and non-maize area planted, output per hectare, and output. For example, each additional kilogram of government-subsidized fertilizer received by a household increases maize output by 2.2 to 2.6 kg, *ceteris* *paribus*. Average partial effects on the rate of fertilizer application to maize and maize yield are 0.11-0.21 kg/ha and 0.74 kg/ha, respectively. These results are more or less consistent with the findings of Ricker-Gilbert (2011) and Chibwana et al. (2011), both of which focus on the impacts of Malawi's input subsidy programs on smallholder households. Unlike Ricker-Gilbert (2011), who measures both the contemporaneous and lagged effects of participation in the Malawi fertilizer subsidy program, only the contemporaneous effects of participation in Zambian fertilizer subsidy programs are captured in this paper. The dynamic effects of these programs could be explored in future studies. Such efforts would be somewhat constrained by the fact that the Zambia panel survey data capture receipt of subsidized fertilizer in 1999/2000, 2002/03, 2003/04, 2006/07, and 2007/08 but not in the intervening years.

Additional areas for further study include applying the conceptual framework and empirical strategy developed here to other countries where grain markets are characterized by dual marketing channels. Future work could also entail modifying the conceptual framework to accommodate non-separability and then estimating the effects of GMBs/SGRs on smallholder production and consumption behavior. However, panel datasets that capture detailed information on household agricultural production and incomes, such as the one used in this study, often lack detailed consumption modules. Understanding the effects of GMBs/SGRs on smallholder behavior under the assumption of non-separability may therefore require the collection of additional, more comprehensive data.

APPENDIX A

Table A.1. Summary statistics for continuous explanatory variables

Explanatory variables	(A)	(B)	Mean	Std. dev.	Percentile 10th	25th	50th	75th	90th
FRA maize purchases in district ('000 MT, t-1)	X		1.911	4.88	0	0	0	0.33	9.89
Effective FRA maize price (ZMK/kg, t-1)	X		495	219	219	249	611	700	733
Maize producer price (ZMK/kg, t-1)	X		447	186	219	249	498	609	661
Regional wholesale maize prices (pre-planting):									
October (ZMK/kg)	X		447	277	130	146	465	657	856
September (ZMK/kg)	X		426	266	140	180	401	587	793
August (ZMK/kg)	X		433	259	150	173	430	668	771
July (ZMK/kg)	X		422	240	156	178	390	550	742
June (ZMK/kg)	X		412	187	188	238	424	521	710
May (ZMK/kg)	X		365	122	218	263	379	439	530
April (ZMK/kg)	X		524	182	297	361	526	694	789
March (ZMK/kg)	X		697	295	352	416	750	847	1,186
February (ZMK/kg)	X		760	342	364	408	877	1,033	1,161
January (ZMK/kg)	X		727	294	363	446	832	956	1,157
December (ZMK/kg)	X		660	251	343	422	639	883	1,006
November (ZMK/kg)	X		597	264	299	347	555	849	890
Effective market price of fertilizer (ZMK/kg)	X	X	1,442	660	720	780	1,476	1,960	2,400
Kilometers from center of SEA to nearest (as of 2000):									
District town	X	X	34.5	22.6	9.8	16.0	28.9	47.0	70.2
Tarred/main road	X	X	25.5	35.7	0.9	4.0	12.0	29.2	69.8
Feeder road	X	X	3.3	3.3	0.6	1.1	2.4	4.3	7.7
Age of household head in 2001	X		46.1	15.4	28.0	33.0	44.0	58.0	69.0
Age of household head (time-varying)		X	48.3	15.3	30.0	36.0	46.0	60.0	70.0
Landholding size (ha, cultivated+fallow land)	X	X[a]	2.1	2.6	0.5	0.8	1.5	2.5	4.0
Full-time equivalent # of prime-age (15-59) adults	X	X	2.8	1.7	1.0	2.0	2.2	3.9	5.0

Table A.1 (cont'd)

Explanatory variables	(A)	(B)	Mean	Std. dev.	Percentile 10th	25th	50th	75th	90th
Expected growing season rainfall (mm, moving average of past 9 years)	X	X	896	184	660	757	877	1,059	1,167
Expected moisture stress (20-day periods with <40mm rain, moving average of past 9 years)	X	X	1.8	1.0	0.6	0.9	1.9	2.4	3.1
Rainfall variability (moving coefficient of variation of past 9 years, %)	X		22.5	6.9	13.7	17.5	21.8	26.6	30.7
Growing season rainfall (mm)		X[b]	969	254	639	788	943	1,140	1,258
Moisture stress (20-day periods with <40mm rain)		X[b]	1.4	1.4	0	0	1.0	2.0	4.0
Groundnut price (ZMK/kg, t-1, prov. median)		X	1,139	355	769	900	1,053	1,400	1,667
Mixed bean price (ZMK/kg, t-1, prov. median)		X	1,112	302	889	889	992	1,333	1,572
Sweet potato price (ZMK/kg, t-1, prov. median)		X	214	102	100	145	193	232	386
Cattle price (ZMK/head, provincial median)		X	519,656	301,918	160,000	230,000	589,388	789,138	953,272
Value of plows and harrows ('00,000 ZMK)		X	0.649	2.753	0	0	0	0	2.000
% of votes won by MMD in last pres. election[c]			52.2	23.9	16.8	33.5	54.7	72.5	83.6
Pct. pt. spread between MMD & leading opposition party in last pres. election[c]			41.8	23.6	11.6	21.2	41.1	61.4	74.4

Notes: Variables with X in column (A) included in auxiliary regressions for expected maize price. Variables with X in column (B) included in fertilizer demand and output supply equations. N=16,566. [a]Excluded from area planted equations. [b]Included in output/ha equations but not area planted equations. [c]Candidate instrumental variable in government-subsidized fertilizer reduced form Tobit. Sources: CSO/MACO/FSRP 2001, 2004, & 2008 Supplemental Surveys.

Table A.2. Summary statistics for binary explanatory variables

Explanatory variables	(A)	(B)	Share of households (%) 1999/2000	2002/2003	2006/2007
HH owns radio (=1)	X		34.2	47.0	57.6
HH owns cell phone (=1)	X		0	0	21.1
HH does not own but has access to cell phone (=1)	X		0	0	45.7
HH owns bicycle (=1)	X		41.7	46.0	55.6
HH owns motorcycle (=1)	X		0.5	1.1	0.9
HH owns car, pick-up, van, truck/lorry, or tractor-trailer (=1)	X		1.1	0.8	1.1
HH owns ox-cart (=1)	X		5.1	7.1	8.3
HH owns a water pump (=1)		X	0.7	0.7	0.8
Lower primary (grades 1-4) (=1)	X	X	23.0	25.6	27.0
Upper primary (grades 5-7) (=1)	X	X	36.2	34.0	34.5
Secondary (grades 8-12) (=1)	X	X	19.3	18.3	19.4
Post-secondary education (=1)	X	X	2.5	2.7	1.8
Female-headed with non-resident husband (=1)	X	X	0.6	0.9	0.4
Female-headed with no husband (=1)	X	X	20.8	21.8	23.6
Disease-related PA male head/spouse death in last 3-4 years (=1)		X	1.2	1.8	0.1
Disease-related PA female head/spouse death in last 3-4 years (=1)		X	1.0	2.1	1.3
Disease-related PA male non-head/spouse death in last 3-4 years (=1)		X	3.3	2.9	4.4
Disease-related PA female non-head/spouse death in last 3-4 years (=1)		X	5.0	3.6	3.7
SEA is suitable for low input management maize production (=1)	X	X	55.3	56.0	56.4
Agro-ecological region I (low rainfall, less than 800 mm) (=1)	X	X	5.6	5.1	5.4
Agro-ecological region IIa (moderate rainfall, 800-1000 mm, clay soils) (=1)	X	X	40.4	42.1	44.1
Agro-ecological region IIb (moderate rainfall, 800-1000 mm, sandy soils) (=1)	X	X	9.6	9.5	8.6
Agro-ecological region III (high rainfall, over 1000 mm) (=1)	X	X	44.4	43.3	41.9
MMD won the constituency in the last presidential election (=1)[a]			92.8	44.0	59.1
Total number of households in sample			6,922	5,358	4,286

Notes: Variables with X in column (A) included in auxiliary regressions for expected maize price. Variables with X in column (B) included in fertilizer demand and output supply equations. [a]Candidate instrumental variable in government-subsidized fertilizer reduced form Tobit.
Sources: CSO/MACO/FSRP 2001, 2004, & 2008 Supplemental Surveys.

Table A.3. Summary statistics for dependent variables

Dependent variable	Ag. year	Obs.	Mean	Std. dev.	Percentile 10th	25th	50th	75th	90th
Auxiliary regressions for expected maize price									
Effective maize market price	All	4,475	427.899	237.007	179.105	243.478	375.000	560.462	695.652
Effective FRA maize price	2002/03	48	530.021	63.958	420.000	488.000	537.500	596.000	600.000
	2006/07	482	687.684	55.852	640.000	660.000	690.000	720.000	745.000
HH sold maize to FRA (=1)	2002/03	5,358	0.00761						
	2006/07	4,286	0.0971						
Reduced form Tobit for kg of gov't-subsidized fertilizer acquired by the HH									
HH acquired gov't fertilizer (=1)	All	16,566	0.099						
Kg of gov't fertilizer acquired	All	16,566	29.294	143.258	0	0	0	0	0
Factor demand and output supply equations									
HH used fertilizer on maize (=1)	All	13,095	0.322						
Fertilizer use on maize (kg/ha)	All	13,095	85.113	176.275	0	0	0	114.286	327.869
Total area planted (ha)	All	16,566	1.520	1.514	0.375	0.650	1.125	1.990	3.000
HH planted maize (=1)	All	16,566	0.792						
Maize area planted (ha)	All	16,566	0.746	1.085	0	0.155	0.500	1.000	1.620
HH planted non-maize crop(s) (=1)	All	16,566	0.794						
Non-maize area planted (ha)	All	16,566	0.774	0.949	0	0.180	0.500	1.013	1.820
Total output/ha (FIQI/ha)	All	16,148	20.994	18.781	5.693	9.903	16.598	26.476	39.549
Maize yield (kg/ha)	All	13,092	1568.644	1208.216	402.000	744.444	1240.741	2010.000	3130.328
Non-maize output/ha (FIQI/ha)	All	13,087	24.316	26.741	4.763	9.511	17.329	30.025	48.091
Total output (FIQI)	All	16,148	31.044	47.925	4.319	9.265	19.404	37.019	64.550
Maize output (kg)	All	13,092	1504.640	2934.940	172.500	345.000	804.000	1608.000	3162.500
Non-maize output (FIQI)	All	13,087	21.328	31.929	2.001	5.176	12.794	27.232	48.023

Notes: "All" refers to all three agricultural years (1999/2000, 2002/03, and 2006/07). Obs. is the number of unweighted observations. 16,566 is the total number of observations in the SS panel dataset (6,922 for SS01; 5,358 for SS04; 4,286 for SS08).
Sources: CSO/MACO/FSRP 2001, 2004, & 2008 Supplemental Surveys.

Table A.4. Fertilizer use on maize (kg/ha) regression results

	Fertilizer use on maize (kg/ha)					
Estimator:	------Fixed effects------			--------CRE Tobit--------		
Explanatory variables	Coef.	Sig.	p-value	APE	Sig.	p-value
Expected effective maize price (ZMK/kg)	0.000230		0.995	0.0102		0.817
Kg of government-subsidized fertilizer	0.208	***	0.000	0.106	***	0.000
Tobit residuals from gov't fertilizer reduced form	-0.0959	***	0.000	-0.113	***	0.000
Groundnut price (ZMK/kg, t-1)	-0.00560		0.750	0.00820		0.526
Mixed bean price (ZMK/kg, t-1)	0.0114		0.653	0.00778		0.692
Sweet potato price (ZMK/kg, t-1)	0.0309		0.325	0.0512	*	0.059
Effective market fertilizer price (ZMK/kg)	0.00768		0.346	0.00312		0.732
Cattle price (ZMK/head)	0.0000846	**	0.012	0.0000471	*	0.072
Landholding size (ha)	-8.839	***	0.000	-4.285[a]	***	0.000
Landholding size, sqd.	0.0788		0.202			
Plows & harrows ('00,000 ZMK)	2.324	**	0.011	2.190[a]	***	0.004
Plows & harrows, sqd.	-0.0288	*	0.064			
HH owns a water pump (=1)	53.914	**	0.021	35.397	*	0.069
Full-time equivalent prime-age (15-59) adults	1.831		0.263	1.834		0.248
Age of HH head	-0.310		0.303	-0.274		0.367
Highest level of education completed by HH head (base is no formal education):						
Lower primary (grades 1-4) (=1)	6.292		0.236	9.977	*	0.098
Upper primary (grades 5-7) (=1)	1.314		0.853	3.931		0.529
Secondary (grades 8-12) (=1)	1.034		0.911	3.739		0.663
Post-secondary (=1)	21.595		0.376	25.035		0.168
Gender & residence status of HH head (non-resident if <6 months; base is resident male):						
Female, non-resident husband (=1)	16.682		0.535	4.513		0.817
Female, no husband (=1)	4.036		0.656	-0.432		0.958
Disease-related prime-age death in last 3-4 years:						
Male head/spouse (=1)	3.002		0.903	11.328		0.546
Female head/spouse (=1)	-32.708	**	0.015	-12.573		0.235
Male non-head/spouse (=1)	-10.211		0.275	-5.874		0.450
Female non-head/spouse (=1)	-1.714		0.829	-7.717		0.232

Table A.4 (cont'd)

	Fertilizer use on maize (kg/ha)					
Estimator:	------Fixed effects------			--------CRE Tobit--------		
Explanatory variables	Coef.	Sig.	p-value	APE	Sig.	p-value
Km from center of SEA to nearest (as of 2000):						
District town				-0.577	***	0.000
Tarred/main road				0.0979		0.263
Feeder road				-0.921		0.467
Expected rainfall ('00 mm)	-0.858		0.881	-2.506		0.659
Expected moisture stress (#20-day periods)	-15.520	**	0.044	-4.894		0.585
SEA suitable for low input management maize (=1)				0.696		0.908
Agricultural year (base is 2006/2007):						
1999/2000 (=1)	85.532	***	0.004	71.691	*	0.056
2002/2003 (=1)	40.287	***	0.003	32.684	*	0.022
Constant	100.052		0.196			
Province & agro-region dummies	N/A			Yes		
Time averages (CRE)	N/A			Yes		
Observations	11,953			11,953		
Within R-squared (pseudo R-squared for Tobit)	0.087			0.054		
Overall model F-stat.	9.30	***	0.000	26.56	***	0.000
Hansen J test for over-identifying restrictions	2.086		0.352			

Notes: ***, **, * significant at the 1%, 5%, and 10% levels. p-values from standard errors based on 500 bootstrap replications to account for generated regressor (Tobit residuals from government fertilizer reduced form). [a]APE includes effect of squared term.

Table A.5. Total and maize area planted (ha) regression results

	Total area planted (ha)			Maize area planted (ha)					
Estimator:	------Fixed effects------			------Fixed effects------			---------CRE Tobit--------		
Explanatory variables	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	APE	Sig.	p-val.
Expected effective maize price (ZMK/kg)	0.00148	*	0.063	8.81E-4	**	0.044	6.26E-4	*	0.063
Kg of government-subsidized fertilizer	0.00147	***	0.000	0.00122	***	0.000	8.52E-4	***	0.000
Tobit residuals from gov't fertilizer reduced form	*Excluded*		0.559	*Excluded*		0.197	*Excluded*		0.150
Groundnut price (ZMK/kg, t-1)	-6.99E-4	***	0.000	-4.41E-4	***	0.000	-2.86E-4	***	0.000
Mixed bean price (ZMK/kg, t-1)	-1.16E-4		0.554	5.10E-5		0.696	3.43E-6		0.975
Sweet potato price (ZMK/kg, t-1)	2.83E-4		0.271	-2.88E-4	**	0.035	-2.59E-4	**	0.022
Effective market fertilizer price (ZMK/kg)	1.76E-4	**	0.026	3.64E-5		0.490	1.82E-5		0.650
Cattle price (ZMK/head)	0.000		0.885	0.000		0.422	0.000		0.403
Plows & harrows ('00,000 ZMK)	0.101	***	0.000	0.0700	***	0.000	0.0455[a]	***	0.000
Plows & harrows, sqd.	-5.89E-4	*	0.071	-3.21E-4		0.277			
HH owns a water pump (=1)	0.452		0.202	0.0513		0.795	0.0300		0.825
Full-time equivalent prime-age (15-59) adults	0.0601	**	0.034	0.0361	*	0.076	0.0370[a]	***	0.000
Full-time equivalent prime-age adults, sqd.	0.00301		0.399	0.00120		0.641			
Age of HH head	0.0555	***	0.000	0.0275	***	0.000	0.00545[a]	***	0.000
Age of HH head, sqd.	-4.70E-4	***	0.000	-2.29E-4	***	0.000			
Highest level of education completed by HH head (base is no formal education):									
Lower primary (grades 1-4) (=1)	0.0366		0.385	-0.00447		0.852	-0.00122		0.951
Upper primary (grades 5-7) (=1)	0.0439		0.417	-0.00357		0.907	0.0105		0.674
Secondary (grades 8-12) (=1)	0.115	*	0.100	0.0210		0.623	0.0250		0.467
Post-secondary (=1)	0.138		0.342	-0.0462		0.646	-0.0212		0.785
Gender & residence status of HH head (non-resident if <6 months; base is resident male):									
Female, non-resident husband (=1)	0.144		0.223	0.148	**	0.037	0.178	***	0.009
Female, no husband (=1)	-0.306	***	0.000	-0.160	***	0.000	-0.129	***	0.000

Table A.5 (cont'd)

	Total area planted (ha)			Maize area planted (ha)					
Estimator:	------Fixed effects------			------Fixed effects------			--------CRE Tobit--------		
Explanatory variables	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	APE	Sig.	p-val.
Disease-related prime-age death in last 3-4 years:									
Male head/spouse (=1)	0.0866		0.273	0.0986	*	0.060	0.0759		0.132
Female head/spouse (=1)	-0.0256		0.775	0.0362		0.460	0.0214		0.597
Male non-head/spouse (=1)	-0.0106		0.846	-1.92E-4		0.996	-0.00628		0.844
Female non-head/spouse (=1)	-0.0388		0.483	0.00855		0.801	0.0132		0.623
Km from center of SEA to nearest (as of 2000):									
District town							0.00113	*	0.070
Tarred/main road							-8.25E-4	***	0.002
Feeder road							0.00120		0.812
Expected rainfall ('00 mm)	1.102	***	0.000	0.0290		0.882	-0.0594[a]	**	0.021
Expected rainfall, sqd.	-0.0549	***	0.000	-0.00455		0.650			
Expected moisture stress (#20-day periods)	0.303	***	0.000	0.0201		0.669	0.00559		0.873
SEA suitable for low input management maize (=1)							0.0728	***	0.009
Agricultural year (base is 2006/2007):									
1999/2000 (=1)	0.289		0.520	0.0774		0.773	0.00732		0.969
2002/2003 (=1)	-0.0200		0.907	-0.184		0.085	-0.151	**	0.044
Constant	-6.205	***	0.000	-0.0584		0.957			
Province & agro-region dummies	N/A			N/A			Yes		
Observations	14,999			14,999			14,999		
Within R-squared (pseudo for Tobit)	0.084			0.093			0.172		
Overall model F-stat.	17.16	***	0.000	9.88	***	0.000	38.56	***	0.000
Hansen J test for over-ID restrictions	0.323		0.851	1.158		0.560			

Notes: ***, **, * significant at the 1%, 5%, and 10% levels. p-values from standard errors based on 500 bootstrap replications to account for generated regressor (expected maize price). [a]APE includes effect of squared term.

Table A.6. Total, maize, and non-maize output per hectare regression results

	Total (FIQI/ha)			Maize (kg/ha)			Non-maize (FIQI/ha)		
Estimator:	------Fixed effects------			------Fixed effects------			------Fixed effects------		
Explanatory variables	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.
Expected effective maize price (ZMK/kg)	-8.42E-4		0.897	-1.388	***	0.007	0.0114		0.327
Kg of government-subsidized fertilizer	0.00912	***	0.000	0.739	***	0.000	0.00705	**	0.043
Tobit residuals from gov't fertilizer reduced form	-0.00877	***	0.001	-0.421	**	0.045	-0.0142	**	0.014
Groundnut price (ZMK/kg, t-1)	5.90E-4		0.778	0.795	***	0.000	-0.00405		0.401
Mixed bean price (ZMK/kg, t-1)	0.0132	***	0.000	-0.285		0.310	0.0296	***	0.000
Sweet potato price (ZMK/kg, t-1)	0.00210		0.611	-0.467	*	0.098	0.00873		0.245
Effective market fertilizer price (ZMK/kg)	-0.00100		0.329	-0.109		0.160	-0.00286		0.195
Cattle price (ZMK/head)	-3.70E-6		0.364	9.32E-4	***	0.004	-1.94E-5	***	0.005
Landholding size (ha)	-1.815	***	0.000	-89.219	***	0.000	-2.380	***	0.000
Landholding size, sqd.	0.0247		0.105	1.249		0.160	0.0286	*	0.081
Plows & harrows ('00,000 ZMK)	0.311	**	0.020	10.506	*	0.068	0.364	**	0.035
Plows & harrows, sqd.	-0.00221		0.340						
HH owns a water pump (=1)	2.120		0.325	267.771		0.161	-0.187		0.955
Full-time equivalent prime-age (15-59) adults	-0.291		0.461	-22.516		0.437	0.435		0.176
Full-time equivalent prime-age adults, sqd.	0.0634		0.182	5.291		0.119			
Age of HH head	0.305	*	0.065	-0.386		0.902	-0.120		0.171
Age of HH head, sqd.	-0.00361	**	0.021						
Highest level of education completed by HH head (base is no formal education):									
Lower primary (grades 1-4) (=1)	0.382		0.621	78.831		0.165	0.451		0.510
Upper primary (grades 5-7) (=1)	-0.839		0.355	62.985		0.350	0.106		0.193
Secondary (grades 8-12) (=1)	-0.377		0.732	48.125		0.586	0.359		0.436
Post-secondary (=1)	0.524		0.796	141.007		0.371	0.747		0.749
Gender & residence status of HH head (non-resident if <6 months; base is resident male):									
Female, non-resident husband (=1)	0.356		0.879	-204.135		0.187	0.776		0.802
Female, no husband (=1)	-0.629		0.502	-33.844		0.660	0.464		0.446

Table A.6 (cont'd)

	Total (FIQI/ha)			Maize (kg/ha)			Non-maize (FIQI/ha)		
Estimator:	------Fixed effects------			------Fixed effects------			------Fixed effects------		
Explanatory variables	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.
Disease-related prime-age death in last 3-4 years:									
Male head/spouse (=1)	1.845		0.373	189.818		0.178	0.702		0.682
Female head/spouse (=1)	-0.522		0.743	41.609		0.720	0.325		0.350
Male non-head/spouse (=1)	-0.682		0.551	40.470		0.619	0.232		0.277
Female non-head/spouse (=1)	0.659		0.518	1.319		0.985	0.080		0.122
Growing season rainfall ('00 mm)	4.100	***	0.000	110.969	*	0.052	11.418	***	0.000
Growing season rainfall, sqd.	-0.155	***	0.000	-6.063	**	0.011	-0.458	***	0.000
Moisture stress (# of 20-day periods)	0.611	**	0.048	-21.209		0.328	2.065	***	0.000
Expected rainfall ('00 mm)	-0.422		0.697	-1140.590	***	0.004	2.370		0.197
Expected rainfall, sqd.				65.257	***	0.001			
Expected moisture stress	-5.154	***	0.000	-328.891	***	0.000	-3.701		0.148
Agricultural year (base is 2006/2007):									
1999/2000 (=1)	10.680	**	0.019	634.031	*	0.059	11.114		0.258
2002/2003 (=1)	6.085	***	0.001	309.312	**	0.049	7.637		0.106
Constant	-3.638		0.990	6484.142		0.778	-64.659		0.915
Observations	14,629			11,957			11,984		
Within R-squared	0.047			0.051			0.060		
Overall model F-stat.	12.39	***	0.000	9.54	***	0.000	11.96	***	0.000
Hansen J test for over-ID restrictions	22.799	***	0.000	2.683		0.262	39.513	***	0.000

Notes: ***, **, * significant at the 1%, 5%, and 10% levels. p-values from standard errors based on 500 bootstrap replications to account for generated regressors (expected maize price and/or Tobit residuals from government fertilizer reduced form).

APPENDIX B

APPENDIX B: MODIFIED FISHER-IDEAL QUANTITY INDEXES

For total crop output and non-maize crop output, the kilograms harvested of various crops are aggregated using a modified Fisher-Ideal Quantity Index (FIQI) approach. I compute the household- and year-specific FIQIs for total crop output (*C*=17) and non-maize crop output (*C*=16) as:

$$FIQI_{i,t}^{C} = \sqrt{(LQI_{i,t}^{C} \times PQI_{i,t}^{C})}$$

where

$$LQI_{i,t}^{C} = \frac{\sum_{c=1}^{C} q_{i,c,t} p_{c,base}}{\sum_{c=1}^{C} q_{c,base}^{*} p_{c,base}} X100 \qquad , \; PQI_{i,t}^{C} = \frac{\sum_{c=1}^{C} q_{i,c,t} p_{c,t}}{\sum_{c=1}^{C} q_{c,base}^{*} p_{c,t}} X100 \, ,$$

i indexes the household, *t* indexes the year, *c* indexes the crops included in the FIQI, *q* is the kilograms harvested, *p* is the national median nominal crop price per kilogram, and LQI and PQI are the Laspeyres and Paasche Quantity Indexes, respectively. The 1999/2000 agricultural year is used as the base year. The same crop-specific base quantity is used for all households ($q_{c,base}^{*}$) so that index values can be compared across households and so that index values in the base year vary across households. (If a household-specific base quantity were used, the index would be equal to 100 for all households in the base year, thereby washing out all of the cross-sectional variation in the data.) $q_{c,base}^{*}$ is defined as the median quantity harvested of crop *c* in 1999/2000 among households growing crop *c* that year.

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CHAPTER 3: THE EFFECTS OF THE FOOD RESERVE AGENCY ON MAIZE MARKET PRICES IN ZAMBIA – ARE THERE THRESHOLD NONLINEARITIES?

3.1 Introduction

After being scaled back to varying degrees during structural adjustment in the late 1980s and 1990s, direct government involvement in grain markets through marketing boards and/or strategic reserves is once again en vogue in eastern and southern Africa (ESA).[20] For example, the Government of the Republic of Zambia (GRZ), through the Food Reserve Agency (FRA), has become a major player in the domestic maize market in recent years (Govereh et al., 2008; Tembo et al., 2009).

Established by GRZ in 1996 as a national food reserve, the FRA's mandate was expanded in 2005 to include crop marketing. The Agency's stated objective is to "contribute to the stabilization of national food security and market prices of designated crops," although its focus has been almost exclusively on maize (FRA, n.d.). The FRA purchased nearly 400,000 metric tons (MT) of maize, or more than 50% of the total maize marketed by smallholder farmers, in both the 2006/07 and 2007/08 maize marketing years. (The maize marketing year in Zambia, henceforth referred to as "marketing year", is from May to April.) The FRA's largest maize purchase campaign to date was in the 2010/11 marketing year when it bought 878,570 MT of maize or 83% of expected maize sales by smallholders. Substantial GRZ budgetary resources

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[20] A marketing board is a state-controlled or state-sanctioned entity established to direct the market and marketing of specific commodities within a given country or other geographic area (Staatz, 2006; Barrett and Mutambatsere, 2008). A strategic grain reserve (SGR) is a "public stock of grain used to meet emergency food requirements, to stabilize food prices, and [or] to relieve temporary shortages while commercial imports or food aid are being arranged" (Minot, 2010). Some entities that refer to themselves as SGRs, e.g., the Zambian Food Reserve Agency, have functions, such as grain marketing and market facilitation, that are more characteristic of grain marketing boards.

have been devoted to the FRA: in 2006 and 2007, spending on the FRA accounted for approximately 26% of total government agriculture-related expenditures (Govereh et al., 2009). (This figure is based on estimates of actual government expenditures, not budget allocations.)

The FRA sets a pan-territorial 'indicative' price at which it buys maize from individual farmers and cooperatives but private sector traders are allowed to operate and purchase maize at prices above or below the FRA price. Maize purchased by the FRA is sold on the domestic market (mainly to millers and traders) or exported at prices determined by a tender process, at auction, or in consultation with local stakeholders. In deficit production years, GRZ through FRA often imports large quantities of maize and sells it to select large-scale millers, typically at prices below the cost of commercial importation (Govereh et al., 2008).

Despite the resurgence over the last decade of marketing boards and/or strategic reserves as key players in grain markets in Zambia and elsewhere in ESA, there has been relatively little empirical analysis of how these entities' renewed activities are affecting market prices for grain. Two important exceptions are Jayne et al. (2008) and Chapoto and Jayne (2009). Jayne et al. (2008) use a vector autoregression (VAR) model to estimate the effects of National Cereals and Produce Board (NCPB) activities on wholesale maize prices in Kenya. They find that NCPB activities had a stabilizing effect on market prices and that these activities reduced market price levels during the early 1990s but raised them by approximately 20% between 1995 and 2004 (Jayne et al., 2008). Chapoto and Jayne (2009) estimate a single equation reduced form model of current wholesale maize prices in Zambia as a function of lagged maize prices and variables representing supply and demand shifters, including lagged FRA maize purchases and sales and other GRZ maize market policies. They find no significant effect of lagged FRA purchases on maize prices but significant negative effects of lagged FRA sales on maize prices. Chapoto and Jayne do not investigate the impacts of the FRA's pricing decisions on market prices (2009).

In this paper, I use a structural VAR approach similar to Jayne et al. (2008) and monthly data from July 1996 through December 2008 to estimate the impacts of the FRA's pricing decisions and net maize purchases on the level and variability of wholesale maize prices in Zambia. In addition to estimating a linear VAR as in Jayne et al. (2008), I extend their framework to incorporate threshold nonlinearities (see, for example, Balke, 2000; and Saxegaard, 2006). The threshold VAR (TVAR) allows the dynamic relationships among FRA policies and market prices to differ depending on the level of one or more threshold variables. Testing for threshold effects and estimating a TVAR if such nonlinearities are detected is important because if thresholds exist but the system is constrained to be linear (no thresholds), then the inferences drawn and resultant conclusions and policy implications may be incorrect.

After estimation, the VAR results are used to evaluate the effects of FRA policy shocks on market prices using impulse response analysis. The estimation results are also used to simulate the path of market prices that would have occurred in the absence of the FRA. The level and variability of these simulated prices are compared to those of the realized historical prices to determine the effects of the FRA on maize market prices.

Beyond extending the Jayne et al. (2008) framework to incorporate multiple regimes, this paper makes two main contributions to the agricultural economics literature. The first is an empirical/policy analysis contribution. The general perception in Zambia is that the FRA's activities have raised the level of maize prices and one of the FRA's goals is to stabilize market prices (Govereh et al., 2008; FRA, n.d.). The analysis in this paper provides empirical evidence on the effects of the FRA's activities on the level and variability of maize market prices. Given the importance of maize in domestic production and consumption in Zambia and the high level of government resources devoted to the FRA, empirical analysis is needed to better understand the effects of the Agency's activities and to improve the effectiveness of government expenditures in the agricultural sector. The TVAR approach used in this paper is readily applicable to estimating the effects of strategic grain reserve and/or grain marketing board activities on market prices in other countries.

Second, past applications of TVARs in the agricultural economics literature have typically considered only one potential threshold variable and relied on the multivariate version of Hansen's bootstrap p-value procedure to test for threshold effects (Hansen, 1996; Lo and Zivot, 2001; Hansen and Seo, 2002). In this paper, I consider four candidate threshold variables and test for the existence and number of thresholds using both the Hansen approach and a sequential procedure developed by Gonzalo and Pitarakis (2002, henceforth "GP"). To my knowledge, this is the first application of the GP approach in a VAR setting.[21] The advantage of the GP approach is that it is valid for selecting between a linear model and a single threshold model, and for discriminating among threshold models with different numbers of regimes. While the Hansen approach has also been used in this way, its validity has only been demonstrated for testing a linear model against a threshold model (Hansen, 1999; Gonzalo and Pitarakis, 2002).

The remainder of this paper is organized as follows. In section 3.2, I discuss GRZ maize marketing and trade policies from liberalization in the early 1990s to present, with an emphasis on how the role and level of involvement of the FRA in the maize market have evolved over

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[21] Clements and Galvão (2004), Galvão and Marcellino (2010), and Deák and Lenarcic (2010) all mention the Gonzalo and Pitarakis (2002) threshold model selection procedure but do not use the full Gonzalo-Pitarakis statistic, which is a function of the likelihoods under the null and alternative hypotheses and the Schwarz-Bayesian information criterion (BIC). Rather, these authors use only the BIC part of the statistic for model selection.

time. I present the general methodology in section 3.3 and then apply these methods to the Zambia maize prices/FRA case in section 3.4. In section 3.5, I describe the data used in the analysis. Linear and threshold VAR testing and estimation results, impulse response analysis, and the estimated effects of the FRA's activities on the level and variability of market prices are presented in section 3.6. Conclusions and policy implications are discussed in section 3.7.

3.2 GRZ maize marketing and trade policies and Food Reserve Agency activities

Maize is the dominant crop in Zambia. Approximately 80% of smallholders grow maize and it accounts for 60% of the calories consumed in Zambia (Zulu et al., 2007; Dorosh et al., 2009). Maize is also a highly politicized commodity. Tembo et al. (2009: 1) argue that GRZ "sees as its moral mandate to ensure that … producers and consumers alike are not solely at the mercy of unpredictable market forces". Since independence, maize has been a critical part of GRZ's implicit 'social contract' with the Zambian people, under which GRZ is expected to support smallholder incomes and keep food prices low for urban consumers (Jayne and Jones, 1997; Jayne et al., 2007).

Prior to liberalization in the 1990s, maize marketing in Zambia was controlled by the government agricultural marketing parastatal, the National Agricultural Marketing Board (NAMBOARD), which set pan-territorial/pan-seasonal producer prices for maize and also handled government maize imports and distribution. Private inter-district trade of maize was prohibited (Govereh et al., 2008). NAMBOARD was abolished in 1989, its marketing functions transferred to cooperatives, and an Economic Structural Adjustment Programme was initiated in 1991 (Jayne and Jones, 1997; Govereh et al., 2008). Private maize trade was legalized and pan-territorial/pan-seasonal pricing of maize was eliminated.

The Food Reserve Agency was established by GRZ in 1996 with the enactment of the Food Reserve Act of 1995. The FRA's original mandate was to establish and administer a national food reserve (GRZ, 1995). Private maize trade remained legal but buffer stocks held by the FRA were intended to reduce maize price variability and to provide liquidity in the maize market as the private sector established itself in the early years of market liberalization (Govereh et al., 2008).

Table 3.1 summarizes the tonnage of maize purchased on the domestic market by the FRA each year from 1996/97 through 2010/11 as well as the number of districts from which maize was purchased, the price at which it was purchased, and the estimated tonnage of maize produced and sold by smallholders each year. FRA's purchases on the domestic market can be divided into roughly three periods: 1996/97-1997/98, when it bought small quantities of maize from smallholders via private traders; 1998/99-2001/02, when it purchased nothing on the domestic marketing due to lack of funding; and 2002/03 to present, when it has purchased maize directly from smallholders.

During the first period (1996/97-1997/98), the FRA contracted small-scale traders to buy maize from smallholder on its behalf. By buying through private traders rather than directly from smallholders, the FRA intended to help foster the development of private sector maize trading in the liberalizing environment (Kabaghe, 2010). FRA buy prices were uniform within districts but differentiated across districts to better reflect market conditions. The quantities of maize purchased by the FRA were small and only made in four or five of Zambia's 72 districts (Table 3.1).

Table 3.1. FRA maize prices and purchases, and estimated smallholder maize production and sales, 1996/97-2010/11 marketing years

Marketing year	FRA pan-territorial price (ZMK/ 50 kg)	# of districts in which FRA purchased maize	FRA domestic maize purchases (MT)	Estimated smallholder maize:[d] Production (MT)	Estimated smallholder maize:[d] Sales (MT)	FRA purchases as % of smallholder maize sales	Production & sales data source
1996/1997	11,800[a]	5	10,500	1,117,955	280,955	3.7	PHS
1997/1998	7,880[a]	4	4,989	804,626	206,557	2.4	PHS
1998/1999	N/A	0	0	724,024	175,515	0	PHS
1999/2000	N/A	0	0	929,304	242,753	0	PHS
2000/2001	N/A	0	0	1,253,722	303,738	0	PHS
				1,282,352	323,387	0	SS
2001/2002	N/A	0	0	957,437	209,326	0	CFS
				938,539	197,915	0	PHS
2002/2003	40,000[b]	10	23,535	673,673	143,453	16.4	CFS
				947,825	195,407	12.0	PHS
2003/2004	30,000	36	54,847	970,317	260,885	21.0	CFS
				1,126,316	291,462	18.8	PHS
				1,365,538	370,332	14.8	SS
2004/2005	36,000	46	105,279	1,364,841	331,006	31.8	CFS
				1,216,943	356,750	29.5	PHS
2005/2006	36,000	50	78,667	652,414	151,514	51.9	CFS
				800,574	206,092	38.2	PHS
2006/2007	38,000	53	389,510	1,339,479	454,676	85.7	CFS
				1,388,311	674,020	57.8	PHS
2007/2008	38,000	58	396,450	1,419,545	533,632	74.3	CFS
				1,960,692	762,093	52.0	SS
2008/2009	45,000[c]	58	73,876	1,392,180	522,033	14.2	CFS
2009/2010	65,000	59	198,630	1,657,117	613,356	32.4	CFS
2010/2011	65,000	62	878,570	2,463,523	1,062,010	82.7	CFS

Notes: [a]Not a pan-territorial price but the average price paid by FRA to private traders. [b]Not a pan-territorial price but the price paid by FRA directly to smallholder farmers in the districts where it was purchasing; initial FRA price of K30,000 was raised to K40,000 in August 2002. [c]FRA price increased to 55,000 in September 2008. [d]Smallholder maize production and sales based on CFS data are expected, not realized, levels.
Sources: FRA; CSO/MACO Crop Forecast Surveys (CFS); CSO/MACO Post-Harvest Surveys (PHS); CSO/MACO/FSRP Supplemental Surveys (SS).

Then, after four years of no purchases on the domestic market, the FRA began to participate more directly in maize marketing during the 2002/03 marketing year. Following a drought-related failed harvest in large swathes of the country, the FRA purchased 23,535 MT of maize directly from smallholders in 10 'surplus' districts in 2002/03. At the beginning of the 2003/04 marketing year, the FRA announced plans to purchase 205,700 MT of maize directly from smallholders in 37 districts at a pan-territorial price of K30,000 per 50-kg bag. This was the first time in more than a decade that the government set a pan-territorial price for maize (FEWSNET, 2003a; FEWSNET, 2003b). The Agency only managed to buy approximately 55,000 MT of maize in 36 districts in 2003/04 due to funding shortfalls but its plans sent a clear signal: the FRA intended to be a major player in the Zambian maize market. The FRA's expanded role was codified when the Food Reserve Act was amended in October 2005, adding crop marketing and price setting as major functions of the Agency. According to the Amendment, the FRA was to "establish or determine prices and create markets for designated commodities in rural areas where involvement of the private sector is minimal" (GRZ, 2005: 134).

Each year from 2003/04 to present, the FRA has purchased maize directly from smallholders at a pan-territorial price. The FRA typically announces its maize buy price and target purchase quantities in May, then starts buying in June or July once the maize is sufficiently dry. The end of the FRA crop purchasing exercise has varied from year to year, ending as early as the end of September in the 2007/08 marketing year, and as late as the end of February in 2003/04. Farmers selling to the FRA are not paid on the spot; the Agency aims to pay them within 10 days of delivery but long delays are common. Private maize trade has remained legal and private traders are free to buy at prices above or below the FRA price; however, the GRZ has consistently encouraged farmers not to sell below the FRA price.

From 2004/05 to 2010/11, FRA local purchases ranged from a low of approximately 74,000 MT in 2008/09, to nearly 400,000 MT in 2006/07 and 2007/08, to a high of 878,570 MT in 2010/11. Over this period, FRA's share of the smallholder maize market was at its lowest in 2008/09 (14%), exceeded 50% in both 2006/07 and 2008/09, and was 83% of expected smallholder maize sales in 2010/11. The spatial coverage of FRA's purchases increased steadily over time from 36 districts in 2003/04 to 62 districts in 2010/11 (Table 3.1).

Table 3.2 compares the prices at which the FRA bought and sold maize, and average wholesale market prices in several locations in Zambia. The FRA pan-territorial buy price is typically above market prices in remote areas and below market prices in more accessible areas (Govereh et al., 2008). Since 2002/03, the FRA buy price has consistently exceeded average wholesale prices, particularly in major maize-producing areas such as Choma, Kabwe, Chipata, and Kasama (Table 3.2). The above-market prices that the FRA pays for maize make it difficult for the Agency to export maize – the FRA essentially prices itself out of export markets. FRA exports in 2007/08 and 2010/11 were at a loss (Govereh et al., 2008; Nkonde et al., 2011).

Table 3.2. FRA buy price and weighted average sell price, and average market wholesale prices, 1996/97-2009/10 marketing years (ZMK/50-kg)

Marketing year	FRA buy price	Weighted average FRA sell price[a]	Wholesale price Lusaka	Ndola	Choma	Kabwe	Chipata	Kasama
1996/1997	11,800	No sales	6,815	7,672	4,601	5,944	5,504	6,718
1997/1998	7,880	16,876	10,718	11,262	8,506	11,339	11,634	10,782
1998/1999	N/A	22,357	16,014	18,902	14,617	14,974	16,028	17,161
1999/2000	N/A	N/A	14,768	16,175	12,583	12,166	11,392	11,116
2000/2001	N/A	15,811	15,973	17,304	14,518	13,001	11,922	13,786
2001/2002	N/A	13,392	31,900	26,667	30,344	32,520	24,933	27,975
2002/2003	40,000[b]	49,000	48,290	36,575	40,017	39,193	32,903	34,276
2003/2004	30,000	44,471	31,525	27,757	23,096	26,455	20,543	28,716
2004/2005	36,000	35,332	30,480	26,642	25,859	25,400	25,121	26,863
2005/2006	36,000	36,202	39,113	40,749	39,363	36,801	36,544	37,339
2006/2007	38,000	43,184	29,877	31,062	23,839	26,746	22,737	30,167
2007/2008	38,000	39,821	34,962	37,655	30,673	31,699	26,576	37,474
2008/2009	55,000[c]	63,000	58,877	57,266	51,554	49,175	45,681	48,958
2009/2010	65,000	No data	60,879	58,722	55,518	48,160	48,801	54,599

Notes: [a]Weighted average sell price based on share of total sales in Zambia in the marketing year sold at a given price. [b]Initial FRA price of K30,000 was raised to K40,000 in August 2002. [c]Initial FRA price of K45,000 was increased to K55,000 in September 2008.
Sources: FRA, AMIC.

Much of the maize purchased by the FRA is channeled to large industrial millers and trading firms but the GRZ Disaster Management and Mitigation Unit, the World Food Programme, cooperative unions, and consumers also occasionally buy maize from the FRA. Most FRA maize sales occur during the hungry season months of December through March and are done via a tender process. The FRA periodically sells maize on the market at a pan-territorial price that is determined in consultation with stakeholders such as the Zambia National Farmers Union, the Grain Traders Association of Zambia, and the Millers Association of Zambia. Beginning in October 2010, the FRA sold small quantities of maize (20,000 MT) through an auction-like mechanism on the Zambia Agricultural Commodity Exchange. As a result these different pricing institutions, the FRA sell price often varies from transaction to transaction within a given marketing year. While the Agency typically purchases maize at above-market prices, it sometimes sells maize on the domestic market at below-market prices. In most years, however, the weighted average FRA sell price exceeded average wholesale prices throughout Zambia (Table 3.2). See Appendix F for additional background information on the FRA.

In addition to the maize marketing activities of the FRA, the GRZ uses a number of other policy tools to influence maize markets and prices. These are: (i) explicit export bans and implicit export bans through limited issuance of export licenses; (ii) adjusting import tariff rates; (iii) government-arranged maize imports and sales of subsidized maize to large industrial millers; (iv) levies on the inter-district movement of maize; and (v) targeted fertilizer subsidies (Govereh et al., 2008).[22]

3.3 Methodology

3.3.1 Rationale for the VAR approach

In this paper, I use a structural VAR model to estimate the effects of FRA activities on maize market prices in Zambia. I also considered using a structural simultaneous equations model (SEM). While SEMs have the advantage of being able to trace out the pathways through which policies affect market outcomes, such models also have disadvantages. In order to identify SEMs, it is often necessary to impose exclusion restrictions and to decide, *a priori*, which variables to treat as exogenous versus endogenous. Such exclusion restrictions and exogeneity assumptions may be invalid and frequently go untested (Sims, 1980; Myers et al., 1990; Tomek

[22] See Govereh et al. (2008) for a detailed timeline of maize marketing and trade policy changes in Zambia from 1990 to 2007 and Nkonde et al. (2011) for a timeline of key maize market policies and events in 2010.

and Myers, 1993). Invalid exclusion restrictions and/or exogeneity assumptions could result in biased and misleading inference and, potentially, inappropriate conclusions and policy recommendations. Sims (1980: 1) developed the structural VAR approach as an alternative to macroeconomic SEMs after concluding that "the identification claimed for existing large-scale models is incredible".

Structural VARs circumvent some of these difficulties by treating all variables as endogenous, thus identification does not rest on the designation of variables as exogenous or endogenous. However, identification in structural VARs still poses challenges. The dynamics of these models are generally left unrestricted but some assumptions regarding the contemporaneous relationships among variables are necessary for identification (Fackler, 1988).

In the present context of estimating the effects of FRA activities on maize market prices in Zambia, a structural VAR model is preferred over an SEM for two main reasons. First, the complexity of the maize value chain in Zambia and the cobweb-like relationships among subsector actors make structural simultaneous equation modeling a daunting task. Myers et al. (1990: 244) suggest that "SEMs are most useful when substantial certainty exists regarding the true economic structure generating data". There is substantial *uncertainty* with respect to the true economic structure generating maize prices in Zambia, making the SEM approach less attractive. Second, very little data is available on quantities supplied and demanded and prices at various levels in the maize value chain. Because SEMs require such data, the paucity thereof is another major motivation for the use of the structural VAR approach.

I also considered a multimarket simulation model (see, for example, Quízon and Binswanger, 1986; Braverman and Hammer, 1986; and Dorosh et al., 2009). While the multimarket approach has some potential, I chose not to use it here for several reasons. First, the complexity of the Zambian maize subsector poses challenges for structural modeling in multimarket models in much the same way that it does in SEMs. Second, multimarket models are typically used for *ex ante* policy analysis but the goal of this paper is to estimate *ex post* how the activities of the FRA affected historical maize market prices (Croppenstedt et al., 2007). Third, when specified in log-linearized form (as they often are when the functional forms of all equations are not known), multimarket models are only appropriate to study small changes from an equilibrium point and simulated equilibria cannot be used as starting points in subsequent simulations (Sadoulet and de Janvry, 1995). But to study the effects of the FRA on maize market prices, price expectations would need to be incorporated, suggesting that a multi-period, dynamic model would be required. These substantial drawbacks of a multimarket model approach made the decision to examine the dynamic relationships between FRA operations and maize market prices using a structural VAR approach more compelling.

3.3.2 Linear and threshold VAR methodology

Consider a vector of maize market variables ($\boldsymbol{y}_t$) and a vector of government policy variables intended to influence maize market outcomes ($\boldsymbol{p}_t$). The goal of this paper is to measure the effects of shocks to $\boldsymbol{p}_t$ on $\boldsymbol{y}_t$ and to simulate the historical path of $\boldsymbol{y}_t$ under counterfactual policy scenarios. In this subsection, I first outline a structural linear VAR approach, and then discuss the extension to incorporate threshold effects. I then describe the methods used to estimate the optimal threshold level and to test for the existence and number of thresholds.

Linear VAR

A linear structural VAR of the dynamic relationships between p_t and y_t can be written as

$$(1) \quad \begin{aligned} \boldsymbol{By_t} &= \sum_{i=1}^{k} \boldsymbol{B_i y_{t-i}} + \sum_{i=0}^{k} \boldsymbol{C_i p_{t-i}} + \boldsymbol{A^y v_t^y} \\ \boldsymbol{Gp_t} &= \sum_{i=0}^{k} \boldsymbol{D_i y_{t-i}} + \sum_{i=1}^{k} \boldsymbol{G_i p_{t-i}} + \boldsymbol{A^p v_t^p} \end{aligned}$$

where $\boldsymbol{B}, \boldsymbol{B_i}, \boldsymbol{C_i}, \boldsymbol{A^y}, \boldsymbol{G}, \boldsymbol{D_i}, \boldsymbol{G_i}$, and $\boldsymbol{A^p}$ are matrices of unknown parameters, *k* is the maximum lag length for variables in the system, and vectors $\boldsymbol{v_t^y}$ and $\boldsymbol{v_t^p}$ are mutually uncorrelated 'structural' error terms or innovations (Jayne et al., 2008; Bernanke and Mihov, 1998). The $\boldsymbol{v_t^y}$ and $\boldsymbol{v_t^p}$ represent "random shocks to the fundamental supply, demand, and policy processes that are generating data for $\boldsymbol{y_t}$ and $\boldsymbol{p_t}$" (Jayne et al., 2008: 315). The $\boldsymbol{A^y}$ and $\boldsymbol{A^p}$ matrices allow error terms from one equation to enter other equations in the block, so the assumption that the error terms within each of these vectors are mutually uncorrelated is not restrictive (Jayne et al., 2008; Bernanke and Mihov, 1998). Furthermore, the assumption that $\boldsymbol{v_t^y}$ and $\boldsymbol{v_t^p}$ are uncorrelated is not restrictive because "independence from contemporaneous economic conditions [is] part of the definition of an exogenous policy shock" (Bernanke and Mihov, 1998: 874).

In order to identify the dynamic response of market variables to a structural policy shock, we need to restrict the contemporaneous relationships among variables in (1). The dynamic relationships are left unconstrained. Bernanke and Mihov (1998) suggest setting either $\boldsymbol{C_0} = 0$ or $\boldsymbol{D_0} = 0$. Setting $\boldsymbol{C_0} = 0$ means that the maize market variables ($\boldsymbol{y_t}$) depend on current and past values of $\boldsymbol{y_t}$ but only on past values of the policy variables ($\boldsymbol{p_t}$) (Bernanke and Mihov, 1998; Jayne et al., 2008). Since the model will be estimated using monthly data, this assumption means that market variables may respond to policy variables but with a one-month lag. Conversely, setting $\boldsymbol{D_0} = 0$ assumes that contemporaneous values of market variables do not affect the policy variables.

With either $\boldsymbol{C_0} = 0$ or $\boldsymbol{D_0} = 0$, the system is still not identified. Bernanke and Blinder (1992) show that if $\boldsymbol{C_0} = 0$ then the effects of policy shocks on market variables are independent of the identification scheme used in the market variables block (the $\boldsymbol{B}$ and $\boldsymbol{A^y}$ matrices). On the other hand, the effects of policy shocks on market variables are sensitive to the identification scheme used in the policy variables block (the $\boldsymbol{G}$, $\boldsymbol{D_0}$, and $\boldsymbol{A^p}$ matrices). Both recursive and non-recursive identification schemes are possible but recursive ordering and Cholesky decomposition is the most commonly used identification scheme in structural VAR modeling (see, for example, Sims, 1980; and Hamilton, 1994). If $\boldsymbol{C_0} = 0$, Cholesky decomposition requires $\boldsymbol{G}$ to be lower triangular with ones along the principal diagonal and $\boldsymbol{A^p}$ to be a diagonal matrix; no restrictions on $\boldsymbol{D_0}$ are necessary. Defining $\boldsymbol{G}$ in this way imposes a recursive ordering on the policy variables , $\boldsymbol{p_t}$.

The reduced form of (1) is unrestricted and can be estimated by ordinary least squares (OLS) (Myers et al., 1990; Jayne et al., 2008). With $\boldsymbol{C_0} = 0$, the identification scheme selected for $\boldsymbol{G}$ and $\boldsymbol{A^p}$, and a normality assumption, the reduced form residuals can then be used to solve for the structural parameters in (1) as described in Fackler (1988) and Myers et al. (1990).

Given the estimated VAR, one can simulate what the historical paths of the market variables would have been under alternative policy scenarios. This is achieved by setting the market structural error terms ($\boldsymbol{v_t^y}$) to their estimated historical values, recursively constructing the policy innovations ($\boldsymbol{v_t^p}$) to obtain the desired alternative policy scenario, and then constructing dynamic forecasts for the market variables (Jayne et al., 2008). The simulated paths of the market variables can then be compared to their historical (factual) paths (e.g., in terms of means, standard deviations, coefficients of variation, etc.).

The estimated VAR can also be used to conduct impulse response analysis, which shows the dynamic response of a given market variable to a one-time random shock to one of the policy variables holding other factors fixed; i.e., $\frac{\partial y_{i,t+s}}{\partial v_{j,t}^p}$, where y_i is a market variable and v_j^p is the structural error for one of the policy variables. Because the structural errors or innovations are orthogonal, the impulse responses have a causal, *ceteris paribus* interpretation.

The VARs in the paper are estimated under the assumption of stationarity. (Full sample unit root test results support this assumption for four of the six endogenous variables in the Zambia/FRA VAR; see Table C.1 in Appendix C.) If there are indeed unit roots (and potentially cointegration), OLS estimates of the VAR parameters are consistent but not efficient (Hamilton, 1994). As long as these estimates are consistent, the simulated "no FRA" price paths and related estimates of the effects of the FRA on market prices should be consistent. As discussed in Jayne et al. (2008), a second cost of not imposing valid unit root and cointegration restrictions is inconsistent impulse response estimates at very long horizons (Phillips, 1998). However, this is not a major concern in the current paper because the main policy conclusions are based on the simulated counterfactual prices, not on long-horizon impulse response analysis.

Threshold VAR

In equation (1), it is implicitly assumed that the dynamic relationships among the endogenous variables in the system are constant. It may be, however, that these relationships change depending on the level of one or more threshold variables. Let $\boldsymbol{q_t}$ be a vector of exogenous threshold variables and $\boldsymbol{\theta}$ be a vector of threshold parameters. Define a threshold structural VAR as:

$$(2)\quad \left.\begin{aligned} \boldsymbol{B^j y_t} &= \sum_{i=1}^{k} \boldsymbol{B_i^j y_{t-i}} + \sum_{i=0}^{k} \boldsymbol{C_i^j p_{t-i}} + \boldsymbol{A^{y,j} v_t^y} \\ \boldsymbol{G^j p_t} &= \sum_{i=0}^{k} \boldsymbol{D_i^j y_{t-i}} + \sum_{i=1}^{k} \boldsymbol{G_i^j p_{t-i}} + \boldsymbol{A^{p,j} v_t^p} \end{aligned}\right\} \text{for } \boldsymbol{q_t} \in R_j(\boldsymbol{\theta})$$

where $R_j(\boldsymbol{\theta})$ is a set of nonintersecting and exhaustive sets. In the case of a single threshold variable with two regimes (one threshold), the TVAR could be written as:

$$(3a)\quad \left.\begin{aligned} \boldsymbol{B^1 y}_t &= \sum_{i=1}^{k} \boldsymbol{B_i^1 y_{t-i}} + \sum_{i=0}^{k} \boldsymbol{C_i^1 p_{t-i}} + \boldsymbol{A^{y,1} v_t^y} \\ \boldsymbol{G^1 p_t} &= \sum_{i=0}^{k} \boldsymbol{D_i^1 y_{t-i}} + \sum_{i=1}^{k} \boldsymbol{G_i^1 p_{t-i}} + \boldsymbol{A^{p,1} v_t^p} \end{aligned}\right\} \text{for } q_{1t} \le \theta_1$$

$$\text{(3b)}\quad \left.\begin{aligned} \boldsymbol{B}^2 \boldsymbol{y}_t &= \sum_{i=1}^{k} \boldsymbol{B}_i^2 \boldsymbol{y}_{t-i} + \sum_{i=0}^{k} \boldsymbol{C}_i^2 \boldsymbol{p}_{t-i} + \boldsymbol{A}^{y,2} \boldsymbol{v}_t^y \\ \boldsymbol{G}^2 \boldsymbol{p}_t &= \sum_{i=0}^{k} \boldsymbol{D}_i^2 \boldsymbol{y}_{t-i} + \sum_{i=1}^{k} \boldsymbol{G}_i^2 \boldsymbol{p}_{t-i} + \boldsymbol{A}^{p,2} \boldsymbol{v}_t^p \end{aligned}\right\} \text{for } q_{1t} > \theta_1$$

Equations (3a) and (3b) are similar to the model in Saxegaard (2006), which extends the structural VAR framework of Bernanke and Mihov (1998) to incorporate a threshold nonlinearity.

Estimation of the optimal threshold level

A grid search procedure is used to estimate the optimal threshold level ($\hat{\theta}$) for a given candidate threshold variable (*q*). The range of possible threshold values, $[\underline{\theta}, \overline{\theta}]$, is defined and each regime is required to have a minimum number or proportion of observations. I follow Balke (2000) and require each regime to have at least 15% of the observations plus the number of parameters in an individual equation. Linear reduced form VARs are estimated by OLS for the lower (*l*) and upper (*h*) regimes defined by each possible threshold value. The residuals, $\hat{\boldsymbol{u}}$ (a $T \times n$ matrix where $T = T_l + T_h$ is the total number of observations and *n* is the number of endogenous variables in the system), are then used to construct the residual variance-covariance matrix for the two-regime TVAR: $\hat{\Sigma}(\theta) = (\hat{\boldsymbol{u}}' \hat{\boldsymbol{u}}) / T$. The maximum likelihood estimate of $\hat{\theta}$ is:

$$\text{(4)}\quad \hat{\theta} = \min_{\underline{\theta} \le \theta \le \overline{\theta}} \ln\left(|\hat{\Sigma}(\theta)| \right)$$

The right hand side of equation (4) is equivalent to maximizing a normal likelihood function (Goodwin and Smith, 2009).

Testing for thresholds

Testing the null hypothesis of a linear VAR versus the alternative hypothesis of a TVAR is complicated by the so-called Davies' problem (Davies, 1977). The Davies' problem in the current context is that the threshold parameter (a 'nuisance parameter') only exists under the alternative hypothesis and is not identified under the null hypothesis. As a result, the distribution of the test statistic (e.g., a Wald, Lagrange Multiplier, or likelihood ratio (LR) statistic) is nonstandard. I use two different approaches that circumvent the Davies' problem to determine the existence and number of thresholds.

The first is the Hansen bootstrap p-value approach (1996, 1999), which was originally developed for the single equation case and extended to the VAR/vector error correction model context by Lo and Zivot (2001). In this approach, a *sup-LR* statistic is computed as

(5) $LR_1 = T\left[\ln\left(|\hat{\Sigma}_R|\right) - \left(\ln|\hat{\Sigma}_U(\hat{\theta})|\right)\right]$

where *R* denotes the restricted model (a linear VAR with no thresholds) and *U* denotes the unrestricted model (say, a two-regime TVAR). The empirical distribution of LR_1 is calculated using simulation methods as described in Hansen and Seo (2002) and the p-value is the percentage of simulated test statistics that exceed the actual LR_1. 10,000 bootstrap replications are used for the simulations.[23] If the p-value is less than 0.10, then we reject the null hypothesis of a linear VAR in favor of the TVAR under the alternative. Hansen's approach is valid for testing no thresholds against one or multiple thresholds but it has not been shown that the

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[23] GAUSS code for estimating the optimal threshold level was adapted from Galvão (2006, http://qed.econ.queensu.ca.proxy2.cl.msu.edu/jae/datasets/galvao001) and GAUSS code for the Hansen bootstrap p-value procedure was adapted from Lo and Zivot (2001, http://129.3.20.41/md/2001-v5.4/lo-zivot/) and Hansen and Seo (2002, http://www.ssc.wisc.edu/~bhansen/progs/joe_02.html). Many thanks to these authors for making their code publicly available.

bootstrap procedure approximates the sampling distribution of the test statistic when testing one threshold model against another (Hansen, 1999; Gonzalo and Pitarakis, 2002).

The second method is the sequential procedure developed by Gonzalo and Pitarakis (2002). Unlike the Hansen p-value approach, the GP method is valid for discriminating between linear and threshold models as well as between threshold models with different numbers of regimes. The GP approach was developed for the single equation case but Pitarakis (2010, 2011) indicates that it extends readily to the VAR case and suggests that the log likelihood form of the statistic be used. In the VAR setting, the GP Schwarz-Bayesian information criterion (GP BIC) value is calculated as:

$$(6)\ \ GP\ BIC(m) = \frac{-2}{T}\left[\ln L_T - \ln L_T(\hat{\theta})\right] - \frac{\ln T}{T} mn(nk+1)$$

where *m* is the number of threshold parameters to be estimated, *n* is the number of endogenous variables in the VAR, *k* is the lag order of the VAR, and L_T and $L_T(\hat{\theta})$ are, respectively, the maximized likelihoods for the single regime model and the multiple-regime model with optimal threshold. The decision rule is to select the threshold model if the GP BIC is greater than zero, and to prefer the single regime model otherwise.

If the GP BIC and/or Hansen p-value suggest the existence of a threshold and if there are sufficient observations in the one or both of the regimes of the two-regime model, the GP BIC procedure can be repeated to test for additional thresholds. If multiple candidate threshold variables are significant as the first threshold (for example), then the one with the stronger case based on economic logic is selected.

3.4 A VAR model for Zambian maize market prices and FRA activities

In order to apply the framework described in section 3.3 to analyze the effects of FRA activities on maize market prices in Zambia, the steps are to identify variables for inclusion as market variables ($\boldsymbol{y}_t$) and FRA policy variables ($\boldsymbol{p}_t$), to choose an identification scheme, and to propose candidate threshold variables. I discuss each of these elements in turn.

3.4.1 Market variables

Since 2003, the FRA has purchased maize directly from smallholders at a pan-territorial buy price. Private traders also buy maize from smallholders and the FRA buy price might affect the prices paid by private traders to farmers. Thus a logical variable to include in $\boldsymbol{y}_t$ is farmgate maize market prices in Zambia. Unfortunately, reliable, high frequency time series data on farmgate maize prices are not available. However, monthly data on into-mill wholesale maize prices are available for several urban centers in Zambia. Jayne et al. (2008) suggest including as market variables maize prices for a major consumption area, a major production area, and one or more important cross-border trade areas. For the Zambia application, I use Lusaka, the national capital and largest city in the country, as the major maize consumption area. Choma in Southern Province is used as the major maize production area. Over the 1993/94 to 2009/10 agricultural seasons, Southern Province accounted for 21% of national smallholder maize production and 18% of smallholder maize sales. Among Zambia's nine provinces, only Eastern Province had a larger share of smallholder maize production (26%) and only Central Province had a larger share of smallholder maize sales (25%).

South Africa and Malawi are two of Zambia's important maize trading partners. In addition to wholesale maize prices in Lusaka and Choma, $\boldsymbol{y}_t$ includes wholesale maize prices on the South African Futures Exchange (SAFEX) in Randfontein/Johannesburg and retail maize prices in Mchinji, Malawi, near the border with Zambia's Eastern Province. (Wholesale price data are not available for Malawi.) South Africa is the major source of formal maize imports for Zambia, accounting for 72% of such imports between 1999 and 2006, the most recent year for which detailed formal trade data are available (FAOSTAT, 2010). The major sources of informal maize imports are Tanzania, Mozambique, and Malawi (FEWSNET, 2010). The main formal and informal export destinations for Zambian maize are the Democratic Republic of Congo (DRC), Zimbabwe, and Malawi (FAOSTAT, 2010; FEWSNET, 2010). No suitable maize price series are available for Tanzania, Mozambique, DRC, or Zimbabwe.

3.4.2 FRA policy variables

The variables in the $\boldsymbol{p}_t$ vector are intended to capture FRA policies that affect maize prices in Zambia. The FRA sets a pan-territorial price for maize and buys directly from smallholders, and then sells maize to millers, traders, and other buyers, mainly in Lusaka, at prices determined by a tender, consultative, or auction process, or exports the maize. In deficit maize production years, GRZ imports maize through the FRA and typically sells it to select large-scale millers, often at subsidized prices. I follow Jayne et al. (2008) and define three candidate policy variables: (i) the FRA buy price premium (BPP, the FRA buy price minus the wholesale price in the major maize production area); (ii) the FRA sell price premium (SPP, the weighted average FRA sell price minus the wholesale price in the major maize consumption area); and (iii) net FRA maize purchases (equal to FRA domestic purchases minus FRA domestic sales in MT). The FRA net purchases variable was ultimately dropped from the model because sensitivity analysis shows that its inclusion has no substantive impact on the estimated effects of

FRA policies on maize market prices in Zambia; the FRA buy and sell price premiums capture most of the FRA effects. Jayne et al. (2008) find the same in their Kenya/NCPB VAR analysis.

Variables representing other policies used by GRZ to influence maize prices, such as banning exports, adjusting import tariff rates, and charging levies on maize transported across district borders are not explicitly included in $\boldsymbol{p_t}$. (The GRZ import tariff is implicitly included via the SAFEX and Mchinji prices, which are adjusted by the exchange and tariff rates.) Estimating the effects of these policies on maize market prices is beyond the scope of the paper. Policy and other variables that are not included in the VAR are assumed to "continue to play the same role they have played historically in influencing market price levels" (Jayne et al., 2008: 319). In the final model specification, $\boldsymbol{p_t}$ includes the FRA BPP and SPP.

A positive shock to the BPP is expected to put upward pressure on maize market prices (Jayne et al., 2008). Such a shock means that the FRA buy price has increased relative to the market price in the major production area. This would be expected to attract more maize sales to the FRA marketing channel and shift the private sector supply curve to the left. A positive shock to the SPP is also expected to put upward pressure on market prices (ibid). Such a shock means that the FRA sell price has increased relative to the market price in the major consumption area. This would likely attract more maize purchases to the private sector channel and shift the demand curve it faces to the right.

3.4.3 Identification scheme

For identification, I assume that: (i) $\boldsymbol{C_0} = 0$ (i.e., there is no contemporaneous response of market prices to changes in FRA policies); (ii) $\boldsymbol{A^p}$ is a diagonal matrix; and (iii) the causal ordering of the FRA policy variables is BPP then SPP. For assumption (i), adjustment costs and rigidities may prevent an immediate change in market prices when FRA's policies change (Jayne et al., 2008). The rationale for assumption (iii) is the following. The FRA rarely both buys and sells maize in the same month; however, most of the FRA's emphasis with respect to pricing has been on setting its buy price level/premium. The buy price level/premium may then be taken into consideration when the sell price level/premium is determined. This suggests a causal ordering of BPP then SPP. Although the impulse response results reported below use this causal ordering, results using the reverse order are very similar. Note that the causal ordering chosen matters only for the impulse response analysis and has no effect on the "no FRA" price path simulations because setting both the BPP and SPP to zero makes the market price outcomes invariant to the recursive ordering.

3.4.4 Candidate threshold variables

The dynamic relationships among market prices and FRA policies, represented by the parameters of the VAR model, may change depending on the level of one or more threshold variables. The four candidate threshold variables considered in this paper are: (i) FRA's share of expected smallholder maize sales (%), which I will also refer to as the FRA (smallholder) market share; (ii) expected smallholder maize marketable surplus remaining after FRA purchases (in kg per capita); (iii) the quantity of maize harvested by smallholders at the most recent harvest (in kg per capita); and (iv) time.

Candidates (i) and (ii) are related to the scale of FRA purchases from smallholders relative to expected smallholder maize sales. A positive shock to the FRA BPP is expected to put upward pressure on market prices but the effects of such a shock may be larger in magnitude if the FRA smallholder market share exceeds some threshold level (candidate (i)). On the other hand, regime shifts may not depend on the FRA's *share* of smallholder marketable surplus but rather on the *level* of marketable maize remaining after FRA purchases (candidate (ii)). If this level drops below some threshold (i.e., if the maize market becomes sufficiently thin), then the dynamic relationships among FRA policies and market prices may change.

Threshold variables (i) and (ii) are defined in cumulative terms over the course of a given marketing year (May to April). Candidate (i), FRA smallholder market share, is calculated as the Agency's cumulative maize purchases in the current marketing year through month *t-1* as a percentage of expected smallholder maize sales for that marketing year. Candidate (ii) is calculated as expected smallholder maize sales for the current marketing year minus FRA cumulative maize purchases in that marketing year through month *t-1*, all divided by the estimated population of Zambia in that marketing year. See Figure C.1 in Appendix C for a graph of candidate threshold variables (i) and (ii).

The rationale for candidate threshold variable (iii), smallholder maize quantity harvested in kg per capita, is that the underlying relationships between FRA policies and market prices may differ in surplus years versus deficit years. For example, one might expect a positive shock to the FRA BPP or SPP to have a greater effect on market prices in years when there is a maize production shortfall than when there is a maize surplus. Unlike threshold variables (i) and (ii), which change over the course of a marketing year depending on FRA's cumulative monthly maize purchases, candidate (iii) is constant during the marketing year. See Table C.2 in Appendix C for these values for 1996/97 through 2008/09.

A significant threshold effect related to time, the fourth candidate threshold variable, would indicate structural change in the relationship between FRA policies and market prices.

Structural change may be due, for example, to a shift in how the FRA sources maize in Zambia, as when the Agency switched from buying maize from smallholders via private traders to setting up its own depots and sourcing maize directly from individual smallholders or groups thereof.

3.5 Data

This paper uses monthly data from July 1996 through December 2008. This period of analysis is used because the FRA first became active in the Zambian maize market in July 1996 and the most recently available data on FRA maize sales are for December 2008. (The FRA has not released sales data for January 2009 to present.) Data on FRA purchase and sales quantities and prices are from the FRA. The original sales quantity and price data, which are at the transaction level, are aggregated to the monthly level. As sales prices differ across transactions, a weighted average sell price is computed for each month, where the weights are the share of total monthly maize sales at that price. The FRA purchase quantity data obtained from the Agency are monthly totals.

Lusaka and Choma wholesale maize prices are from the Agriculture Market Information Center (AMIC) of the Zambia Ministry of Agriculture and Cooperatives (MACO). Monthly average prices are computed from the original weekly price data. The Lusaka (Choma) series is missing price observations for 20.0% (20.7%) of the months over the July 1996 to December 2008 period (150 months). Missing values for a given wholesale maize price series were imputed using best-subset regressions on retail maize grain prices in that location as well as wholesale and retail maize prices in the other eight locations for which wholesale price data are collected by AMIC. (The nine locations are Kabwe/Central Province, Ndola/Copperbelt Province, Chipata/Eastern Province, Mansa/Luapula Province, Lusaka/Lusaka Province, Kasama/Northern

Province, Solwezi/Northwestern Province, Choma/Southern Province, and Mongu/Western Province.) The monthly retail maize prices used in the procedure are from the Zambia Central Statistical Office (CSO).

The SAFEX maize price data are monthly average wholesale spot prices computed from the original daily data. Monthly South African Rand-US dollar exchange rates computed from daily data are also from SAFEX. The Mchinji, Malawi maize price data are monthly retail prices from the Malawi Ministry of Agriculture and Food Security. Malawian Kwacha-US dollar exchange rates are from the Reserve Bank of Malawi. Zambian Kwacha-US dollar exchange rates are from the Bank of Zambia. Import tariff rates applied to the SAFEX and Mchinji prices are from the Zambia Revenue Authority.

For candidate threshold variables (i) and (ii), expected smallholder maize sales estimates for marketing years 2001/02 to 2008/09 are computed from MACO/CSO Crop Forecast Survey (CFS) data. Before the FRA announces its buy price and purchase plans each marketing year, the Minister of Agriculture and Cooperatives announces expected smallholder maize quantities to be harvested and marketed based on the CFS results. These figures are likely to influence the FRA's and private sector's activities in the maize market during the marketing year. For marketing years 1996/97 to 2000/01, no CFS data on expected smallholder maize sales are available. In these years, actual smallholder maize sales derived from MACO/CSO Post-Harvest Survey (PHS) data or MACO/CSO/Food Security Research Project Supplemental Survey (SS) data are used in lieu of expected smallholder maize sales.

For candidate threshold variable (iii), estimates of smallholder maize quantity harvested are actual quantities harvested derived from PHS and SS data for marketing years 1996/97 through 2007/08. Actual smallholder production estimates have not yet been released for the

2008/09 marketing year and so the expected smallholder quantity harvested based on CFS data is used instead. Estimates of the total population in Zambia (used in candidate threshold variables (ii) and (iii)) are from the World Bank World Development Indicators database. Marketing year population estimates are the weighted average of the population estimates for the two calendar years spanned by the marketing year.

3.6 Results

3.6.1 Linear VAR estimation results

Three lags of each of the six endogenous variables in the system are included in the VARs estimated in this paper. This is the minimum number of lags required to eliminate autocorrelation in the reduced form VAR residuals. See Table 3.3 for Ljung-Box Q autocorrelation test results. The squared residuals were also tested for autocorrelation using the same test. Statistically significant autocorrelation in the squared residuals indicates autoregressive conditional heteroskedasticity (ARCH). As shown in Table 3.3, ARCH effects are evident in the SAFEX, Mchinji, BPP, and SPP equations but not in the Choma and Lusaka equations. Nonetheless, ARCH effects are not explicitly modeled because the VAR parameter estimates are consistent even in the presence of such effects (Enders, 1995). Estimation results for the reduced form third order linear VAR are reported in Table 3.4.

Table 3.3. Autocorrelation and ARCH test results for linear VAR residuals

	Equation					
Test	Choma price	Lusaka price	SAFEX price	Mchinji price	BPP	SPP
AR(1)	0.036	0.455	0.005	0.1224	0.208	0.122
	(0.849)	(0.500)	(0.942)	(0.726)	(0.648)	(0.727)
AR(6)	0.912	3.314	3.501	4.371	1.503	7.784
	(0.989)	(0.769)	(0.744)	(0.627)	(0.959)	(0.2544)
AR(12)	12.439	14.925	7.295	11.770	9.917	14.138
	(0.411)	(0.246)	(0.838)	(0.464)	(0.623)	(0.292)
ARCH(1)	0.084	0.186	11.073***	11.841***	3.977**	0.157
	(0.773)	(0.667)	(0.001)	(0.001)	(0.046)	(0.692)
ARCH(6)	2.495	5.044	20.940***	18.302***	11.201*	25.443***
	(0.869)	(0.538)	(0.002)	(0.006)	(0.082)	(0.000)
ARCH(12)	13.922	15.902	31.796***	19.342*	29.262***	27.392***
	(0.306)	(0.196)	(0.002)	(0.081)	(0.004)	(0.007)

Note: Values in the AR(j) (ARCH(j)) rows are Ljung-Box Q statistics for jth order autocorrelation in the residuals (squared residuals) of the series. Numbers in parentheses under the statistics are associated p-values. *** $p<0.01$, ** $p<0.05$, * $p<0.10$.

3.6.2 Linear VAR impulse response results

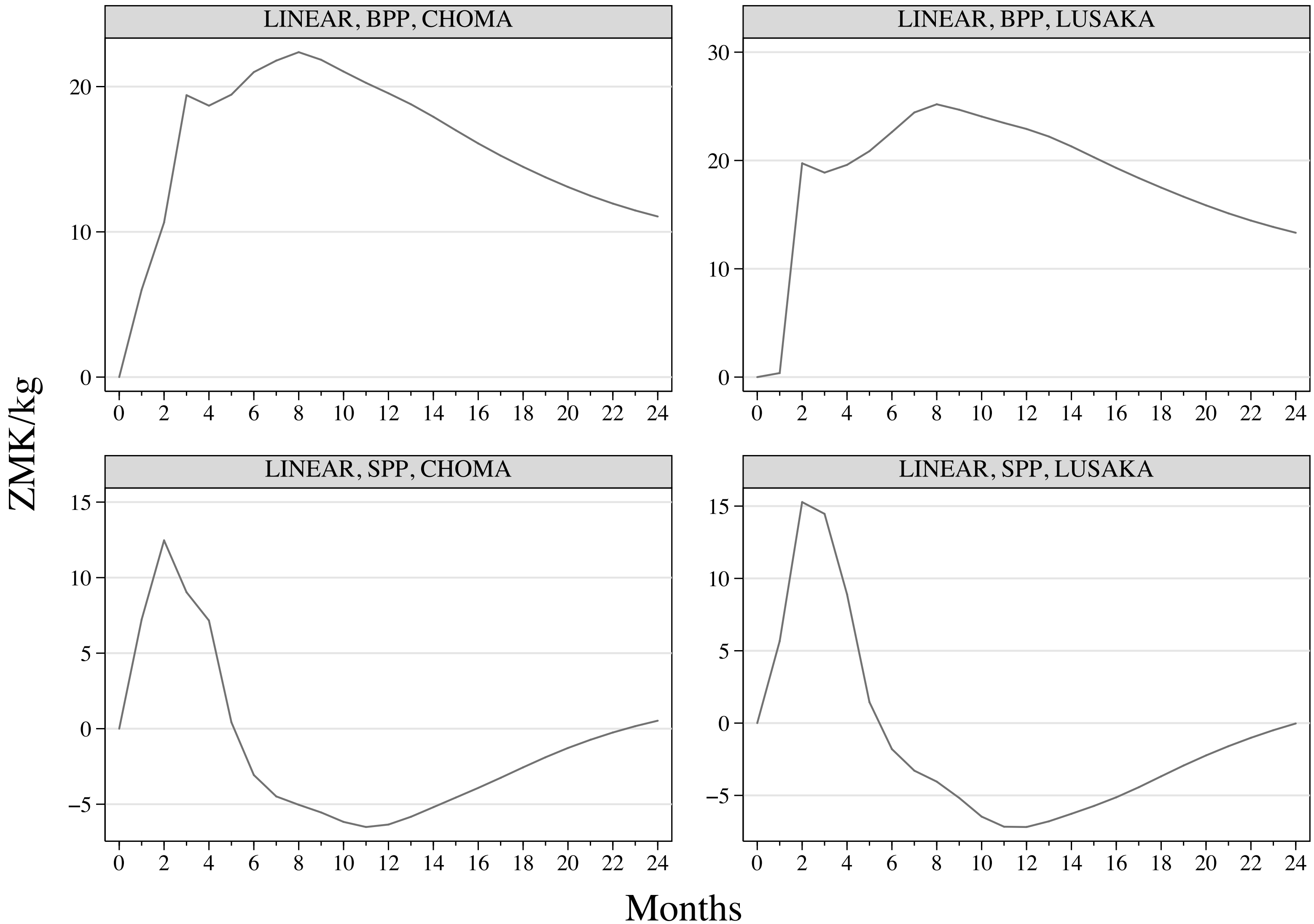
Orthogonalized impulse response functions for the Choma and Lusaka maize market prices with respect to one-time, one-ZMK/kg shocks to the BPP and SPP are shown in Figure 3.1. As expected, positive shocks to the BPP and SPP generally raise maize market prices in Choma and Lusaka. (It is not clear why the market price responses to an SPP shock turn negative six months after the shock.) The market price-raising effect of a positive shock to the BPP is quite persistent, lasting more than 24 months. The Lusaka market price responses to shocks to the BPP and SPP are somewhat larger in magnitude than those of the Choma market price.

Table 3.4. Linear VAR estimation results

	Equation					
Coefficient	Choma price	Lusaka price	SAFEX price	Mchinji price	BPP	SPP
Choma (t-1)	0.757***	0.431***	-0.034	0.670***	-0.164	-0.379**
	(4.976)	(3.069)	(-0.384)	(3.013)	(-1.340)	(-2.026)
Choma (t-2)	0.111	0.184	0.023	-0.218	0.070	-0.330
	(0.674)	(1.213)	(0.237)	(-0.910)	(0.529)	(-1.633)
Choma (t-3)	0.296**	0.132	0.063	-0.171	-0.074	-0.013
	(2.024)	(0.979)	(0.728)	(-0.799)	(-0.631)	(-0.071)
Lusaka (t-1)	0.179	0.548***	0.047	0.207	-0.027	0.241
	(1.468)	(4.859)	(0.654)	(1.160)	(-0.277)	(1.600)
Lusaka (t-2)	-0.253*	-0.250*	0.018	-0.381*	0.089	0.566***
	(-1.654)	(-1.773)	(0.196)	(-1.705)	(0.724)	(3.012)
Lusaka (t-3)	-0.303**	-0.273**	-0.059	-0.161	0.155	0.042
	(-2.298)	(-2.242)	(-0.767)	(-0.834)	(1.459)	(0.260)
SAFEX (t-1)	-0.127	0.002	1.072***	-0.041	0.116	-0.124
	(-0.893)	(0.016)	(12.843)	(-0.195)	(1.015)	(-0.707)
SAFEX (t-2)	0.408*	0.182	-0.165	-0.047	-0.269	-0.147
	(1.942)	(0.938)	(-1.339)	(-0.154)	(-1.592)	(-0.568)
SAFEX (t-3)	-0.183	-0.038	-0.004	0.150	0.202*	0.184
	(-1.278)	(-0.287)	(-0.043)	(0.717)	(1.749)	(1.045)
Mchinji (t-1)	0.239***	0.204***	0.043	0.729***	-0.030	-0.171**
	(3.885)	(3.596)	(1.197)	(8.119)	(-0.603)	(-2.262)
Mchinji (t-2)	-0.273***	-0.302***	-0.008	0.045	0.070	0.266***
	(-3.772)	(-4.524)	(-0.188)	(0.426)	(1.194)	(2.992)
Mchinji (t-3)	0.125**	0.241***	-0.018	0.164*	-0.119**	-0.204***
	(2.104)	(4.403)	(-0.508)	(1.890)	(-2.483)	(-2.790)
BPP (t-1)	0.144	0.029	0.094	0.330	0.616***	-0.077
	(0.970)	(0.210)	(1.081)	(1.522)	(5.148)	(-0.422)
BPP (t-2)	-0.010	0.282	0.055	0.126	0.150	-0.117
	(-0.053)	(1.642)	(0.506)	(0.462)	(1.002)	(-0.509)
BPP (t-3)	0.011	-0.167	0.024	-0.308	-0.104	0.046
	(0.077)	(-1.211)	(0.278)	(-1.407)	(-0.866)	(0.249)
SPP (t-1)	0.077	0.061	0.036	-0.120	-0.071	0.779***
	(0.936)	(0.796)	(0.732)	(-0.999)	(-1.061)	(7.672)
SPP (t-2)	0.047	0.076	0.034	-0.001	-0.028	-0.048
	(0.447)	(0.781)	(0.551)	(-0.006)	(-0.332)	(-0.372)
SPP (t-3)	-0.091	-0.075	-0.056	0.058	0.071	0.039
	(-1.114)	(-0.997)	(-1.169)	(0.485)	(1.084)	(0.384)
Constant	6.794	-4.777	8.456	55.360*	8.877	20.575
	(0.315)	(-0.240)	(0.667)	(1.756)	(0.511)	(0.776)
R-squared	0.876	0.9113	0.964	0.8943	0.6951	0.7626

Notes: Numbers in parentheses under the coefficient estimates are associated z-statistics.
*** p<0.01, ** p<0.05, * p<0.10. T=147.

Figure 3.1. Impulse response functions based on linear VAR estimation results



3.6.3 Linear VAR-based estimates of the effects of FRA activities on maize market prices

Figure 3.2 shows historical and simulated "no FRA" maize prices in Choma. Figure 3.3 shows the same for Lusaka and the two sets of results are summarized in Table 3.5. With the exception of 1996/97, the FRA's first marketing year in operation, prior to mid-2003 there is little difference between the levels of historical and simulated prices (Figures 3.2 and 3.3). From October 1996 through June 2003, mean historical prices exceed mean counterfactual prices by less than 1% in both Choma and Lusaka (Table 3.5). The FRA began buying maize directly from smallholders throughout Zambia at a pan-territorial price in July 2003. Since then, simulated "no FRA" maize market prices are substantially lower than historical prices in all marketing years except 2005/06 (Figures 3.2 and 3.3). (The 2005 smallholder maize harvest was by far the smallest of the 2003 to 2008 period, and FRA maize purchases in 2005/06 were relatively small (Table 3.1).) Between July 2003 and December 2008, the FRA's activities are estimated to have raised mean maize market prices by 19% in Choma and 17% in Lusaka (Table 3.5).

Table 3.5. Summary of FRA effects on Choma and Lusaka wholesale maize prices

	Choma price (ZMK/kg)			Lusaka price (ZMK/kg)		
Period, statistic	Historical	Simulated	% difference	Historical	Simulated	% difference
(i) Full sample period (October 1996-December 2008):						
Mean	486	439	10.5%	559	512	9.2%
SD	271	298	-9.1%	296	326	-9.0%
CV	0.559	0.679	-17.7%	0.530	0.636	-16.7%
(ii) October 1996-June 2003:						
Mean	377	374	0.8%	435	433	0.4%
SD	272	312	-12.9%	309	356	-13.1%
CV	0.721	0.835	-13.6%	0.710	0.821	-13.5%
(iii) July 2003-December 2008:						
Mean	618	519	19.1%	711	609	16.8%
SD	204	261	-21.7%	192	256	-24.8%
CV	0.331	0.503	-34.2%	0.270	0.420	-35.6%

Notes: SD=standard deviation. CV=coefficient of variation.

Figure 3.2. Historical and simulated (no FRA) Choma wholesale maize prices

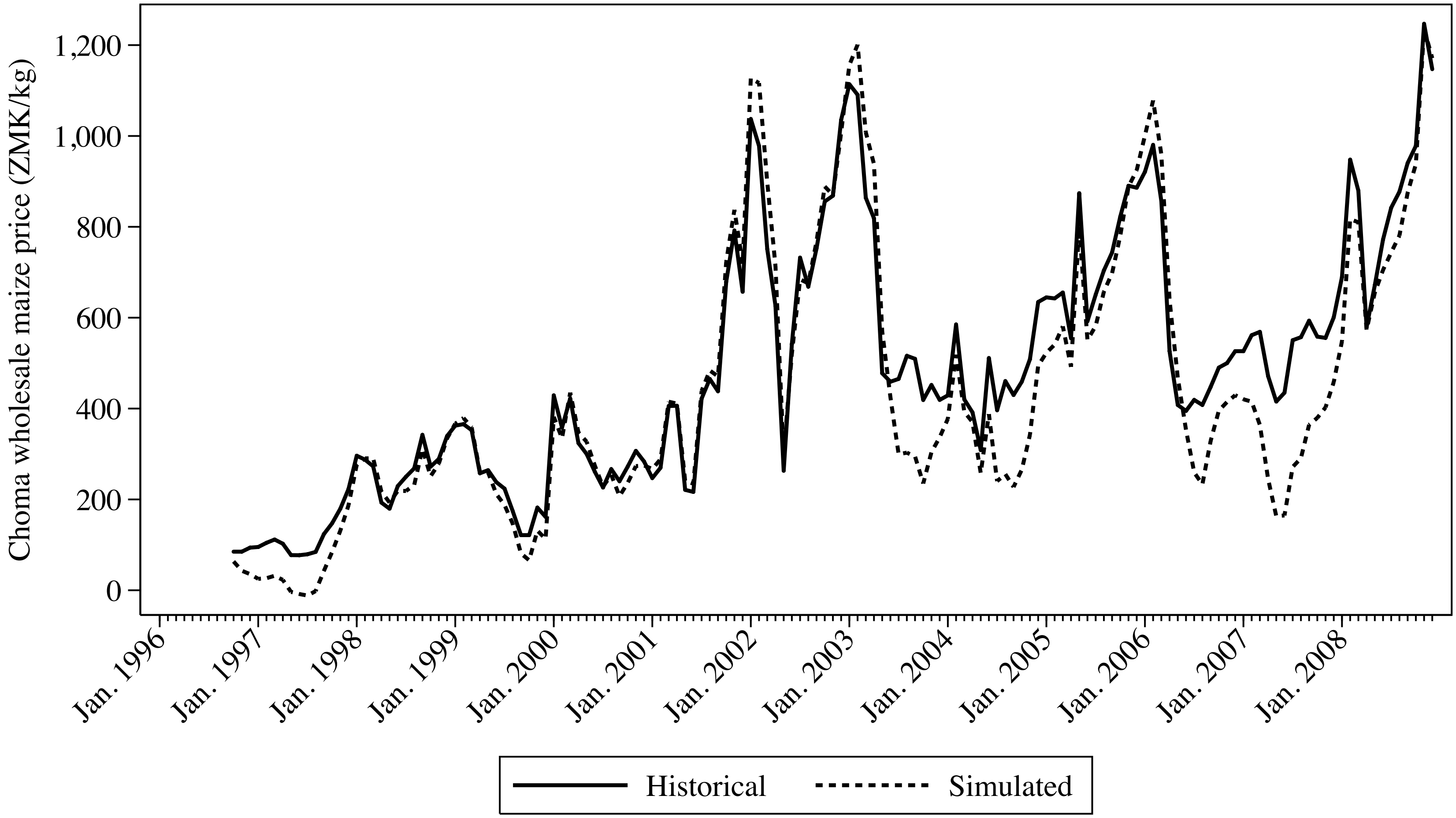
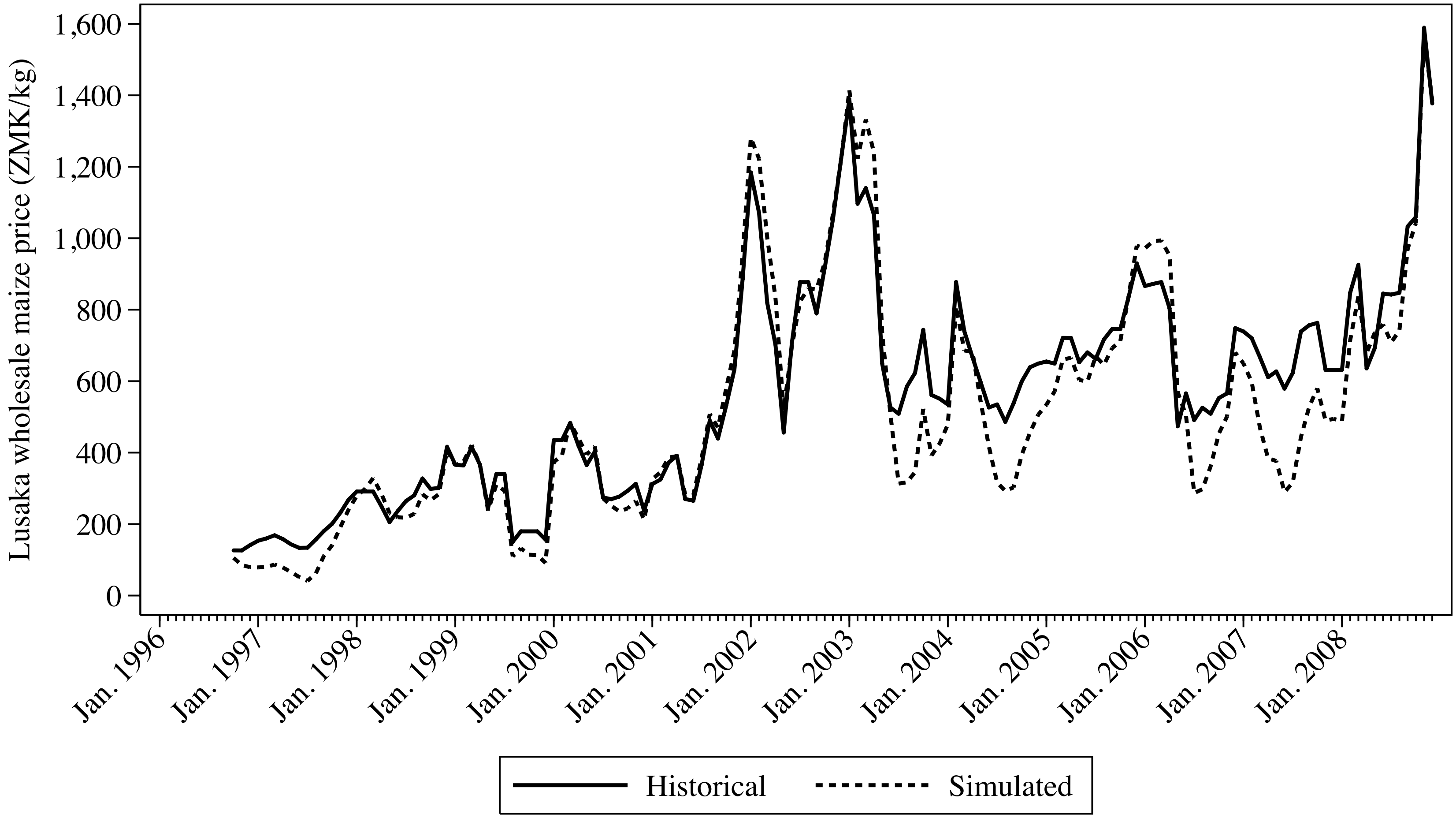


Figure 3.3. Historical and simulated (no FRA) Lusaka wholesale maize prices



Although FRA activities had little effect on mean maize market prices prior to July 2003, these activities reduced the standard deviations (SD) of Choma and Lusaka wholesale prices by 13%, resulting in 14% reductions in the coefficients of variation (CV). The market price-stabilizing effects of the FRA's involvement in domestic maize marketing are even greater in the July 2003 through December 2008 period. The Agency's activities are estimated to have reduced the CV of maize market prices in Choma and Lusaka by 34% and 36%, respectively. The CV reductions are due to both large increases in mean market prices and large decreases in the SD of market prices (Table 3.5).

3.6.4 Threshold estimation and testing

A linear VAR constrains the dynamic relationships among maize market prices and the FRA's pricing decisions to be constant. However, if these relationships change depending on the level of one or more threshold variables, then a threshold VAR (TVAR) is more appropriate. Table 3.6 summarizes threshold estimation and testing results. There is no estimable threshold for the FRA market share candidate threshold variable; the residual variance-covariance matrix is not positive definite. GP BIC values are not greater than zero for any of the other three candidate threshold variables, suggesting that a linear VAR is favored over the TVARs. In contrast, Hansen bootstrap p-values are less than 0.10 for these candidate threshold variables, suggesting that the TVARs are favored over a linear VAR (Table 3.6).

Table 3.6. Threshold estimation and testing results

Threshold variable	Statistic				
	Threshold estimate	T (Low)	T (High)	GP BIC	Bootstrap p-value
(i) FRA market share (%)	No estimable threshold				
(ii) Marketable surplus after FRA (kg/cap)	18.260	54	93	-1.312	0.002
(iii) Maize quantity harvested (kg/cap)	105.263	84	63	-0.914	0.001
(iv) Time	June 2005	105	42	-1.000	0.008

Given the Hansen test support for candidate threshold variables (ii) through (iv), I estimate the three corresponding two-regime TVARs. However, many simulated "no FRA" Choma and Lusaka prices based on these TVARs are unreasonably low and/or high (e.g., negative or many times higher than the highest historical value). The linear VAR is supported by the GP BIC procedure and produces plausible "no FRA" price paths. Therefore the main policy conclusions in this paper are based on the simulated counterfactual prices from the linear VAR (see section 3.6.3).

3.7 Conclusions & policy implications

Over the last decade, governments in eastern and southern Africa have showed a renewed interest in using strategic grain reserves and/or grain marketing boards to influence grain market outcomes. Kenya, Malawi, Zimbabwe, Ethiopia, Tanzania, and Zambia all have one or both of these entities, and their level of involvement in grain marketing has generally been on the rise in recent years (Jayne et al., 2007). Yet, to date, relatively little is known about how the resurgent activities of these strategic grain reserves and marketing boards are affecting market prices.

In this paper, I estimate a structural vector autoregression model (VAR) using monthly data from July 1996 through December 2008 to determine the impacts of the Food Reserve Agency's (FRA) pricing policies and net maize purchases on the level and variability of maize market prices in Zambia. The modeling framework extends the approach of Jayne et al. (2008) to incorporate multiple regimes and thresholds. Hansen bootstrap p-value (1996; Lo and Zivot, 2001) and Gonzalo and Pitarakis (2002) Schwarz-Bayesian information criterion (GP BIC) methods are used to determine the existence and number of thresholds. This paper is the first application of the latter in a VAR context.

The Zambia maize market prices in the VAR are wholesale prices in Lusaka (the major maize consumption area) and in Choma (a major maize production area). The FRA's pricing policies are modeled as a buy price premium (the FRA buy price minus the market price in Choma) and a sell price premium (the FRA sell price minus the market price in Lusaka). The estimated VAR is used to simulate the path of market prices that would have occurred in the absence of the FRA. Three key findings emerge from the analysis.

First, the paper's title asks if there are threshold nonlinearities in the effects of the FRA on maize market prices in Zambia. The GP BIC procedure suggests that the answer is no, favoring a linear VAR over the threshold VAR specifications tested. The linear VAR produces credible simulated "no FRA" price paths, and the estimated effects of the FRA on market prices are greatest during the periods in which the FRA most aggressively participated in maize marketing in Zambia. In contrast, Hansen tests favor two-regime threshold VARs over the linear model but the threshold VARs do not produce plausible counterfactual price paths. Thus the weight of the evidence suggests that there are not threshold nonlinearities in the effects of the FRA on maize market prices in Zambia, at least for the candidate threshold variables examined.

Second, consistent with the general perception in Zambia (Govereh et al., 2008), simulation results suggest that the FRA's activities have indeed raised average market prices, particularly since the Agency began buying maize directly from smallholders throughout Zambia at a pan-territorial price in mid-2003. The FRA's activities are estimated to have increased mean maize market prices between July 2003 and December 2008 by 17% in Lusaka and 19% in Choma.

Third, in line with the FRA's strategic goal to stabilize market prices (FRA, n.d.), wholesale maize prices were less variable between October 1996 and December 2008 than they would have been in the absence of the FRA. Simulation results suggest that the FRA's activities reduced the coefficient of variation of maize market prices by 14% between October 1996 and June 2003, and by 34-36% between July 2003 and December 2008.

The findings that the FRA's involvement in maize marketing raised the level and reduced the variability of maize market prices in Zambia between July 2003 and December 2008 are similar in direction and magnitude to the findings of Jayne et al. (2008) for the effects of the NCPB on maize market prices in Kenya. Their results suggest that NCPB activities raised average maize market prices in Kenya by approximately 20% and reduced the coefficient of variation of these prices by 36-45% between July 1995 and October 2004. The FRA and NCPB seek to stabilize maize market prices and are involved in maize marketing in similar ways (the main exception is that the NCPB sources maize mainly from large-scale farmers while the FRA buys mainly from smallholders). It is therefore not surprising that the agencies' activities have similar effects on maize market prices in their respective countries.

The results in this paper suggest that two of the major outcomes of the FRA's activities since mid-2003 have been an increase in the average level of and a reduction in the variability of maize market prices in Zambia. Who are the likely winners and losers in this scenario? Higher average maize market prices are beneficial for net sellers of maize and detrimental for net buyers of maize. Nationally-representative household survey data collected by the Zambia Central

Statistical Office and Ministry of Agriculture and Cooperatives indicate that only approximately 1/4 of smallholder farm households sell more maize than they buy; the remaining 3/4 either buy more maize than they sell (36%) or neither buy nor sell maize (38%) (Nkonde et al., 2011). Thus higher maize prices hurt urban consumers and roughly 75% of smallholders. (Households that are autarkic with respect to maize are unlikely to be completely disengaged from the market, and would likely be indirectly harmed by the inflationary pressure higher maize prices would put on the prices of other consumer goods.) Large-scale farmers and the 25% of smallholders that are net-maize sellers benefit from higher average maize prices. Among smallholder net-maize sellers, gains from higher maize market prices would be highly concentrated in the hands of the 2.5% of maize-growing smallholders that account for 50% of all smallholder marketed maize (Kuteya et al., 2011). This group of smallholders tends to have more land and non-land assets than other small- and medium-scale farm households. Therefore, to the extent that they raise average maize market prices in Zambia, the FRA's policies are regressive: higher maize prices harm urban consumers and the vast majority of rural households, and help large-scale farmers and a small number of relatively better off smallholders. There may be additional welfare impacts associated with the market price-stabilizing effects of the FRA's activities.

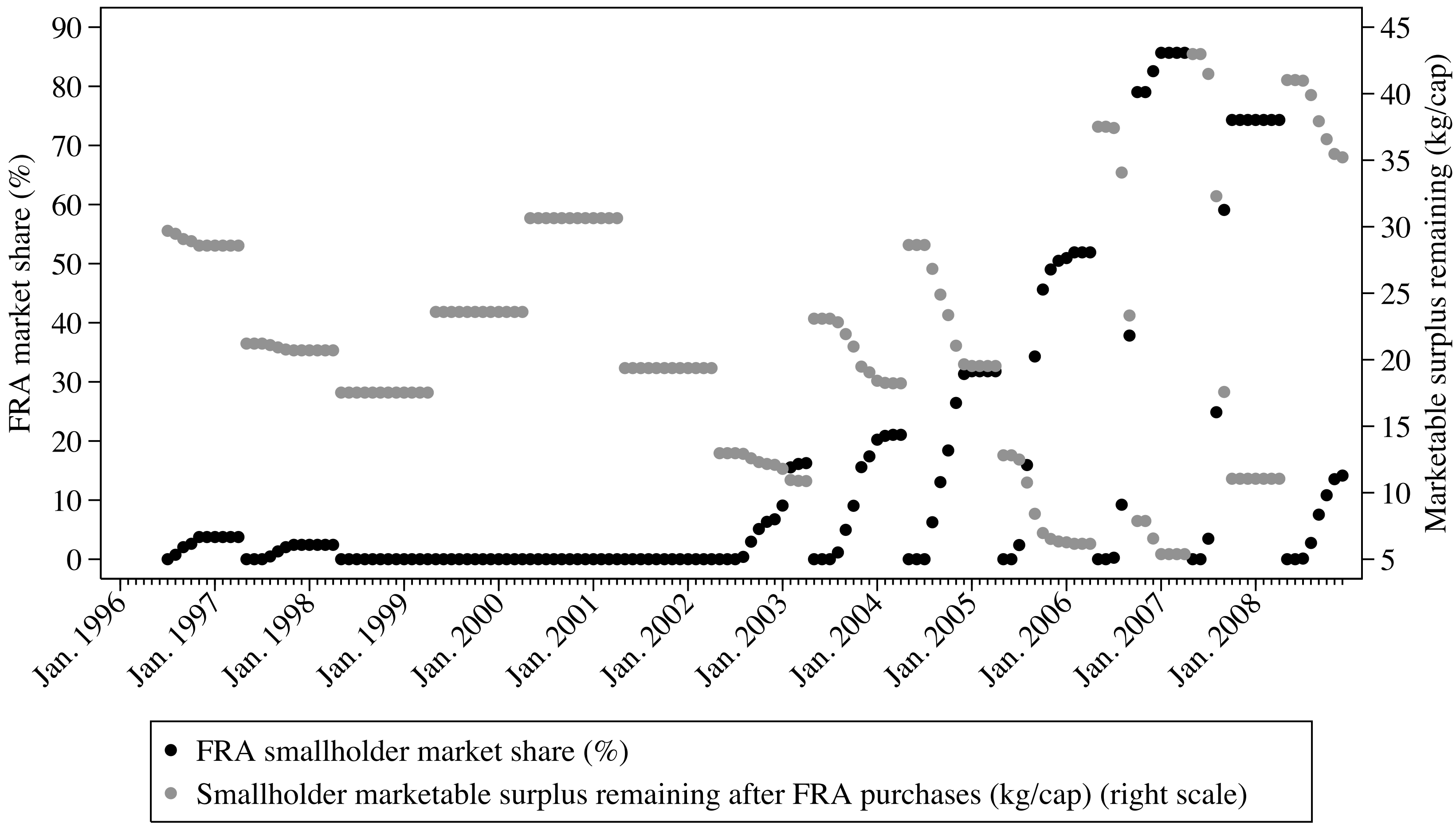
APPENDIX C

Table C.1. Full sample unit root test results

Test and hypotheses	Choma price	Lusaka price	SAFEX price	Mchinji price	BPP	SPP
KPSS (H_1: Unit root)						
(1a) H_0: Trend stationary	0.186	0.233	0.110	0.242	0.147	0.085
	(<0.05)	(<0.01)	(>0.10)	(<0.01)	(<0.05)	(>0.10)
(1b) H_0: Level stationary	2.21	2.34	2.99	0.856	0.582	0.116
	(<0.01)	(<0.01)	(<0.01)	(<0.01)	(<0.025)	(>0.10)
ADF (H_0: Unit root)						
(1c) H_1: Trend stationary	-3.382	-3.477	-2.972	-2.060	-4.033	-4.123
	(0.054)	(0.042)	(0.140)	(0.569)	(0.008)	(0.006)
(1d) H_1: Level stationary	-2.040	-1.974	-1.626	-1.615	-3.833	-4.112
	(0.269)	(0.298)	(0.470)	(0.476)	(0.003)	(0.001)
PP (H_0: Unit root)						
(1e) H_1: Trend stationary	-3.569	-3.377	-2.728	-2.218	-4.167	-3.913
	(0.033)	(0.055)	(0.225)	(0.480)	(0.005)	(0.012)
(1f) H_1: Level stationary	-2.069	-1.798	-1.500	-1.737	-3.987	-3.901
	(0.257)	(0.381)	(0.534)	(0.412)	(0.002)	(0.002)

Notes: Approximate p-values in parentheses. Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) statistics computed using automatic bandwidth selection and autocovariance function weighted by quadratic spectral kernel. Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) values are $Z(t)$ statistics. The number of lags used for the KPSS, ADF, and PP tests were three, one, and four, respectively.

Figure C.1. Candidate threshold variables: expected FRA smallholder market share and expected smallholder marketable surplus remaining after FRA purchases



Sources: FRA; MACO/CSO Post-Harvest Surveys; MACO/CSO/FSRP Supplemental Surveys; MACO/CSO Crop Forecast Surveys.

Table C.2. Smallholder maize quantity harvested (kg/cap), 1996/97-2008/09 marketing years

Marketing year	Smallholder maize quantity harvested (kg/cap)
1996/1997	118.129
1997/1998	82.615
1998/1999	72.280
1999/2000	90.317
2000/2001	121.518
2001/2002	86.849
2002/2003	85.741
2003/2004	120.808
2004/2005	105.263
2005/2006	67.661
2006/2007	114.570
2007/2008	157.916
2008/2009	109.403

Sources: World Development Indicators; MACO/CSO Post-Harvest Surveys; MACO/CSO/FSRP Supplemental Surveys; MACO/CSO Crop Forecast Surveys.

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CHAPTER 4: REWARDING LOYALTY – ELECTION OUTCOMES & GOVERNMENT-SUBSIDIZED FERTILIZER ALLOCATION IN ZAMBIA

4.1 Introduction

Targeted fertilizer subsidies currently receive substantial public budget and popular support in countries throughout sub-Saharan Africa (SSA). In Zambia and elsewhere in SSA, fertilizer subsidy programs were partially scaled back as part of agricultural market reforms in the 1980s and 1990s. But since the creation of the Fertilizer Support Programme (FSP) in 2002, the quantity of subsidized fertilizer distributed to smallholders by the Government of the Republic of Zambia (GRZ) has increased over time. Significant expansions of FSP, and its successor program, the Farmer Input Support Programme (FISP), have occurred in the lead-up to presidential and parliamentary elections in late 2006 and 2011 (Table 4.1). FSP/FISP has generally been well received by the public but there have been allegations of vote buying and mismanagement of Programme resources. For example, a March 2011 editorial in *The Post*, an independent Zambian newspaper, lambastes GRZ over misuse and politicization of FISP:

> But there is no doubt that this Farmer Input Support Programme, which is supposed to be an economic activity, has sadly been abused or mismanaged by politicians and those seeking patronage and turned into a political tool for their election campaigns, and in some cases a vehicle for stealing public funds. The avenue of sourcing this government-subsidised fertiliser and reaching it to the intended farmer is faced with a lot of abuse, corruption and leakages. And in this election year things will be worse – it will be nothing but a campaign tool; fertiliser bought with taxpayers' money will be exchanged for votes.

To what extent are allegations that electoral politics influence subsidized fertilizer allocation in Zambia supported by empirical evidence?

In this paper, I use nationally representative panel survey data covering more than 5,000 Zambian smallholder farm households over the 1999/2000, 2002/03, and 2006/07 agricultural years in conjunction with constituency-level presidential and parliamentary election data to estimate the average partial effects of several election outcome-related variables on the quantity of government-subsidized fertilizer received by a household.[24] The paper builds on and complements a recent study by Banful (2011) that examines the effects of presidential election outcomes on the allocation of subsidized fertilizer vouchers at the district level in Ghana in 2008.[25] Banful finds that, other factors fixed, districts lost by the ruling party in the last presidential election were allocated more fertilizer vouchers, and that more vouchers were allocated to areas lost by a larger margin. These results are based on an econometric model estimated using district-level cross-sectional data from 2008 (ibid).

Table 4.1. FSP/FISP subsidy level, fertilizer tonnage, and number of intended beneficiaries, 2002/3-2010/11

Agricultural year	Subsidy level	MT of fertilizer delivered to districts	Intended number of beneficiary households
2002/2003	50%	48,000	120,000
2003/2004	50%	60,000	150,000
2004/2005	50%	50,000	125,000
2005/2006	50%	50,000	125,000
2006/2007	60%	84,000	210,000
2007/2008	60%	50,000	125,000
2008/2009	75%	80,000	200,000
2009/2010	75%	106,000	534,000[a]
2010/2011	75%	178,000	891,500[a]

Notes: [a]Pack size reduced from eight to four 50-kg bags under FISP. Elections were held on September 28, 2006, and are scheduled for October 2011. Sources: FSP/FISP Implementation Manuals (MACO, various years); FSP Internal Evaluation (MACO, 2008).

24 Smallholder households are those cultivating less than 20 ha. There are 150 constituencies in Zambia and the agricultural year is from October through September.

25 There were 138 districts in Ghana at the time.

In the current study, I use election outcome variables similar to those employed by Banful (2011) but define them at the household level based on election results in the household's constituency. These are: (i) a binary variable equal to one if a household's constituency was won by the ruling party (the Movement for Multi-Party Democracy, MMD) during the last presidential election, and zero otherwise; (ii) the percentage point spread between the MMD and the lead opposition party in the constituency in the last presidential election; and (iii) the interaction of (i) and (ii). Presidential and parliamentary elections in Zambia take place every five years and the MMD candidate has won all presidential elections since 1991 (i.e., 1991, 1996, 2001, 2006, and the 2008 emergency election following the death of President Levy Mwanawasa).

The current paper differs from and complements Banful (2011) in a number of ways. First, unlike the Banful study, which examines the effects of election outcomes on fertilizer subsidy voucher allocation at the district level, I explore such effects on the quantity of government-subsidized fertilizer received at the household level. By examining the determinants of household-level receipt of subsidized fertilizer, this paper provides valuable insights on the targeting of such programs. Second, whereas Banful uses cross-sectional data, and is thus unable to control for time-invariant heterogeneity that may be correlated with both election outcomes and the number of vouchers received by a district, I use a three-wave panel data set and a correlated random effects approach to control for such heterogeneity. Third, I compare the effects of presidential and parliamentary election outcomes on household-level receipt of subsidized fertilizer, rather than focusing exclusively on presidential election outcomes. And fourth, I estimate two sets of models: one in which the dependent variable is fertilizer acquired through any of the three major government fertilizer programs in place during the study period (the Food Reserve Agency Fertilizer Credit Programme, FSP, and the Food Security Pack Programme), and a second in which the dependent variable is fertilizer obtained through FSP only. FSP/FISP has been GRZ's hallmark fertilizer subsidy program since 2002. The results of the study should be of significant interest to policymakers, donors, and Zambian citizens.

The remainder of the paper is organized as follows. In section 4.2, I provide an overview of the government fertilizer subsidy programs in place during the agricultural years captured in the household panel survey data set (1999/2000, 2002/03, and 2006/07). In section 4.3, I outline the methodology. The data used in the study are described in section 4.4 and the estimation results are summarized in section 4.5. Conclusions and policy implications are discussed in section 4.6.

4.2 Government fertilizer programs in Zambia, 1999/2000-2006/2007

GRZ implemented three main fertilizer programs between 1999/2000 and 2006/2007, the period covered in this study: (i) the Food Reserve Agency Fertilizer Credit Programme (FRA-FCP), which ran from 1997/98 to 2001/02; (ii) the Fertilizer Support Programme (FSP), which replaced FRA-FCP and ran from 2002/03 to 2008/09; and (iii) the Food Security Pack Programme, which has been in place since 2000/01 and was implemented by the Programme Against Malnutrition, a Zambian NGO, during the study period (FSPP/PAM). I discuss each of these in turn.

4.2.1. The Food Reserve Agency Fertilizer Credit Programme

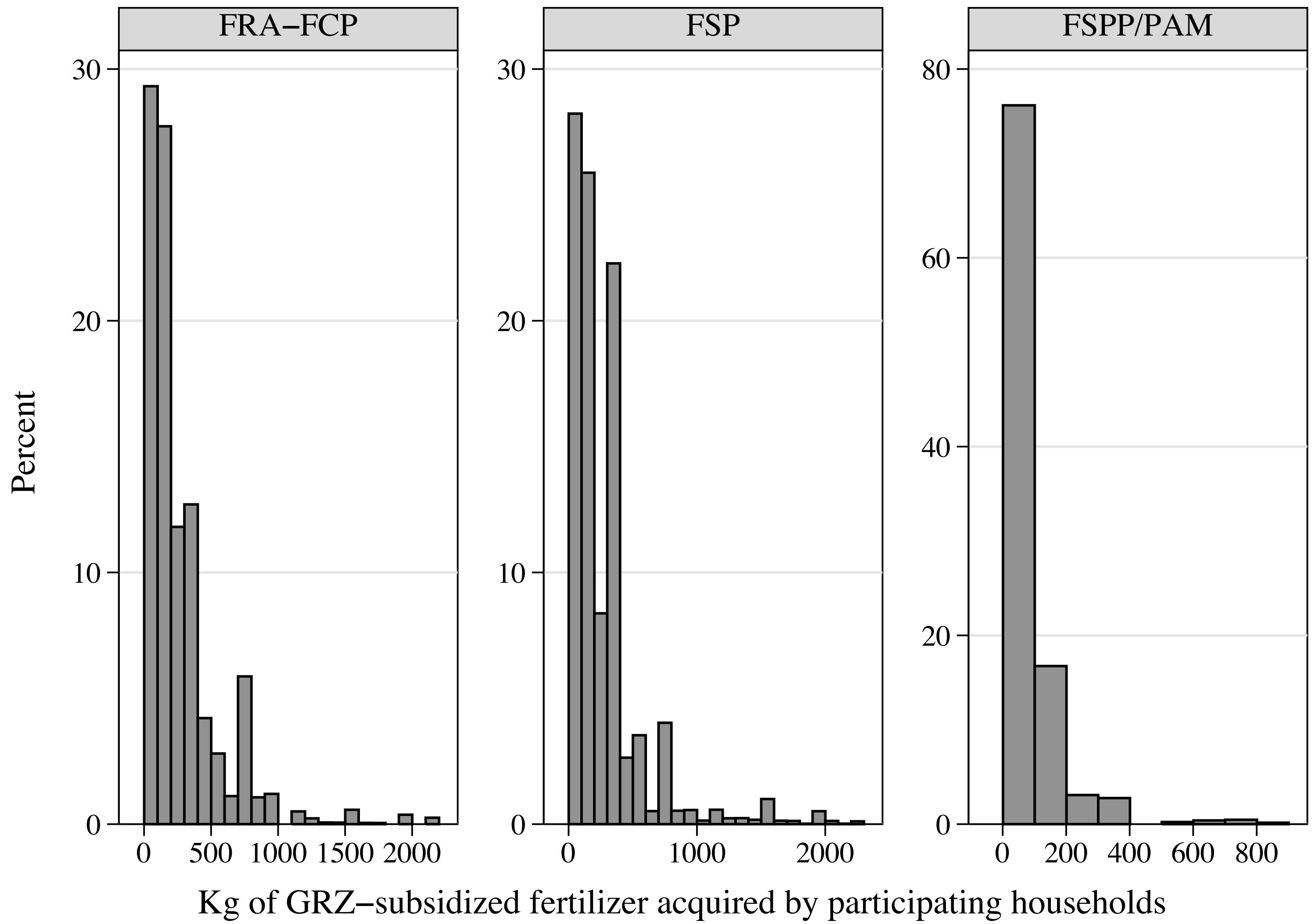
FRA-FCP entailed fertilizer distribution to small-scale farmers on credit at a pan-territorial price (MACO et al., 2002). During the 1999/2000 agricultural season (which corresponds to the first wave of panel data used in the study), approximately 35,000 MT of fertilizer were distributed through the program. Farmers applied to participate in FRA-FCP in November 1999 and, if selected, made a down payment of K5,000 per 50-kg bag of fertilizer. They were to pay the balance of K40,000 per bag in cash or maize in June 2000 (MACO et al., 2002). FRA-FCP fertilizer was not subsidized *per se* but the loan recovery rate was only 34.5% in 1999/2000, so nearly two thirds of FRA-FCP participants received the fertilizer at an 89% effective subsidy (ibid). An FRA-FCP "pack" consisted of one 50-kg bag each of basal and top dressing fertilizer, and farmers could apply for two to eight packs (FRA Agro Support Department, 1999). Approximately 6.5% of smallholder households participated in FRA-FCP in 1999/2000. Figure 4.1 shows the kg of fertilizer received by program participants.

FRA-FCP was implemented through farmer cooperatives and the FRA pre-selected the cooperatives with which it wished to work in each district. In order to participate in FRA-FCP, members of pre-selected cooperatives were required to be: (i) "a bona fide resident and … farming within the village area; (ii) credible and able to pay back the loan; and (iii) not indebted to the FRA as regards seasonal loans" (FRA Agro Support Department, 1999: 3). Village headmen, Camp Extension Officers, and Village Farmers' Committees were involved in the selection of program participants.

4.2.2. The Fertilizer Support Programme

Loan-based FRA-FCP was replaced with cash-based FSP in 2002/03 (which corresponds to the second wave of panel survey). FSP's main goals were to improve household and national food security and smallholders' access to inputs, to raise incomes and rebuild smallholders' capital stocks, and to build private sector capacity to supply agricultural inputs (MACO, 2008).

Figure 4.1. Histograms of kg of fertilizer acquired through FRA-FCP, FSP, and FSPP/PAM by participating households



Note: Quantities are for 1999/2000 for FRA-FCP and for 2002/03 and 2006/07 for FSP and FSPP/PAM.
Sources: CSO/MACO/FSRP 2001, 2004, and 2008 Supplemental Surveys

Like FRA-FCP, FSP was implemented through cooperatives and other farmer organizations. Beneficiary cooperatives/farmer organizations in each district were pre-selected by the District Agriculture Committee in collaboration with other local leaders including Members of Parliament, the District Administrator, NGOs, and village headmen. Pre-selected cooperatives/farmer organizations were then verified and approved by the FSP Programme Coordination Office (MACO, various years). Within pre-selected cooperatives, individual beneficiaries were required to: (i) be small scale farmers actively involved in farming within the cooperative coverage area; (ii) have the capacity to grow one to five hectares of maize; (iii) be capable of meeting the farmer share of the input costs; (iv) not be benefiting from the Food Security Pack; and (v) not be a defaulter from FRA-FCP and/or other agricultural credit programs (ibid). Cooperative Boards, Camp Extension Officers, Village Farmers' Committees, village headmen, and other local leaders were involved in the selection of program participants. Upon selection, beneficiary farmers paid their share of the input costs in cash. Once subsidized fertilizer was positioned at FSP satellite depots, farmers reported to their designated depot to collect the inputs.

An official FSP "pack" consisted of four 50-kg bags each of basal and top dressing fertilizer (400 kg total) and 20 kg of hybrid maize seed. Each participating farmer was to receive only one pack but the quantities of FSP fertilizer actually received varied widely. Approximately 8.8% and 11.2% of smallholder households participated in FSP in 2002/03 and 2006/07, respectively. Figure 4.1 shows the quantities of FSP fertilizer received by participating households.

4.2.3. The Food Security Pack Programme

FSPP/PAM is a grant-based program that targets farming households that cultivate less than one hectare of land and are ‘vulnerable but viable’, e.g., households headed by women or children, households with disabled members or that are supporting orphans, and unemployed youth (Tembo, 2007). A Food Security Pack consists of (i) 0.25 hectare’s worth of cereal seed (maize, millet, rice, or sorghum, depending on the area); (ii) two 50-kg bags of fertilizer (one basal and one top dressing) for households that receive maize seed; (iii) 0.25 hectare’s worth of legume seeds (groundnuts, beans, cowpeas, or soybeans); (iv) 0.25 hectare’s worth of cassava or sweet potato planting materials; and (v) lime for beneficiary households in high rainfall areas (Tembo, 2007).

The main objectives of FSPP/PAM are: (i) to “promote crop diversification for increased food production”; (ii) to “promote farming methods that help restore soil fertility and productivity”; and (iii) to “encourage adoption of conservation farming (CF) technologies” (Tembo, 2007: 1). According to program records, 140,399 and 21,700 households participated in FSPP/PAM in the 2002/03 and 2006/07 agricultural years, respectively (ibid). Based on the panel survey data, approximately 4.5% and 1.1% of smallholder households received fertilizer from the program in these two years, respectively. Figure 4.1 shows the quantities of FSPP/PAM fertilizer received by these households. See Appendix F for additional details on FRA-FCP, FSP, and FSPP/PAM.

4.3 Methodology

4.3.1 Conceptual framework & empirical model

The goal of this paper is to estimate the marginal effects of changes in past presidential or parliamentary election outcomes on the quantity of government-subsidized fertilizer received by smallholder households in Zambia. I achieve this goal by estimating a reduced form model of government behavior, specifically targeting of subsidized fertilizer. In the conceptual model, the quantity of government-subsidized fertilizer allocated to a household ($govtfert$) is a function of past election outcomes (***elect***), household, community, and regional characteristics (***z***), the market price of fertilizer at planting time (w), and expected harvest time prices for maize and other crops ($E(p)$ and $E(\boldsymbol{p_o})$, respectively):

$$govtfert = govtfert\left(\boldsymbol{elect}, \boldsymbol{z}, w, E(p), E(\boldsymbol{p_o})\right) \qquad (1)$$

The key partial effects of interest are $\frac{\partial govtfert}{\partial elect_j}$, $j=1,\ldots,J$, where ***elect*** is a J-vector. Rejection of

$H_0 : \frac{\partial govtfert}{\partial elect_j} = 0$ in favor of $H_1 : \frac{\partial govtfert}{\partial elect_j} \neq 0$ suggests that past election outcomes influence household-level allocation of subsidized fertilizer.

In the empirical work, Eq. (1) is specified as:

$$govtfert_{i,t} = \alpha_0 + \boldsymbol{elect}_{c,t}\boldsymbol{\alpha_1} + \boldsymbol{z}_{i,t}\boldsymbol{\alpha_2} + \alpha_3 w_{i,t} + \alpha_4 \hat{p}^*_{i,t} + \boldsymbol{p}_{\boldsymbol{o},k,t-1}\boldsymbol{\alpha_5} + \boldsymbol{T}_t\boldsymbol{\alpha_6} + \mu_i + \varepsilon_{i,t} \quad (2)$$

where i indexes the household, t indexes the harvest year (t=2000, 2003, and 2007), c indexes the constituency, and k indexes the province. $\boldsymbol{T}_t$ is a vector of year dummies, μ_i is time invariant household-level unobserved heterogeneity, $\varepsilon_{i,t}$ is the error term, and the $\boldsymbol{\alpha}$'s are parameters to be estimated. $govtfert_{i,t}$ is the kg of government-subsidized fertilizer received from FRA-FCP, FSP, and/or FSPP/PAM. $\boldsymbol{elect}_{c,t}$ includes three variables: (i) a binary variable equal to one if the household's constituency was won by the ruling party, the MMD, during the last election, and zero otherwise ($MMD_{c,t}$); (ii) the absolute value of the percentage point spread between the MMD and the lead opposition party in the constituency in the last election ($spread_{c,t}$); and (iii) the interaction, $MMD_{c,t} \times spread_{c,t}$. The interaction term allows the effect of $spread_{c,t}$ to differ between constituencies won versus lost by the MMD. These three variables are similar to the election outcome variables used by Banful (2011) to test for politically motivated district-level allocation of subsidized fertilizer vouchers in Ghana in 2008.

Household characteristics that may affect the quantity of subsidized fertilizer received and that are included in $\boldsymbol{z}$ are: landholding size (measured as hectares of cultivated plus fallow land); the value of plows and harrows owned; a dummy variable equal to one if the household owns a water pump (used for irrigation); the number of full-time equivalent prime-age (15-59 years) adults; the age and highest level of education completed by the household head; the gender and residence status of the household head; and a vector of dummy variables for disease-related prime-age deaths in the household in the last three to four years. Community and regional characteristics that may influence subsidized fertilizer allocation that are included in $\boldsymbol{z}$ are: the kilometers from the center of the household's standard enumeration area (SEA) to the nearest district town, tarred/main road, and feeder road as of the first panel survey year;[26] expected growing season rainfall in the household's district (a moving average of November-March

[26] SEAs are the most disaggregated geographic units in the dataset. An SEA contains approximately 150-200 households (two to four villages).

rainfall over the past nine years); expected moisture stress in the household's district (a nine-year moving average of the number of 20-day periods, November-March, with less than 40 mm of rainfall); a dummy variable equal to one if the household lives in an SEA that is agro-ecologically suitable (in terms of rainfall and soil type) for low input management rainfed maize production; and a vector of provincial dummies.

w is the effective fertilizer market price in ZMK/kg paid by households that purchased fertilizer from commercial sources and the district median effective fertilizer market price otherwise. By 'effective' price, I mean adjusted for estimated transportation costs to the farmgate. $\hat{p}^*_{i,t}$ is the household-level expected effective maize price in ZMK/kg and is estimated as in Mason (2011, Chapter 2). It is a weighted average of the expected effective maize price from private buyers and the expected maximum of effective maize prices from private buyers and the Food Reserve Agency (FRA), where the weights are the predicted probability that a household will sell to the FRA. Both private buyers and the FRA (a strategic food reserve/maize marketing board) buy maize from Zambian smallholders. $\boldsymbol{p}_{\boldsymbol{o},k,t-1}$ is a vector of provincial median groundnut, mixed bean, and sweet potato prices in ZMK/kg at the previous harvest. See Tables D.1 and D.2 in Appendix D for summary statistics for the dependent and explanatory variables in Eq. (2).

4.3.2 Estimation strategy

Eq. (2) is estimated by pooled Tobit and correlated random effects (CRE) Tobit. Tobit is used because there is a positive probability that $govtfert_{i,t} = 0$. Across the three years of the panel, $govtfert_{i,t}$ is greater than zero for only 10% of the observations. If the observed covariates in Eq. (2) (call them $\boldsymbol{X_{i,t}}$) are correlated with time invariant household-level unobserved heterogeneity (μ_i), then the pooled Tobit estimates will be inconsistent. CRE Tobit controls for μ_i but requires the following assumptions: (i) strict exogeneity of $\boldsymbol{X_{i,t}}$ conditional on μ_i, i.e., $E(\varepsilon_{i,t} \mid \boldsymbol{X_i}, \mu_i) = 0,\ t = 1,2,...,T$; (ii) $\mu_i = \psi + \bar{\boldsymbol{X}}_{\boldsymbol{i}}\xi + a_i$; and (iii) $\mu_i \mid \boldsymbol{X_i} \sim Normal(\psi + \bar{\boldsymbol{X}}_{\boldsymbol{i}}\xi,\ \sigma_a^2)$, where $\bar{\boldsymbol{X}}_{\boldsymbol{i}}$ is the average of $\boldsymbol{X_{i,t}}$, t=1,…,T, and σ_a^2 is the variance of a_i. Under these assumptions, the CRE approach controls for μ_i in a Tobit model by including $\bar{\boldsymbol{X}}_{\boldsymbol{i}}$ as additional explanatory variables (Wooldridge, 2002). See Wooldridge (2002) for the likelihood function for and additional details on the Tobit model. Standard errors for the Tobit average partial effects (APEs) are obtained via bootstrapping (500 replications).

Three different specifications of Eq. (2) are estimated. In the first, $govtfert_{i,t}$ is defined as fertilizer obtained through any of the three major government fertilizer programs in place during the study period (FRA-FCP, FSP, and FSPP/PAM) and the variables in $\boldsymbol{elect}_{c,t}$ are based on presidential election results. In the second, $govtfert_{i,t}$ is FSP fertilizer only and presidential election results are used for $\boldsymbol{elect}_{c,t}$. FSP did not exist in the first year of the panel, so this model is estimated using data from 2002/03 and 2006/07 only. In the third specification, $govtfert_{i,t}$ includes FRA-FCP, FSP, and FSPP/PAM fertilizer but parliamentary election results are used for $\boldsymbol{elect}_{c,t}$. The correlation between MMD presidential and parliamentary victories at the constituency level is 0.82 across the 1996, 2001, and 2006 elections, and 0.62, 0.91, and 0.73 in each of these years, respectively.

4.4 Data

The data used in this paper are mainly from a three-wave, nationally representative longitudinal study of smallholder households in rural Zambia. The first wave covers the 1999/2000 agricultural year and was done in two phases. The first phase, the 1999/2000 Post-Harvest Survey (PHS9900) conducted by the Zambia Ministry of Agriculture and Cooperatives (MACO) and the Central Statistical Office (CSO), was done in August/September 2000 and collected information on households' cropping patterns and production levels, agricultural input use, crop marketing, livestock production and marketing, and farm equipment ownership. The second phase, the 2001 Supplemental Survey (SS01) conducted by MACO, CSO, and the Food Security Research Project, was done in May 2001 and collected data from the PHS9900 households on demographics, recent disease-related deaths, off-farm income and remittances, purchases of select crops, and other household details. The second wave of the panel survey, the 2004 Supplemental Survey (SS04), was conducted in May 2004 and covers the 2002/03 agricultural year. And the third wave, SS08, was conducted in June/July 2008 and covers 2006/07. SS04 and SS08 include questions comparable to those on PHS9900 and SS01.

The PHS9900 sample consists of 7,699 rural households in 70 districts. These households were selected using a stratified three-stage sample design (Megill, 2005). In the first stage, Census Supervisory Areas (CSAs), the primary sampling units in the survey, were selected from within each district with Probability Proportional to Size (PPS) based on the sampling frame from the 1990 Census. In the second stage, one Standard Enumeration Area (SEA) was chosen from each selected CSA, again with PPS, for a total of 394 SEAs. All households in selected SEAs were listed and categorized as small-scale (0-4.99 ha) or medium-scale (5-19.99 ha). In the third stage, 20 households were selected from each SEA: 10 medium-scale households (or all medium-scale households in the SEA if there were less than 10), plus a sufficient number of small-scale households to bring the total SEA sample size to 20.

Of the 7,699 PHS9900 households, 6,922 were re-interviewed in SS01. 5,358 SS01 households were re-interviewed in SS04 (a re-interview rate of 77.4%) and 4,286 SS04 households were re-interviewed in SS08 (a re-interview rate of 80.0%). One household is dropped from the analytical sample due to data problems. The remaining 16,563 observations are used in the pooled Tobit estimation and the unbalanced panel of households interviewed in at least SS01 and SS04 is used in the CRE Tobit estimation (14,999 observations).

Given attrition of households between survey waves, attrition bias is a potential problem. I follow the approach described in Wooldridge (2002: 585) to test the null hypothesis of no attrition bias. I fail to reject the null in all cases (p-values range from 0.481 to 0.866) and conclude that there is no evidence of attrition bias.

The following data are used in addition to the SS panel data: (ii) dekad (10-day period) rainfall data covering the 1990/91 to 2006/07 growing seasons and collected from 36 stations throughout Zambia by the Zambia Meteorological Department; (ii) maize, groundnut, mixed bean, and sweet potato prices from the MACO/CSO PHSs for 1998/99, 2001/02, and 2005/06; and (iii) constituency-level data on the percentage of votes won by the MMD and opposition parties during the 1996, 2001, and 2006 presidential and parliamentary elections from the Electoral Commission of Zambia.

4.5 Results

Estimation results for specifications in which $\boldsymbol{elect}_{c,t}$ is based on presidential election outcomes are reported in Table 4.2. These results suggest that households in constituencies won by the MMD in the last presidential election received significantly more subsidized fertilizer ($p<0.05$). This finding is robust to the estimator used (pooled Tobit or CRE Tobit) and to the definition of $govtfert_{i,t}$ (FRA-FCP, FSP, and FSPP/PAM fertilizer or only FSP fertilizer). Based on the CRE Tobit estimates and the broader definition of $govtfert_{i,t}$, households in constituencies won by the MMD are expected to receive 25.6 kg more government-subsidized fertilizer than households in constituencies lost by the MMD, *ceteris paribus*.

The percentage point spread variable is an absolute value so its APE is not, in and of itself, of interest. What is of keen interest is the interaction effect between the spread and the MMD victory variables. It is positive and statistically significant ($p<0.05$), indicating that not only do households in constituencies won by the MMD receive more subsidized fertilizer but also that this effect is larger the wider the MMD's margin of victory. For each percentage point increase in this margin, households in the constituency are expected to receive 0.7 kg more government-subsidized or FSP fertilizer based on the CRE Tobit estimates (Table 4.2). These results hold if parliamentary election results are used instead of presidential ones, although the magnitude of the effects is somewhat smaller. The three key CRE Tobit APEs for this specification are reported in Table 4.3. The key finding across all specifications is that loyalty to MMD is rewarded and more so the greater the support for MMD in an area.

This finding is consistent with the "core supporter" theory of Cox and McCubbins (1986) discussed in Banful (2011), where the ruling party targets subsidized fertilizer or other transfers to areas where it has strong support from voters. Banful's (2011) results for Ghana, on the other hand, align with the "swing voter" theory of redistributive politics (Lindbeck and Weibull, 1993; Dixit and Londregan, 1996 and 1998). In this theory, politicians target transfers to areas with large numbers of undecided voters or where its margin of victory is likely to be small.

Table 4.2. Factors affecting the kilograms of government-subsidized fertilizer or FSP fertilizer acquired by the household

Dependent variable is kilograms of ___ fertilizer:	Gov't-subsidized[a]			Gov't-subsidized[a]			FSP		
Estimator:	Pooled Tobit			CRE Tobit			CRE Tobit		
Explanatory variables:	APE	Sig.	p-val.	APE	Sig.	p-val.	APE	Sig.	p-val.
MMD won const. in last presidential election (=1)	18.274	***	0.000	25.614	***	0.000	11.315	**	0.042
% pt. spread between MMD & lead opposition party	-0.176	***	0.003	-0.181	**	0.017	0.0832		0.469
Interaction effect: MMD won const. × % pt. spread	0.232	**	0.040	0.705	***	0.000	0.726	***	0.001
Effective market fertilizer price (ZMK/kg)	0.0189	***	0.000	0.0253	***	0.000	0.0323	***	0.000
Expected effective maize price (ZMK/kg)	0.0279		0.148	0.0444		0.180	0.154	***	0.009
Groundnut price (ZMK/kg, t-1)	0.00581		0.547	0.00372		0.706	0.0101		0.459
Mixed bean price (ZMK/kg, t-1)	-0.0113		0.413	-0.0354	***	0.009	-0.0683	***	0.001
Sweet potato price (ZMK/kg, t-1)	-0.0308	*	0.072	-0.0313		0.123	-0.0578	*	0.053
Cattle price (ZMK/head)	1.87E-5		0.341	3.94E-5	*	0.057	6.10E-5	**	0.024
Landholding size (cultivated+fallow, ha)	5.119	***	0.000	2.301	***	0.001	3.040	***	0.004
Plows & harrows ('00,000 ZMK)	2.187	***	0.001	-0.115		0.845	-0.521		0.455
HH owns a water pump (=1)	15.092		0.217	9.113		0.559	-7.283		0.666
Full-time equivalent prime-age (15-59) adults	3.040	***	0.000	1.303		0.118	-0.473		0.633
Age of HH head	0.239	***	0.001	0.251		0.240	0.333		0.325
Highest level of education completed by HH head (base is no formal education):									
Lower primary (grades 1-4) (=1)	9.729	***	0.006	-0.0807		0.985	-2.335		0.710
Upper primary (grades 5-7) (=1)	19.280	***	0.000	4.764		0.279	-1.402		0.821
Secondary (grades 8-12) (=1)	43.889	***	0.000	11.831	*	0.061	7.891		0.366
Post-secondary education (=1)	91.806	***	0.000	-4.682		0.589	-12.050		0.220
Gender and residence status of HH head (non-resident if <6 months; base is resident male):									
Female-headed with non-resident husband (=1)	20.848		0.140	13.598		0.437	22.145		0.374
Female-headed with no husband (=1)	-2.376		0.255	-3.289		0.458	-3.176		0.644
Disease-related prime-age death in last 3-4 years:									
Male head/spouse death (=1)	6.652		0.421	7.696		0.564	6.586		0.745
Female head/spouse death (=1)	4.443		0.494	16.111		0.148	20.825		0.420
Male non-head/spouse death (=1)	7.164	*	0.095	9.725	*	0.094	1.329		0.852
Female non-head/spouse death (=1)	-1.887		0.588	5.614		0.317	2.181		0.758

Table 4.2 (cont'd)

Dependent variable is kilograms of ___fertilizer: *Estimator:*	Gov't-subsidized[a] Pooled Tobit			Gov't-subsidized[a] CRE Tobit			FSP CRE Tobit		
Explanatory variables:	APE	Sig.	p-val.	APE	Sig.	p-val.	APE	Sig.	p-val.
Kilometers from center of SEA to nearest (as of 2000):									
District town	-0.136	*	0.065	-0.178	**	0.020	-0.179	*	0.055
Tarred/main road	-0.108	***	0.007	-0.121	***	0.002	-0.147	***	0.004
Feeder road	-2.382	***	0.000	-2.060	***	0.000	-2.062	***	0.001
Expected growing season rainfall ('00 mm, 9-year MA)	5.313	**	0.035	-5.944	*	0.090	3.359		0.541
Expected moisture stress (9-year MA)	6.853	*	0.099	-4.247		0.511	-19.759	**	0.036
SEA suitable for low input mgmt. maize production (=1)	6.097	**	0.036	5.296	*	0.080	6.744	*	0.052
Agricultural year (base is 2006/2007):									
1999/2000 (=1)	21.273		0.431	18.486		0.559	N/A		
2002/2003 (=1)	20.462	*	0.072	15.203		0.162	22.052		0.136
Province (base is Central Province):									
Copperbelt Province (=1)	-2.158		0.841	-8.667		0.531	-34.915	***	0.001
Eastern Province (=1)	24.842	**	0.025	-30.834		0.183	-54.438		0.153
Luapula Province (=1)	-14.683	***	0.007	-22.287	***	0.003	-27.112	***	0.001
Lusaka Province (=1)	21.109		0.111	-13.474		0.276	-25.096	**	0.036
Northern Province (=1)	6.508		0.409	-16.841		0.214	-23.899		0.159
Northwestern Province (=1)	0.308		0.967	-19.428	*	0.056	-30.344	***	0.003
Southern Province (=1)	60.122	***	0.000	-3.819		0.817	-57.654	***	0.003
Western Province (=1)	-5.443		0.510	-28.766	***	0.009	-44.738	***	0.002
Overall model F-statistic	9.83	***	0.000	7.33	***	0.000	5.11	***	0.000
Number of observations	16,563			14,999			9,642		
Number of uncensored (non-zero) observations	1,821			1,729			1,034		
Time averages of time-varying variables included?	No			Yes			Yes		

Notes: ***, **, * significant at the 1%, 5%, and 10% levels. p-values based on 500 bootstrap replications. MA=moving average. N/A=Not applicable. MMD wins constituency and percentage point spread APEs include effects of interaction term. [a]Gov't-subsidized includes FRA-FCP, FSP, and FSPP/PAM fertilizer.

Table 4.3. CRE Tobit estimates of average partial effects of parliamentary election outcomes on the kilograms of government-subsidized fertilizer acquired by the household

Explanatory variables	APE	Sig.	p-val.
MMD won constituency in last parliamentary election (=1)	19.871	***	0.000
% point spread between MMD & lead opposition party	-0.178	**	0.014
Interaction effect: MMD won constituency × % point spread	0.631	***	0.000

Notes: ***, **, * significant at the 1%, 5%, and 10% levels. p-values based on 500 bootstrap replications.

Through what channels might the MMD have been able to influence the allocation of subsidized fertilizer? In other words, at what stages are "party cutters" potentially involved in FSP and other government fertilizer subsidy programs?[27] As discussed in section 4.2, for FRA-FCP, the FRA pre-selected the cooperatives in each district with which it wished to work. For FSP, District Agriculture Committees (DACs) pre-selected such cooperatives in collaboration with other local leaders including Members of Parliament (MPs), District Administrators (DAs), NGOs, and village headmen. Pre-selected groups were then verified and approved by the FSP Programme Coordination Office (PCO) (MACO, various years). Only members of pre-selected cooperatives were eligible to receive FRA-FCP or FSP fertilizer.

Districts where the MMD had fared better may have been allocated more fertilizer. During pre-selection, responsible parties (i.e., the FRA or DACs in conjunction with MPs, DAs, village headmen, and the FSP PCO) may have favored within a given district cooperatives from constituencies that had supported the MMD in the last election and/or cooperatives with members known to be MMD supporters.[28] Furthermore, the FRA Board of Directors is appointed by the Minister of Agriculture and Cooperatives; DAs are appointed by the President

[27] Thanks to Dr. Michael T. Weber for raising this question.

[28] There are 150 total constituencies in Zambia's 72 districts. The numbers of constituencies per district are: 1 (26 districts), 2 (22 districts), 3 (20 districts), 4 (2 districts), 5 (1 district), and 7 (1 district). A constituency contains multiple villages.

of Zambia; DACs are appointed by the DA; and the DAC is chaired by either the DA or the District Agricultural Coordinator (the latter is appointed by the Permanent Secretary in the Ministry of Agriculture and Cooperatives). Given the involvement of MPs and political appointees, it is conceivable that presidential/parliamentary election outcomes and other political considerations influenced the pre-selection of cooperatives for government fertilizer subsidy programs.

Individual farmers within pre-selected cooperatives were chosen to participate in FRA-FCP and FSP by Ministry of Agriculture and Cooperatives Camp Extension Officers in cooperation with Village Farmers' Committees, village headmen, and other local leaders. The data used in this study do not capture individual farmers' political party affiliations, so it is not possible to say whether MMD supporters within pre-selected cooperatives were favored over opposition party supporters.

Other than the results of the last presidential or parliamentary election, what other factors affect the quantity of government-subsidized fertilizer acquired by smallholder households in Zambia? Findings that obtain in all three sets of results in Table 4.2 are the following. First, an increase in the effective market price of fertilizer is associated with an increase in the quantity of subsidized fertilizer allocated to the household. This is consistent with *a priori* expectations. Second, landholding size is an important determinant of the quantity of subsidized fertilizer acquired. Based on the CRE Tobit results households are expected to get 2.3 kg (3.0 kg) more government-subsidized (FSP) fertilizer for each additional hectare of land they control. Third, more subsidized fertilizer is allocated to households that are located closer to district towns, tarred/main roads, and feeder roads. Finally, households in areas that are suitable for low input, rainfed maize production received 5.3 kg (6.7 kg) more government-subsidized (FSP) fertilizer.

4.6 Conclusions & policy implications

Governments in SSA are increasingly using targeted fertilizer subsidies to attempt to strengthen smallholders' access to inputs, increase agricultural productivity, raise farm incomes, and improve household and national food security. These programs often account for a large share of public spending in the agricultural sector and enjoy widespread support from smallholders. However, in some countries there have been allegations of subsidized fertilizer being used to buy votes and other forms of program mismanagement and politicization. A study of the Ghana 2008 fertilizer subsidy program by Banful (2011) finds that districts that the ruling party lost in the last presidential election were allocated more subsidized fertilizer vouchers, and that the number of vouchers allocated increased with the margin of loss.

In this paper, I use nationally representative household panel survey data from Zambia covering the 1999/2000, 2002/03, and 2006/07 agricultural years, and constituency-level presidential and parliamentary election data to estimate the extent to which election outcomes influence household-level allocation of government-subsidized fertilizer. The study builds on Banful (2011) by controlling for unobserved time invariant household-level heterogeneity using a correlated random effects approach; by comparing the effects of presidential and parliamentary election outcomes on household subsidized fertilizer acquisition; and by comparing the extent to which election outcomes affect the allocation of government-subsidized fertilizer in general and fertilizer distributed through the Fertilizer Support Programme (FSP) in particular.

Estimation results indicate that significantly more government-subsidized fertilizer is allocated to households in constituencies won by the ruling party (the Movement for Multi-Party Democracy, MMD) in the last presidential election than to households in constituencies lost by the MMD. The quantity of subsidized fertilizer allocated to households in constituencies won by the MMD rises with each percentage point increase in the MMD's margin of victory. Similar effects are found whether presidential or parliamentary election results are used, whether subsidized fertilizer from all major GRZ programs (i.e., FRA-FCP in 1999/2000, and FSP and FSPP/PAM in 2002/03 and 2006/07) or from only FSP is used, and whether the pooled Tobit or correlated random effects Tobit estimator is used. The results suggest that the MMD uses subsidized fertilizer to reward its supporters, and that the reward is larger the greater the strength of that support. These findings are consistent with the "core supporter" theory of redistributive politics whereas Banful's (2011) results support the "swing voter" theory (Cox and McCubbins, 1986; Lindbeck and Weibull, 1993; Dixit and Londregan, 1996 and 1998). An area for further research is exploring why the ruling parties in Zambia and Ghana adopt different strategies in their allocation of subsidized fertilizer.

Zambian taxpayer and donor resources fund FSP and other GRZ fertilizer programs. It is therefore important that political considerations not drive the allocation of subsidized fertilizer. Such motives are also likely to be detrimental from an efficiency standpoint (Banful, 2011). More transparency in and oversight of the district-, constituency-, and individual-level allocation of GRZ targeted fertilizer subsidies are clearly needed.

APPENDIX D

Table D.1. Summary statistics for the dependent variable and continuous explanatory variables

Variables	Mean	Std. dev.	Percentile 10th	25th	50th	75th	90th
Dependent variables:							
Kg of government-subsidized fertilizer acquired by the HH	29.294	143.258	0	0	0	0	0
Kg of FSP fertilizer acquired by the HH (2002/03 & 2006/07)	31.744	152.212	0	0	0	0	0
Explanatory variables:							
Percentage point spread between MMD & lead opposition party in the last presidential election	41.8	23.6	11.6	21.2	41.1	61.4	74.4
Percentage point spread between MMD & lead opposition party in the last parliamentary election	30.5	19.2	7.1	15.2	27.8	44.0	57.8
Effective market price of fertilizer (ZMK/kg)	1,442	660	720	780	1,476	1,960	2,400
Expected effective maize price (ZMK/kg)	451	180	221	283	464	589	694
Groundnut price (ZMK/kg, t-1, provincial median)	1,139	355	769	900	1,053	1,400	1,667
Mixed bean price (ZMK/kg, t-1, provincial median)	1,112	302	889	889	992	1,333	1,572
Sweet potato price (ZMK/kg, t-1, provincial median)	214	102	100	145	193	232	386
Cattle price (ZMK/head, provincial median)	519,656	301,918	160,000	230,000	589,388	789,138	953,272
Landholding size (ha, cultivated+fallow land)	2.1	2.6	0.5	0.8	1.5	2.5	4.0
Value of plows and harrows ('00,000 ZMK)	0.649	2.753	0	0	0	0	2.000
Full-time equivalent # of prime-age (15-59) adults	2.8	1.7	1.0	2.0	2.2	3.9	5.0
Age of household head	48.3	15.3	30.0	36.0	46.0	60.0	70.0
Kilometers from center of SEA to nearest (as of 2000):							
District town	34.5	22.6	9.8	16.0	28.9	47.0	70.2
Tarred/main road	25.5	35.7	0.9	4.0	12.0	29.2	69.8
Feeder road	3.3	3.3	0.6	1.1	2.4	4.3	7.7
Expected growing season rainfall (mm, 9-year MA)	896	184	660	757	877	1,059	1,167
Expected moisture stress (9-year MA)	1.8	1.0	0.6	0.9	1.9	2.4	3.1

Note: N=16,566 (9,644 for kg of FSP fertilizer acquired by the HH because no FSP in 1999/2000).
Source: CSO/MACO/FSRP 2001, 2004, & 2008 Supplemental Surveys.

Table D.2. Summary statistics for binary explanatory variables

	Share of households (%)		
Explanatory variables	1999/2000	2002/2003	2006/2007
MMD won constituency in the last presidential election	92.8	44.0	59.1
MMD won constituency in the last parliamentary election	86.9	43.0	60.6
HH owns a water pump	0.7	0.7	0.8
Highest level of education completed by HH head:			
Lower primary (grades 1-4)	23.0	25.6	27.0
Upper primary (grades 5-7)	36.2	34.0	34.5
Secondary (grades 8-12)	19.3	18.3	19.4
Post-secondary education	2.5	2.7	1.8
Gender & residence of HH head (non-resident if <6 months):			
Female-headed with non-resident husband	0.6	0.9	0.4
Female-headed with no husband	20.8	21.8	23.6
Disease-related prime-age death in last 3-4 years:			
Male head/spouse	1.2	1.8	0.1
Female head/spouse	1.0	2.1	1.3
Male non-head/spouse	3.3	2.9	4.4
Female non-head/spouse	5.0	3.6	3.7
SEA suitable for low input management maize production	55.3	56.0	56.4
Total number of households in sample	6,922	5,358	4,286

Source: CSO/MACO/FSRP 2001, 2004, & 2008 Supplemental Surveys.

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CHAPTER 5: FERTILIZER SUBSIDIES & SMALLHOLDER FERTILIZER PURCHASES – CROWDING OUT, LEAKAGE, & POLICY IMPLICATIONS FOR ZAMBIA

5.1 Introduction

Governments throughout sub-Saharan Africa (SSA) use fertilizer subsidies to pursue a number of objectives, among them improving access to agricultural inputs, increasing agricultural productivity, raising farm incomes, improving household and national food security, and increasing private sector participation in agricultural input marketing. Many SSA countries devote a large share of their public sector budgets to input subsidy programs. For example, between 2005 and 2008, Malawi allocated 5% to 15% of its national budget to fertilizer and seed subsidy programs (Ricker-Gilbert et al., 2011). In Zambia over the 2006 to 2011 fiscal years, the budget allocation to the Fertilizer Support Programme (renamed the Farmer Input Support Programme in 2010, FSP/FISP) averaged 40% of the total allocation to the ministries responsible for agriculture, livestock, and fisheries, and 64% of the total budget for Poverty Reduction Programmes. The opportunity cost of these funds is high. Government resources devoted to input subsidies cannot be used for other poverty reduction, food security, or agricultural development initiatives, some of which may have higher rates of return than input subsidies.

Unlike the universal fertilizer subsidies that were common prior to the agricultural market reforms of the 1980s and 1990s, today fertilizer subsidies are typically targeted at certain intended beneficiaries. For example, in Malawi, the subsidy is officially targeted at full time smallholder farmers that cannot afford to purchase one to two bags of fertilizer at commercial prices (Dorward et al., 2008). In Zambia, FSP/FISP officially targets smallholder farmers that are members of a cooperative, have the capacity to grow one to five hectares of maize, can pay the farmer share of the input costs (which has ranged from 25% to 50%), and are not beneficiaries of the Food Security Pack Programme, a fertilizer grant targeted at 'vulnerable but viable' farm households that cultivate less than one hectare of land (MACO, various years; Tembo, 2007).[29]

A key measure of the impact of a targeted fertilizer subsidy program is the extent to which it raises total fertilizer use. The inability to afford fertilizer at commercial prices is not always an explicit selection criterion of such programs. However, if subsidized fertilizer is allocated to households that would have otherwise purchased fertilizer at commercial prices, then the program's impact on total fertilizer use will be minimal. However, if subsidy beneficiaries would not have otherwise purchased commercial fertilizer, then each ton of government-subsidized fertilizer injected into the system would, in theory, increase total fertilizer use by one ton. Measuring the extent to which a fertilizer subsidy program "displaces" or "crowds out" commercial fertilizer purchases is therefore necessary to determine the impact of the program on total fertilizer use (Ricker-Gilbert et al., 2011).

Two previous studies have empirically estimated the degree to which fertilizer subsidy programs displace commercial fertilizer purchases. Xu et al. (2009) examine crowding out in Zambia using panel survey data covering the 1999/2000 and 2002/2003 agricultural years.[30] Ricker-Gilbert et al. (2011) estimate the rate of crowding out in Malawi and improve upon the Xu et al. (2009) methodology by explicitly taking into account the potential endogeneity of subsidized fertilizer in a commercial fertilizer demand equation.

Given their econometric estimates of displacement (i.e., the decrease in commercial fertilizer purchases, *comm*, given a one-unit increase in the quantity of government-subsidized

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[29] Smallholder households are those cultivating less than 20 ha.

[30] The agricultural year in Zambia is from October through September.

fertilizer acquired by the household (*govt*)), Xu et al. (2009) and Ricker Gilbert et al. (2011) calculate the change in total fertilizer use (*total*) as one minus the displacement estimate. This is based on the following identity and associated derivative:

$$total = govt + comm \quad (1)$$

$$\frac{\partial total}{\partial govt} = \frac{\partial govt}{\partial govt} + \frac{\partial comm}{\partial govt} = 1 + \frac{\partial comm}{\partial govt} \quad (2)$$

However, if there is leakage of government-subsidized fertilizer and it is being resold through private retailers at market or near-market prices, making it indistinguishable from commercial fertilizer for the researcher, then estimates of $\frac{\partial comm}{\partial govt}$ and hence $\frac{\partial total}{\partial govt}$ may be biased upward. Neither of the two aforementioned studies addresses the leakage issue.

In Zambia there have been widespread allegations of FSP/FISP fertilizer being diverted by program implementers and resold through formal or informal commercial channels.[31] Empirical evidence is consistent with leakage of government-subsidized fertilizer into commercial channels. The estimated quantity of FSP/FISP fertilizer received by smallholders based on nationally-representative household survey data collected by the Zambia Central Statistical Office (CSO) and Ministry of Agriculture and Cooperatives (MACO) is only 34% to 87% of the quantity of this fertilizer delivered to the district level according to MACO records (Table 5.1, column E).[32] Similar problems may plague the Malawi program (Dorward and Chirwa, 2011).

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[31] See, for example, Mulenga (2009), Sinyangwe (2009), and Chulu (2010), as well as http://www.aec.msu.edu/fs2/zambia/tour/FSP_Difficulties_Press_Clipping_Nov_Dec_2008.pdf for a compilation of Zambian newspaper articles from Nov./Dec. 2008 related to this issue.

[32] Dr. Michael T. Weber (Michigan State University) was the first to examine this relationship between official FSP distribution numbers and household survey data estimates.

Table 5.1. GRZ subsidy level, number of participating districts, fertilizer tonnage, and number of beneficiaries, 1997/8-2009/10

			From MACO records		Estimated from household survey data		
Agricultural year	Subsidy level	# of districts allocated FRA-FCP or FSP/FISP fertilizer	MT of fertilizer delivered to districts	Intended number of beneficiary households	MT of fertilizer received by smallholder households (as % of column C in parentheses)	# of beneficiary smallholder households (as % of column D in parentheses)	Data source
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1997/1998	0% (loan)	16	15,495	--	--	--	--
1998/1999	0% (loan)	23	50,001	--	--	--	--
1999/2000	0% (loan)	45	34,999	--	21,038 (60%)	64,493	PHS9900
2000/2001	0% (loan)	42	23,227	--	11,266 (49%)	30,103	PHS0001
2001/2002	0% (loan)	45	28,985	--	8,365 (29%)	26,763	PHS0102
2002/2003	50%	72	48,000	120,000	31,722 (66%)	102,113 (85%)	SS04
2003/2004	50%	72	60,000	150,000	33,372 (56%)	101,139 (67%)	SS04
2004/2005	50%	67[a]	50,000	125,000	16,792 (34%)	64,854 (52%)	PHS0405
2005/2006	50%	72	50,000	125,000	23,595 (47%)	74,040 (59%)	PHS0506
2006/2007	60%	68[a]	84,000	210,000	58,404 (70%)	164,229 (78%)	SS08
2007/2008	60%	72	50,000	125,000	43,596 (87%)	140,612 (112%)	SS08
2008/2009	75%	72	80,000	200,000	55,114 (69%)	192,860 (96%)	CFS0809
2009/2010	75%	72	106,000	534,000[b]	69,103 (65%)	292,685 (55%)	CFS0910

Notes: GRZ = Government of the Republic of Zambia. -- Information not available. [a]Indicates number of districts allocated FSP in original allocations. Additional districts may have been added when FSP received supplemental funding. [b]Pack size reduced to four 50 kg bags under FISP.
Sources: FRA Agro Support Department; MACO (various years); MACO (2008); the 2004/05 and 2005/06 Post-Harvest Surveys (PHS0405, PHS0506); 2004 and 2008 CSO/MACO/FSRP Supplemental Surveys (SS04 and SS08); and 2008/09 and 2009/10 Crop Forecast Surveys (CFS0809 and CFS0910).

In this paper, I use nationally representative panel household survey data from Zambia to estimate the change in smallholder total and commercial fertilizer purchases given a one-unit increase in the quantity of government-subsidized fertilizer distributed. The study builds on the work of Xu et al. (2009) and Ricker-Gilbert et al. (2011) in several ways. First, it explicitly takes into account the leakage issue described above. Second, since the publication of Xu et al. (2009), which uses panel data covering the 1999/2000 and 2002/03 agricultural years, a third wave of panel data covering 2006/07 has become available. FSP began in 2002/03 and 48,000 MT of fertilizer were distributed through the program that year. During the next three years, the program operated at approximately the same scale (Table 5.1). Then in 2006/07, FSP was expanded to 84,000 MT and the subsidy level was raised from 50% to 60%. Thus FSP has changed significantly since the Xu et al. (2009) study, and the newly available data provide the means to compare the rate of crowding out in 2002/03 to the rate in 2006/07 when the program was 75% larger.

Third, I follow Ricker-Gilbert et al. (2011) and use the control function/instrumental variables approach to test and control for the endogeneity of subsidized fertilizer in the commercial fertilizer demand equations estimated. Xu et al. (2009) do not address the endogeneity issue, consequently their estimates of crowding out may be biased and inconsistent. Finally, I control for the potentially confounding effects of the Food Reserve Agency (FRA), a strategic food reserve/maize marketing board, when estimating the degree of displacement/crowding out. The FRA buys maize from smallholders at a pan-territorial price that is typically above market prices. A farmer's expected maize price is likely to be an important determinant of his/her commercial fertilizer purchases and the FRA's activities are likely to affect such price expectations. Failure to control for the effects of the FRA in a commercial fertilizer demand equation could result in biased and inconsistent estimates of crowding out and other parameters. This is not an issue in Xu et al. (2009) because the FRA was largely dormant during its period of analysis (1999/2000-2002/03). But the FRA ramped up its activities between 2002/03 and 2006/07, so its potential effects on commercial fertilizer demand cannot be ignored here given the 1999/2000-2006/07 study period.[33] The need to control for marketing board effects is not unique to Zambia; other countries in eastern and southern Africa also have both fertilizer subsidies and maize marketing boards (e.g., Malawi and Kenya).

The remainder of this paper is organized as follows. In section 5.2, I provide an overview of the Government of the Republic of Zambia (GRZ) fertilizer subsidy programs that were in place during the agricultural years captured in the household panel survey data set (1999/2000, 2002/03, and 2006/07) and compare the socioeconomic characteristics of households that received fertilizer from government programs to those of households that purchased fertilizer from commercial sources. In section 5.3, I outline the methodology. The data used in the study are described in section 5.4, and the estimation results are summarized in section 5.5. Conclusions and policy implications are discussed in section 5.6.

5.2 GRZ fertilizer programs & household socioeconomic characteristics by fertilizer source

GRZ implemented three main fertilizer programs during the period of analysis (1999/2000 to 2006/2007): (i) the Food Reserve Agency Fertilizer Credit Programme (FRA-FCP), which ran from 1997/98 to 2001/02; (ii) the Fertilizer Support Programme (FSP), which replaced FRA-FCP and ran from 2002/03 to 2008/09; and (iii) the Food Security Pack Programme, which has been in place since 2000/01 and was implemented by the Zambian NGO

[33] See Appendix F for detailed information on the Food Reserve Agency.

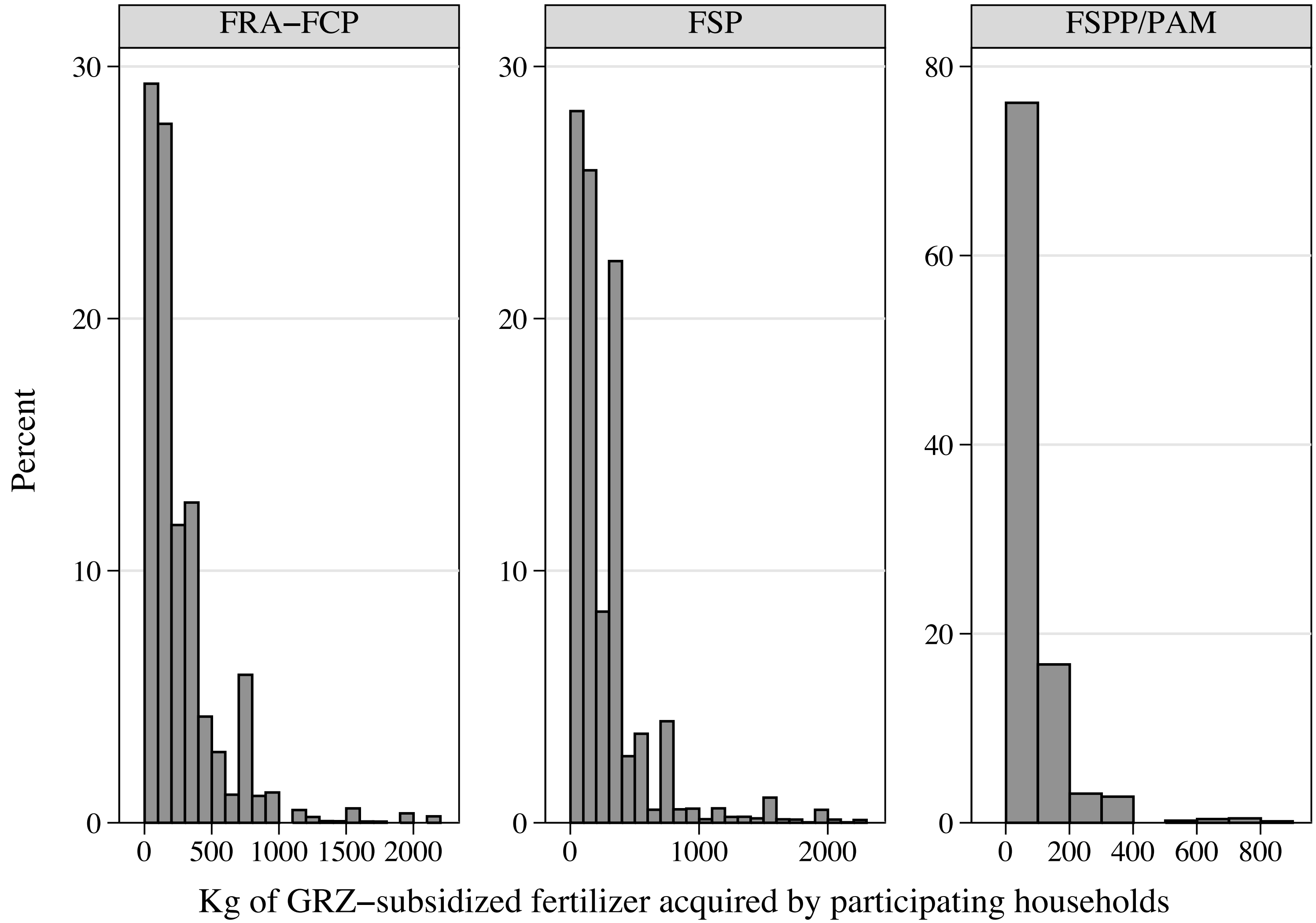
the Programme Against Malnutrition during the study period (FSPP/PAM). I discuss each of these in turn.

5.2.1. The Food Reserve Agency Fertilizer Credit Programme

Under FRA-FCP, fertilizer was distributed to small-scale farmers on credit at a pan-territorial price (MACO et al., 2002). In 1999/2000 (the first wave of the panel survey), approximately 35,000 MT of fertilizer were distributed through FRA-FCP. Farmers applied to participate in November 1999 and made a down payment of K5,000 per 50-kg bag of fertilizer; the balance of K40,000 per bag was to be repaid in cash or in maize in June 2000 (MACO et al., 2002). Farmers could apply for 200 to 800 kg of fertilizer and each 100 kg "pack" consisted of one 50-kg bag of basal and one 50-kg bag of top dressing fertilizer (FRA Agro Support Department, 1999). See Figure 5.1 for a histogram of the quantities of FRA-FCP fertilizer acquired by participating households in 1999/2000 based on the panel survey data. FRA-FCP fertilizer was not subsidized *per se*. However, the loan recovery rate was only 34.5% in 1999/2000, so approximately two thirds of FRA-FCP participants received the fertilizer at an 89% effective subsidy (MACO et al., 2002).

FRA-FCP was implemented through farmer cooperatives that were pre-selected by the FRA. In order to participate in the program, members of these cooperatives were required to be: (i) "a bona fide resident and … farming within the village area; (ii) credible and able to pay back the loan; and (iii) not indebted to the FRA as regards seasonal loans" (FRA Agro Support Department, 1999: 3). Village headmen, Camp Extension Officers, and Village Farmers' Committees were involved in the selection of program participants.

Figure 5.1. Histograms of kg of fertilizer acquired through FRA-FCP, FSP, and FSPP/PAM by participating households



Note: Quantities are for 1999/2000 for FRA-FCP and for 2002/03 and 2006/07 for FSP and FSPP/PAM.
Sources: CSO/MACO/FSRP 2001, 2004, and 2008 Supplemental Surveys

5.2.2. The Fertilizer Support Programme

GRZ moved to a cash-only (no credit) system when it replaced FRA-FCP with the Fertilizer Support Programme in 2002/03 (which is captured by the second wave of panel survey). Two main goals of FSP were "improving household and national food security, incomes, [and] accessibility to agricultural inputs by small-scale farmers through a subsidy" and "building the capacity of the private sector to participate in the supply of agricultural inputs" (MACO, 2008: 3).

Like FRA-FCP, FSP was implemented through cooperatives and other farmer organizations. Beneficiary organizations were pre-selected by District Agriculture Committees in collaboration with other local leaders (MACO, various years). Within pre-selected cooperatives, individual beneficiaries were required to: (i) be small scale farmers actively involved in farming within the cooperative coverage area; (ii) have the capacity to grow one to five hectares of maize; (iii) be capable of meeting the farmer share of the input costs; (iv) not be benefiting from the Food Security Pack; and (v) not be a defaulter from FRA-FCP and/or other agricultural credit programs (ibid). Cooperative Boards, Camp Extension Officers, Village Farmers' Committees, village headmen, and other local leaders were involved in the selection of program participants.

Upon selection, beneficiary farmers paid their share of the input costs in cash. Once subsidized fertilizer was positioned at FSP satellite depots, farmers reported to their designated depot to collect the inputs. The official FSP "pack" consisted of four 50-kg bags of basal fertilizer, four 50-kg bags of top dressing fertilizer, and 20 kg of hybrid maize seed. Each participating farmer was to receive only one pack. However, as shown in Figure 5.1, the quantity of FSP fertilizer received varied widely across participants.

Fertilizer for FSP was supplied and delivered to the district level by traders that were selected through a national tender process. Local distributors in the districts then transported the fertilizer to satellite depots where it was distributed to selected farmers. This process was to be supervised by MACO extension agents and other MACO staff (MACO, various years).

5.2.3. The Food Security Pack Programme

Unlike FRA-FCP and FSP, FSPP/PAM is a grant-based government fertilizer program. FSPP/PAM targets farming households that cultivate less than one hectare of land and are 'vulnerable but viable', e.g., households headed by women or children, households with disabled members or that are supporting orphans, and unemployed youth (Tembo, 2007). A Food Security Pack consists of (i) 0.25 hectare's worth of cereal seed (maize, millet, rice, or sorghum, depending on the area); (ii) two 50-kg bags of fertilizer (one basal and one top dressing) for households that receive maize seed; (iii) 0.25 hectare's worth of legume seeds (groundnuts, beans, cowpeas, or soybeans); (iv) 0.25 hectare's worth of cassava or sweet potato planting materials; and (v) lime for beneficiary households in high rainfall areas (Tembo, 2007). The main objectives of FSPP/PAM are: (i) to "promote crop diversification for increased food production"; (ii) to "promote farming methods that help restore soil fertility and productivity"; and (iii) to "encourage adoption of conservation farming (CF) technologies" (Tembo, 2007: 1). According to program records, 140,399 and 21,700 households participated in FSPP/PAM in the 2002/03 and 2006/07 agricultural years, respectively (ibid). (FSP intended to reach 120,000 and 210,000 households in these years, respectively.) Figure 5.1 shows the quantities of FSPP/PAM fertilizer acquired by participating households in 2002/03 and 2006/07 based on the panel survey data. See Appendix F for additional details on FRA-FCP, FSP, and FSPP/PAM.

5.2.4. Household socioeconomic characteristics by fertilizer source

Table 5.1 summarizes fertilizer purchases by and the socioeconomic characteristics of smallholder households by source of fertilizer for each year of the panel survey. (These data are described in detail in section 5.4.) More than 70% of smallholder households in Zambia do not acquire fertilizer from any channel, although this percentage declined from 79% in 1999/2000 to 71% in 2002/03 and 2006/07. Approximately 15-18% of smallholders purchased fertilizer from commercial retailers while 7-13% acquired it through government programs. (Less than 2% of households obtain fertilizer from both government and commercial channels.) There was a larger increase between 1999/2000 and 2006/07 in the share of households acquiring fertilizer from government programs than in the share acquiring it from commercial sources. The mean and median quantities of fertilizer acquired among households sourcing it through FSP and commercial channels increased between 2002/03 and 2006/07.

In terms of socioeconomic characteristics, FRA-FCP and FSP beneficiary households have larger average land and farm asset holdings than those that source fertilizer from commercial retailers. Assuming that landholding size and value of farm assets are positively correlated with a household's ability to afford fertilizer at commercial prices, these results are indicative of potential targeting problems and crowding out. FSPP/PAM participants and households that acquire no fertilizer have similar levels of land, farm assets, educational attainment, and female-headed households. These households have smaller average land and asset holdings, lower median educational attainment, and a higher percentage of female-headed households than households that acquire fertilizer from FRA-FCP, FSP, or commercial retailers.

Table 5.2. Socioeconomic characteristics of households by source of fertilizer

Descriptive result	Agricultural year	Source of fertilizer: (A) FRA-FCP	(B) FSP	(C) FSPP-PAM	Government programs (A, B or C)	Commercial retailers	Both government & commercial sources		Did not acquire fertilizer
Share of households	1999/2000	6.5%	--	--	6.5%	15.4%	0.7%		78.8%
	2002/2003	--	8.8%	4.5%	13.2%	16.4%	0.7%		71.1%
	2006/2007	--	11.2%	1.1%	12.4%	18.2%	1.6%		71.1%
							Gov't	Comm.	
Mean kg fertilizer from source	1999/2000	338	--	--	338	243	144	139	0
	2002/2003	--	300	131	244	245	325	229	0
	2006/2007	--	356	131	336	336	471	645	0
Median kg fertilizer from source	1999/2000	200	--	--	200	150	100	100	0
	2002/2003	--	200	100	100	150	180	200	0
	2006/2007	--	300	100	200	200	400	300	0
Mean landholding size (ha)	1999/2000	3.12	--	--	3.12	2.84	2.76		2.02
	2002/2003	--	3.13	2.14	2.79	2.84	4.21		1.86
	2006/2007	--	3.13	1.80	3.01	2.84	5.39		1.71
Mean value of farm assets	1999/2000	36.3	--	--	36.3	24.6	21.0		8.8
(Real 100,000 ZMK,	2002/2003	--	48.3	19.1	38.5	35.6	70.6		18.3
2007/08=100)	2006/2007	--	53.3	12.7	49.7	46.0	120.1		15.1
% female-headed	1999/2000	8.7%	--	--	8.7%	14.2%	4.8%		21.8%
	2002/2003	--	15.7%	24.6%	18.9%	14.3%	9.4%		23.9%
	2006/2007	--	14.3%	28.9%	15.6%	17.9%	11.1%		26.7%
Median education of HH head	1999/2000	7	--	--	7	7	7		5
(highest grade completed)	2002/2003	--	7	6	7	7	6		4
	2006/2007	--	7	5	7	7	7		5

Notes: Weighted results based on the balanced panel of 4,286 households. Among households acquiring fertilizer from both sources, 77% and 96% of these households obtained the government fertilizer through FSP in 2002/03 and 2006/07. (The other households obtained it through FSPP/PAM). Sources: CSO/MACO/FSRP 2001, 2004, and 2008 Supplemental Surveys.

5.3 Methodology

5.3.1 Conceptual framework: fertilizer subsidies, leakage, and effects on fertilizer demand

In this paper, the goal is to measure the extent to which an increase in the quantity of government-subsidized fertilizer distributed affects smallholders' commercial fertilizer and total fertilizer demand. However, as noted in the introduction, subsidized fertilizer may leak from the government channel and be resold through private retailers. Eq. (1) and (2) still hold but it is helpful to decompose total government fertilizer distributed (*govt*) into that which is acquired by end users through the government channel (*nonleaked*) and that which leaks out of the government channel and is acquired by end users from commercial retailers (*leaked*):

$$govt = nonleaked + leaked \tag{3}$$

Similarly, we can separate all fertilizer acquired by end users through commercial channels (*allcomm*) into the portion that is truly commercial fertilizer (*comm*) and that which is leaked government-subsidized fertilizer (*leaked*):

$$comm = allcomm - leaked \tag{4}$$

Plugging (3) and (4) into (1) and taking the derivative with respect to *govt* gives:

$$\frac{\partial total}{\partial govt} = \frac{\partial(nonleaked + leaked + allcomm - leaked)}{\partial govt} = 1 + \frac{\partial allcomm}{\partial govt} - \frac{\partial leaked}{\partial govt} \tag{5}$$

We as researchers cannot (and smallholder households probably cannot) distinguish between "real" commercial fertilizer (*comm*) and identical government-subsidized fertilizer that is resold through commercial channels at or close to the market price (*leaked*). We only observe *allcomm*, i.e., fertilizer that respondents acquired from commercial sources. If $\frac{\partial leaked}{\partial govt}$ is positive, Eq. (5) shows that estimates of $\frac{\partial total}{\partial govt}$ will be biased upward if leakage is ignored.

In the empirical work, the challenge is to estimate $\frac{\partial allcomm}{\partial govt}$ and $\frac{\partial leaked}{\partial govt}$. For the former, a household-level factor demand equation is estimated for *allcomm* with *govt* as an explanatory variable. The coefficient on *govt* is then the estimate of $\frac{\partial allcomm}{\partial govt}$. The conceptual framework motivating the factor demand model specification is outlined in the next section. For the latter, $\frac{\partial leaked}{\partial govt}$ is assumed to be constant (i.e., $\frac{\partial leaked}{\partial govt} = \frac{leaked}{govt}$) and it is estimated as the share of FRA-FCP/FSP fertilizer delivered to the district level (based on FRA & MACO records) that did not reach smallholders through the government channel (e.g., 40% in 1999/2000 per Table 5.1, column E). The quantity of FRA-FCP/FSP fertilizer received by smallholders through the government channel is estimated from the household panel survey data described in section 5.4.

5.3.2 Conceptual framework: factor demand equation for "allcomm"

Consider a risk-neutral, expected profit-maximizing agricultural producer (or a farm household for which production and consumption decisions are separable). Assume that production is deterministic and that the household's implicit production function is $G(\boldsymbol{q},\boldsymbol{x};govt,\boldsymbol{z}) = 0$, where $\boldsymbol{q}$ is a vector of quantities harvested of various crops, $\boldsymbol{x}$ is a vector of variable input quantities, *govt* is the quantity of government-subsidized fertilizer acquired by the household, and $\boldsymbol{z}$ is a vector of other production shifters such as quasi-fixed factors of production, agro-ecological conditions, and household characteristics affecting production. Following Ricker-Gilbert et al. (2011), *govt* is treated as a quasi-fixed factor and the quantity of fertilizer purchased from commercial retailers (*allcomm*) is treated as a variable input.

Let $\boldsymbol{p}$ be a vector of crop prices at the next harvest; these prices are random variables and unobserved by the household at the time that commercial fertilizer purchases and other crop production decisions are made. Variable input prices ($\boldsymbol{w}$) are assumed known at this time. Let $\boldsymbol{y} = [\ \boldsymbol{q}, \quad \boldsymbol{x}]'$ be the vector of output and variable input quantities. Solving the household's expected profit maximization problem gives factor demand and output supply functions $\boldsymbol{y} = \boldsymbol{y}\left(E(\boldsymbol{p}), \boldsymbol{w}; govt, \boldsymbol{z}\right)$, where *E(.)* is the expectation operator. The main decision rule of interest is a household's commercial fertilizer demand function:

$$allcomm = allcomm\left(E(\boldsymbol{p}), \boldsymbol{w}; govt, \boldsymbol{z}\right) \tag{6}$$

5.3.3 Empirical model

In the empirical application, Eq. (6) is specified as:

$$allcomm_{i,t} = \alpha_0 + \alpha_1 \hat{p}^*_{i,t} + \boldsymbol{p}_{\boldsymbol{o},k,t-1}\boldsymbol{\alpha_2} + \alpha_3 w_{i,t} + \alpha_4 govt_{i,t} + z_{i,t}\boldsymbol{\alpha_5} + c_i + u_{i,t} \tag{7}$$

where *i* indexes the household, *t* indexes the harvest year (t=2000, 2003, and 2007), and *k* indexes the province; *allcomm* is the kilograms of commercial fertilizer purchased; $\hat{p}^*_{i,t}$ is the household-level expected effective maize price in ZMK/kg (discussed further below); $\boldsymbol{p}_{\boldsymbol{o},k,t-1}$ is a vector of provincial median groundnut, mixed bean, and sweet potato prices at the previous harvest in ZMK/kg, i.e., households are assumed to have naïve expectations of the prices of these commonly-marketed non-maize crops;[34] *w* is the effective fertilizer market price in ZMK/kg

[34] Seed cotton prices are also available; however, Dunavant, the major buyer of cotton in Zambia, typically announces its cotton buy price before planting time. Since the cotton price is observed at planting time, no assumptions regarding households' price expectations are necessary. The announced pre-planting Dunavant price is not included as a regressor in the

paid by households that purchased commercial fertilizer and the district median effective fertilizer market price otherwise (price data are not available for other variable farm inputs); *govt* is the kilograms of government-subsidized fertilizer acquired by the household through FRA-FCP, FSP, and/or FSPP/PAM; **z** is a vector of other factor demand/output supply shifters; c_i is time invariant household-level unobserved heterogeneity; $u_{i,t}$ is the error term; and the α's are parameters to be estimated. By effective price, I mean adjusted for estimated transportation costs from the point of sale or purchase to the farmgate. Prices and other monetary values are in nominal terms because under the maintained hypothesis of separability, consumer prices are irrelevant for farm input use and crop production decisions.

z includes the household's landholding size (measured as hectares of cultivated plus fallow land); the value of plows and harrows owned by the household and a dummy variable equal to one if the household owns a water pump (used for irrigation); the number of full-time equivalent prime-age (15-59 years) adults in the household; the age and highest level of education completed by the household head; the gender and residence status of the household head; a vector of dummy variables for disease-related prime-age deaths in the household in the last three to four years; the kilometers from the center of the household's standard enumeration area (SEA) to the nearest district town, tarred/main road, and feeder road as of the first panel survey year;[35] expected growing season rainfall (a moving average of November-March rainfall over the past nine years); expected moisture stress (a nine-year moving average of the number of 20-day periods, November-March, with less than 40 mm of rainfall); a dummy variable equal to

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fertilizer demand and output supply equations because it is essentially a pan-territorial price. It would therefore be perfectly collinear with the year dummies in the regressions.

[35] SEAs are the most disaggregated geographic units in the dataset. An SEA contains approximately 150-200 households (two to four villages).

one if the household lives in an SEA that is agro-ecologically suitable (in terms of rainfall and soil type) for low input management rainfed maize production; and provincial and year dummies. See Tables E.1 and E.2 in Appendix E for summary statistics for the explanatory variables in Eq. (7).

The expected effective maize price in Eq. (7), $\hat{p}_{i,t}^{*}$, is estimated as in Mason (2011, Chapter 2). The rationale and general approach are as follows. Maize is the most important crop in Zambia and is grown by approximately 80% of smallholders. Both the FRA and private traders buy maize from these farmers. FRA purchases are made at satellite depots set up in rural areas at harvest time. The FRA pays a pan-territorial price at the satellite depots but the effective FRA price varies across households based on their proximity to an FRA depot and the cost of transporting maize to the depot. The locations of FRA depots, the quantity of maize the Agency will buy at each depot, and FRA and private sector maize prices (p_f and p_p, respectively) are not known to the farmer when commercial fertilizer purchase decisions are made. Let γ be a Bernoulli random variable equal to one if the FRA channel is available to a household at harvest time, and zero otherwise. Assuming that the private sector maize marketing channel is always available and that the FRA channel is available with probability $E(\gamma)$, then the expected effective maize price is defined as:

$$p^{*} \equiv E(\gamma)E[\max(p_f, p_p)] + [1 - E(\gamma)]E(p_p) \quad (8)$$

Under a bivariate lognormal distribution for (p_f, p_p), p^{*} is a function of $E(\gamma)$ and the means, variances, and covariance of p_f and p_p. Household and time-varying subjective values for these terms are obtained by first regressing the harvest time observed value of the term (e.g.,

$\log p_{f,i,t}$) on a vector of variables that are observable to the household when fertilizer purchase decisions are made and that may inform households' expectations of harvest time maize prices and FRA channel availability. Included in this vector, *inter alia*, are past effective FRA and market maize prices and the quantity of maize bought by the Agency in the household's area in past years. Then the fitted (predicted) values from the regressions are used to construct $\hat{p}^{*}_{i,t}$ per Eq. (8). Thus in the empirical models, past FRA behavior can affect $\hat{p}^{*}_{i,t}$, which can in turn affect demand for commercial fertilizer ($allcomm_{i,t}$). This gives the resultant estimates of crowding out/displacement a "holding past FRA behavior fixed" interpretation.

5.3.4 Estimation strategy

Eq. (7) is estimated using fixed effects (FE), correlated random effects (CRE) Tobit, and a CRE truncated normal hurdle model (CRE TNH). Each of these estimators controls for time invariant household-level unobserved heterogeneity (c_i), which may be correlated with the observed covariates in Eq. (7) (call them $\boldsymbol{X_{i,t}}$). To produce consistent estimates, all three estimators require, *inter alia*, strict exogeneity of $\boldsymbol{X_{i,t}}$ conditional on c_i (i.e., $E(u_{i,t} \mid \boldsymbol{X_i}, c_i) = 0, \ t = 1,2,...,T$). FE is consistent under the assumptions of strict exogeneity and a rank condition (Wooldridge, 2002).

CRE Tobit and CRE TNH are used in addition to FE because of the corner solution nature of the dependent variable. *allcomm* is greater than zero for only 16% of the observations hence the partial effect of *govt* on *allcomm* may not be constant over the range of $\boldsymbol{X_{i,t}}$. A Tobit or TNH model may therefore better characterize the full distribution of *allcomm*, $D(allcomm_{i,t} \mid \boldsymbol{X}_{i,t}, c_i)$.

For the CRE approach, if in addition to strict exogeneity we assume that $c_i = \psi + \bar{\boldsymbol{X}}_{\boldsymbol{i}}\xi + a_i$ and $c_i \mid \boldsymbol{X}_{\boldsymbol{i}} \sim Normal(\psi + \bar{\boldsymbol{X}}_{\boldsymbol{i}}\xi,\ \sigma_a^2)$, where $\bar{\boldsymbol{X}}_{\boldsymbol{i}}$ is the average of $\boldsymbol{X}_{\boldsymbol{i,t}}$, t=1,…,T, and σ_a^2 is the variance of a_i, then we can control for c_i in a Tobit or TNH model by including $\bar{\boldsymbol{X}}_{\boldsymbol{i}}$ as additional explanatory variables (Wooldridge, 2002). For the TNH model, CRE also requires the assumption that the a_i in the probit and truncated normal regression parts of the model (call them a_{1i} and a_{2i}) be independent (Wooldridge, 2010). See Wooldridge (2002) for the likelihood functions for and additional details on the Tobit and TNH models.

Eq. (7) is estimated separately for districts with high versus low initial levels of fertilizer private sector activity (PSA). *A priori*, one would expect the degree of crowding out to be greater in initially high PSA areas than in initially low ones. Chow test results suggest that the two areas should not be pooled. High PSA districts are defined as those in the top tercile when ranked by mean kilograms of commercial fertilizer purchased per household in 1997/98. The cutoff between the top and bottom terciles is 20 kg per household. Across the three years of the panel, 1999/2000, 2002/03, and 2006/07, 39%, 40%, and 42% of smallholder households, respectively, are located in initially high PSA districts. The level of PSA in 1997/98 is used because this is before the scaling up of fertilizer subsidies in Zambia (see Table 5.1). Although 1997/98 was the first year of FRA-FCP, the program was small scale that year and there had been no GRZ smallholder fertilizer subsidy programs from liberalization in the early 1990s through 1996/97. Ideally, 1996/97 would have been used as the 'baseline' year for fertilizer PSA; however, this is not possible because household survey data that identify the source of fertilizer are not available for 1996/97.

All explanatory variables in Eq. (7) are assumed to be strictly exogenous except for $govt_{i,t}$. GRZ fertilizer program participants are not randomly selected and it is possible that unobserved time-varying factors that affect a household's participation in these programs also influence their commercial fertilizer purchases; i.e., $govt_{i,t}$ may be correlated with $u_{i,t}$. $govt_{i,t}$ is also a corner solution variable: most households acquire zero government-subsidized fertilizer in a given year, and the quantity acquired by recipients is an approximately continuous variable (see Figure 5.1 and Table 5.2). I therefore use the control function approach to test and control for the potential endogeneity of $govt_{i,t}$ (Rivers and Vuong, 1988; Vella 1993; Ricker-Gilbert et al., 2011).

The control function approach entails first estimating via CRE Tobit a reduced form model in which $govt_{i,t}$ is the dependent variable and the explanatory variables are all of the right-hand side variables in Eq. (7), the structural equation, and at least one instrumental variable (IV). The Tobit residuals from the reduced form are then included as an additional regressor in Eq. (7). A simple test of endogeneity is a t-test of the coefficient on the Tobit residuals. If this coefficient is statistically significant, then we reject the null hypothesis that $govt_{i,t}$ is exogenous. Including the Tobit residuals in the structural equation also solves the endogeneity problem (Rivers and Vuong, 1988; Vella 1993). Both the Tobit residuals and expected maize price are generated regressors so bootstrapping is used to obtain standard errors for Eq. (7) parameter estimates that account for the sampling variation and first-stage estimation (Wooldridge, 2002).

Three IVs are included in the reduced form Tobit for $govt_{i,t}$. The first is a binary variable equal to one if the household's constituency was won by the ruling party (the Movement for Multi-Party Democracy, MMD) during the last presidential election, and zero otherwise. Call this variable $MMD_{c,t}$, where *c* indexes the constituency.[36] Presidential and parliamentary elections in Zambia take place every five years and the MMD candidate has won all presidential elections since 1991 (i.e., 1991, 1996, 2001, 2006, and the 2008 emergency election following the death of President Levy Mwanawasa). The second IV is the percentage point spread between the MMD and the lead opposition party in the constituency in the last presidential election ($spread_{c,t}$). The third IV is the interaction, $MMD_{c,t} \times spread_{c,t}$. Banful (2011) uses similar variables to explain subsidized fertilizer allocation at the district level in Ghana in 2008.

To be valid, these IVs should be (i) partially correlated with $govt_{i,t}$, and (ii) partially uncorrelated with $u_{i,t}$. Reduced form CRE Tobit results for $govt_{i,t}$ (reported in Table E.3 in Appendix E) support condition (i). The average partial effect (APE) of $MMD_{c,t}$ ($spread_{c,t}$) is positive (negative) and significant at the 1% (5%) level in both the high and low PSA area models. The interaction effect between these two variables is positive in both models, and significant at the 10% and 1% levels in high and low PSA areas, respectively. (See Mason (2011, Chapter 4) for a detailed discussion of the political economy implications of these results.) Condition (ii) is a maintained hypothesis but with only one suspected endogenous variable (*govt*) and three IVs, it is possible to test the null hypothesis that the two 'extra' IVs are uncorrelated

[36] There are 150 total constituencies in Zambia's 72 districts. The numbers of constituencies per district are: 1 (26 districts), 2 (22 districts), 3 (20 districts), 4 (2 districts), 5 (1 district), and 7 (1 district). A constituency contains multiple villages.

with $u_{i,t}$. Hansen J tests fail to reject this null hypothesis in both the high (p=0.428) and low PSA (p=0.316) models.

5.4 Data

The data used in this paper are mainly from a three wave, nationally representative panel survey of smallholder households in Zambia. The first wave of the survey covers the 1999/2000 agricultural season and was done in two phases: the 1999/2000 Post-Harvest Survey (PHS9900) conducted by CSO and MACO in August/September 2000, and the 2001 Supplemental Survey (SS01) conducted by CSO, MACO, and the Food Security Research Project (FSRP) in May 2001. The second and third waves of the CSO/MACO/FSRP Supplemental Survey (SS) were conducted in May 2004 to cover the 2002/03 agricultural season (SS04) and in June/July 2008 to cover the 2006/07 agricultural season (SS08). PHS9900 included questions on households' cropping patterns and production levels, agricultural input use, crop marketing, livestock production and marketing, and farm equipment ownership. SS01 complemented this agricultural profile with questions on household demographics, recent disease-related deaths among household members, off-farm income and remittances, purchases of select crops, and other household details. SS04 and SS08 collected the complete set of household agricultural and non-agricultural information.

The PHS99900 sample of 7,699 households was selected using a stratified three-stage sample design (Megill, 2005). In stage 1, Census Supervisory Areas (CSAs), the primary sampling units, were selected from each of 70 districts with probability proportional to size (PPS). In stage 2, one Standard Enumeration Area (SEA) was selected from each CSA with PPS for a total of 394 selected SEAs. All households in these SEAs were listed and identified as small-scale (0-4.99 ha) or medium-scale (5-19.99 ha). Then in stage 3, 20 households were selected from each SEA: 10 medium-scale households (or all medium-scale households in the SEA if there were fewer than 10) and 10 small-scale households (or 20 minus the number of medium-scale households selected).

Of the 7,699 PHS9900 households, 6,922 were interviewed in SS01. 5,358 (77.4%) of the SS01 households were successfully re-interviewed in SS04, and of these, 4,286 (80.0%) were re-interviewed in SS08. In the analysis, I use the unbalanced panel of households that were interviewed in at least SS01 and SS04. Given attrition between survey waves, attrition bias is a potential concern. I therefore follow the approach recommended in Wooldridge (2002: 585) to test for attrition bias but fail to reject the null of no attrition bias in all models.

Data used in the analysis that are drawn from sources other than the SS are: (i) household-level fertilizer purchases from private retailers in 1997/98 from the MACO/CSO 1997/98 PHS; (ii) dekad (10-day period) rainfall data covering the 1990/91 to 2006/07 growing seasons and collected from 36 stations throughout Zambia by the Zambia Meteorological Department; (iii) maize, groundnut, mixed bean, and sweet potato prices from the MACO/CSO PHSs for 1998/99, 2001/02, and 2005/06; and (iv) constituency-level data on the percentage of votes won by the MMD and opposition parties during the 1996, 2001, and 2006 presidential elections from the Electoral Commission of Zambia.

5.5 Results

What do the econometric results suggest about the degree to which government-subsidized fertilizer crowds out commercial fertilizer purchases by Zambian smallholders? Displacement estimates for high versus low PSA areas based on the three different estimators

(FE, CRE Tobit, and CRE TNH) are summarized in Table 5.3. (See Tables E.4 and E.5 in Appendix E for the full regression results.) The CRE TNH estimates are the most conservative and the CRE Tobit model is rejected in favor of the CRE TNH model in both high and low PSA areas based on likelihood ratio tests ($p<0.001$). Both CRE TNH and CRE Tobit are preferred over FE because these estimators take into account the fact that most smallholder households do not purchase any fertilizer from commercial retailers.

The APE of a 1-kg increase in government-subsidized fertilizer received by a household (*govt*) on the kg of fertilizer purchased from commercial retailers (*allcomm*) is negative and highly statistically significant ($p<0.001$) in all six models estimated (three each for high and low PSA areas, Tables E.4 and E.5 in Appendix E). The displacement estimates are also economically significant, particularly in high PSA areas where crowding out is expected to be greater *a priori*. In high PSA areas, each additional kg of government-subsidized fertilizer received reduces commercial fertilizer purchases by 0.24 to 0.35 kg (Table 5.3). The estimated displacement rate is much lower in low PSA areas (0.07 based on CRE Tobit and CRE TNH). Taken together, the high and low PSA CRE TNH results suggest a national displacement rate of 0.14.

How do these results compare to those in Xu et al. (2009)? The current paper suggests a somewhat higher rate of displacement at the national level than the 0.07 to 0.08 rate reported in Xu et al. (2009). Results in the current paper do not support the Xu et al. (2009) finding of “crowding in” in low PSA areas, nor do the results support their finding of such a high degree of crowding out in high PSA areas that total fertilizer acquisition actually decreases with each additional kg of government-subsidized fertilizer injected into the system.

Table 5.3. Average partial effects of a 1-kg increase in government-subsidized fertilizer received by the household on kg of commercial fertilizer purchased

Population	Fixed effects	CRE Tobit	CRE TNH
PANEL A. High PSA areas	**-0.354**	**-0.319**	**-0.239**
Farm size			
< 2 ha cultivated		-0.285	-0.220
>= 2 ha cultivated		-0.395	-0.282
Gender of HH head			
Male		-0.342	-0.258
Female		-0.231	-0.165
Agricultural year			
1999/2000		-0.305	-0.243
2002/2003		-0.307	-0.225
2006/2007		-0.350	-0.252
PANEL B. Low PSA areas	**-0.199**	**-0.0747**	**-0.0680**
Farm size			
< 2 ha cultivated		-0.0587	-0.0524
>= 2 ha cultivated		-0.132	-0.124
Gender of HH head			
Male		-0.0824	-0.0763
Female		-0.0495	-0.0409
Agricultural year			
1999/2000		-0.0634	-0.0538
2002/2003		-0.0761	-0.0643
2006/2007		-0.0874	-0.0910
PANEL C. National estimate	**-0.262**	**-0.174**	**-0.137**
Farm size			
< 2 ha cultivated		-0.143	-0.115
>= 2 ha cultivated		-0.263	-0.202
Gender of HH head			
Male		-0.190	-0.152
Female		-0.116	-0.0868
Agricultural year			
1999/2000		-0.160	-0.129
2002/2003		-0.168	-0.129
2006/2007		-0.198	-0.159

Note: All APEs are statistically significant at the 1% level.

The differences in results between the current study and Xu et al. (2009) are likely due to differences in methodology. The main econometric improvement in the current paper is the careful treatment of potential endogeneity using the control function approach (following Ricker-Gilbert et al., 2011). The residuals from the reduced form CRE Tobit models for government-subsidized fertilizer are statistically significant at the 10% level or lower in five of the six commercial fertilizer demand equations estimated here (Tables E.4 and E.5 in Appendix E). This suggests that government-subsidized fertilizer is indeed endogenous. Xu et al. (2009) do not directly address the endogeneity issue. They use the community/SEA-level average quantity of government-subsidized fertilizer received per household rather than the observed household-level quantity received in their household-level commercial fertilizer demand equations. Although the correlation between this community-level average and the error term may be weaker than the correlation between the household-level quantity of subsidized fertilizer received and the error term, using the community-level average does not solve the endogeneity problem.

Although the current paper's overall Zambia crowding out estimate of 0.14 is larger than those in Xu et al. (2009), at 0.22 the estimated Malawi displacement rate is even larger (Ricker-Gilbert et al., 2011). Since this paper follows the econometric methods in Ricker-Gilbert et al. (2011), the gap in displacement rates is not due to methodological differences. The higher displacement rate in Malawi may be due to the fact that a far greater percentage of smallholder households receive subsidized fertilizer in Malawi than in Zambia. Ricker-Gilbert et al. (2011) report that 31% and 57% of Malawian smallholders received government fertilizer in 2002-2004 and 2006/07, respectively. In Zambia, only 13% and 12% of smallholders received subsidized fertilizer in 2002/03 and 2006/07 (Table 5.2). The broader coverage of the Malawi input subsidy program may exacerbate targeting challenges and lead to the higher rate of displacement of commercial fertilizer purchases observed there.

In addition to overall displacement estimates, Table 5.3 reports APEs of *govt* on *allcomm* by farm size and by agricultural year. The crowding out effect of subsidized fertilizer on commercial fertilizer purchases is smaller among households cultivating less than two hectares than among those cultivating larger areas. This finding is consistent with *a priori* expectations. Landholding size and area planted are highly positively correlated with household income and assets thus households planting smaller areas are less likely to have the means to purchase fertilizer at commercial prices.

Results also suggest a slightly higher displacement rate in 2006/07 than in earlier years (Table 5.3). A likely driver of the higher level of crowding out in 2006/07 compared to 2002/03 in particular is the scaling up of FSP and the scaling down of FSPP/PAM. Smallholder households acquired approximately 29% more total government-subsidized fertilizer in 2006/07 than in 2002/03 based on the balanced panel of households. However, the increase was due entirely to an increase in fertilizer acquired through FSP (+53%); the quantity of fertilizer acquired through FSPP/PAM shrank by 75%. Recall that FSPP/PAM targets 'vulnerable but viable' households such as female- and child-headed households and households with disabled members or that are supporting orphans. Displacement rates are expected to be lower among such households and estimation results suggest that they are indeed lower among female-headed households (Table 5.3). Holding fixed the total quantity of government-subsidized fertilizer distributed but reducing the share distributed under FSPP/PAM compared to FSP, we would expect an increase in crowding out as happened between 2002/03 and 2006/07. Targeting is generally worse under FSP than FSPP/PAM, and the scaling up (in absolute terms) of FSP in

2006/07 may have increased the targeting challenges, thereby contributing to the somewhat higher rates of crowding out in 2006/07 compared to 2002/03.

In the two previous studies on the topic (Xu et al., 2009, and Ricker-Gilbert et al., 2011), the change in total fertilizer purchases given a one-unit increase in government-subsidized fertilizer ($\frac{\partial total}{\partial govt}$) was calculated as one minus the displacement rate (e.g., 1 - 0.22 = 0.78 for Malawi). However, as discussed in section 5.2.1 and shown in Eq. (5), if there is leakage of government-subsidized fertilizer into the commercial channel and it is impossible for the researcher to determine if fertilizer that households report as purchasing from commercial sources is 'real' commercial fertilizer or leaked government-subsidized fertilizer, then the change in total fertilizer calculated in this way will be overestimated. An adjustment must be made to account for the leakage.

Table 5.4 reports unadjusted and adjusted estimates of $\frac{\partial total}{\partial govt}$ based on the CRE TNH displacement estimates in Table 5.3 and assuming that $\frac{\partial leaked}{\partial govt} = \frac{leaked}{govt}$. Estimates of $\frac{leaked}{govt}$ in Table 5.4, column B, are the share of FRA-FCP/FSP fertilizer delivered to the district level according to MACO records that was not ultimately acquired by smallholders as government-subsidized fertilizer based on the household panel survey data.[37] A non-trivial share of the fertilizer intended for government subsidy programs leaks out of the government channel: 21%

[37] The national $\frac{leaked}{govt}$ value is based on all three agricultural years covered by the panel survey. The $\frac{leaked}{govt}$ values for high versus low PSA districts are based on 1999/2000 and 2002/03 only because disaggregated data on the quantity of FSP fertilizer delivered to the district level in 2006/07 has not been released by MACO.

in high PSA areas, 53% in low PSA areas, and 33% nationally. Assuming the leaked fertilizer is resold through commercial channels, each additional kg of government-subsidized fertilizer injected into the system increases total fertilizer acquisition by just 0.53 kg (0.55 kg in high PSA areas and 0.41 kg in low PSA areas) (Table 5.4, column D). Failure to account for leakage would have resulted in a 63% overestimate of the change in total fertilizer acquisition given a 1-kg increase in the quantity of government-subsidized fertilizer distributed (a 38% overestimate in high PSA areas and a 130% overestimate in low PSA areas where leakage was much greater).

Table 5.4. Estimated kg change in total smallholder fertilizer acquisition given a 1-kg increase in government-subsidized fertilizer distributed

Area	$\frac{\partial allcomm}{\partial govt}$ [a]	$\frac{leaked}{govt}$ [b]	$\frac{\partial total}{\partial govt}$ Unadjusted	$\frac{\partial total}{\partial govt}$ Adjusted	% difference
	A	B	C=1+A	D=1+A-B	E=(C-D)/D
High PSA	-0.239	0.208	0.761	0.553	37.6%
Low PSA	-0.068	0.527	0.932	0.405	130.1%
National	-0.137	0.334	0.863	0.529	63.1%

Notes: [a]From CRE TNH estimates in **bold** in Table 5.3. [b]Based on 1999/2000 and 2002/2003 for high and low PSA areas; based on 1999/2000, 2002/2003, and 2006/2007 for the national estimate. The national estimate for (B) based on 1999/2000 and 2002/03 only is 0.364.

5.6 Conclusions & policy implications

Targeted fertilizer subsidies are growing in popularity in sub-Saharan Africa. However, if subsidized fertilizer is allocated to households that would have otherwise purchased it at commercial prices, then the impact of the fertilizer subsidy program on total fertilizer use will be negligible. In other words, the change in total fertilizer use will depend on, *inter alia*, the extent to which government fertilizer subsidy programs “crowd out” or “displace” commercial fertilizer purchases. Two studies have estimated the displacement effect of fertilizer subsidies: Xu et al. (2009) for Zambia and Ricker-Gilbert et al. (2011) for Malawi.

In this paper, I revisit this issue and build on the previous studies in several ways. I extend the conceptual framework used by Xu et al. (2009) and Ricker-Gilbert et al. (2011) to incorporate leakage of government-subsidized fertilizer into commercial channels, a problem reflected in empirical evidence from Zambia. I show that if such leakage exists, then an adjustment needs to be made when going from the econometric estimate of crowding out to an estimate of the change in total fertilizer acquisition given an increase in the quantity of government-subsidized fertilizer injected into the system. I then apply the framework to the case of Zambia and use nationally representative panel household survey data covering 1999/2000, 2002/03, and 2006/07 to produce updated estimates of the effects of government fertilizer subsidies on total and commercial fertilizer demand by smallholders. The econometric models estimated deal with endogeneity issues following the approach used by Ricker-Gilbert et al. (2011) and also control for the potentially confounding effects of past Food Reserve Agency activities on smallholder fertilizer demand.

The study highlights six key findings. First, each additional kg of subsidized fertilizer received by a household decreases its fertilizer purchases from commercial retailers by 0.14 kg. This estimate is larger than Xu et al.'s (2009) overall displacement estimates for Zambia (0.07 to 0.08) but smaller than Ricker-Gilbert et al.'s (2011) estimate for Malawi (0.22). A far greater percentage of smallholders receive government-subsidized fertilizer in Malawi (31-57%) than in Zambia (12-13%), which may explain the higher level of crowding out in Malawi.

Second, at 0.24, the displacement rate in areas where the private sector was initially more active in fertilizer retailing ("high PSA areas") is substantially higher than in low PSA areas (0.07). This is consistent with *a priori* expectations and the general insight from Xu et al. (2009) that displacement rates differ in important ways between areas with high versus low fertilizer

PSA. Third, the displacement rate is higher among households that cultivate two or more hectares of land (0.20) than among households cultivating smaller areas (0.12). Displacement rates are also higher among male-headed households (0.15) than among female-headed ones (0.09). Fourth, the displacement rate was somewhat higher in 2006/07 (0.16) than in 2002/03 (0.13), perhaps due to greater targeting challenges in 2006/07 resulting from a more than 50% increase in the scale of the Fertilizer Support Programme (FSP) and a reduction in government-subsidized fertilizer distributed through the typically better-targeted Food Security Pack Programme (FSPP/PAM).

Fifth, comparisons of the quantity of fertilizer delivered to the district level to be distributed as government-subsidized fertilizer with the total quantity of government-subsidized fertilizer actually received by smallholders in Zambia suggest significant leakage. In the years covered in the panel survey data used in this study, 67% of the fertilizer intended for distribution through the Fertilizer Credit Programme or FSP reached smallholders (i.e., 33% leaked out of the government channel and was likely resold through commercial channels). Sixth, coupling this leakage figure with the crowding out estimate of 0.14 suggests that each additional kg of fertilizer intended for government subsidies that is injected into the system increases total fertilizer acquisition by 0.53 kg. Without adjusting for leakage, we would have concluded that total fertilizer acquisition increases by 0.86 kg, an overestimate of approximately 63%.

Based on these findings, the Zambian government may be able to add more to total fertilizer use through its fertilizer subsidy programs by reducing leakage and by targeting households in low PSA areas, those with relatively small landholdings or cultivated area, and female-headed households. The government could also consider channeling more subsidized fertilizer through FSPP/PAM, which has a better targeting track record. The use of a voucher system, where the vouchers are redeemable at commercial retailers, may be a way of crowding in private investment in fertilizer marketing. Under the current Farmer Input Support Programme modalities (the successor program to FSP), there is limited engagement of the private sector.

Although much research has already been done on the issue of crowding out, knowledge gaps remain. This paper, Xu et al. (2009), and Ricker-Gilbert et al. (2011) examine only the contemporaneous displacement effects of government fertilizer subsidy programs. Future work could include testing for and estimating dynamic effects. Ricker-Gilbert (2011) has done this for the effects of Malawi's input subsidy programs on household crop production and incomes but not for crowding out. The Zambia panel survey data somewhat constrain such efforts because it captures receipt of subsidized fertilizer in 1999/2000, 2002/03, 2003/04, 2006/07, and 2007/08 but not in the intervening years. Another area for further study would be to relax the separability assumption and test to see if displacement estimates under non-separability differ significantly from those reported in this paper.

APPENDIX E

Table E.1. Summary statistics for continuous explanatory variables

Explanatory variables	Mean	Std. dev.	Percentile 10th	25th	50th	75th	90th
Kg of government-subsidized fertilizer acquired by HH	29.294	143.258	0	0	0	0	0
Effective market price of fertilizer (ZMK/kg)	1,442	660	720	780	1,476	1,960	2,400
Expected effective maize price (ZMK/kg)	451	180	221	283	464	589	694
Groundnut price (ZMK/kg, t-1, provincial median)	1,139	355	769	900	1,053	1,400	1,667
Mixed bean price (ZMK/kg, t-1, provincial median)	1,112	302	889	889	992	1,333	1,572
Sweet potato price (ZMK/kg, t-1, provincial median)	214	102	100	145	193	232	386
Cattle price (ZMK/head, provincial median)	519,656	301,918	160,000	230,000	589,388	789,138	953,272
Landholding size (ha, cultivated+fallow land)	2.1	2.6	0.5	0.8	1.5	2.5	4.0
Value of plows and harrows ('00,000 ZMK)	0.649	2.753	0	0	0	0	2.000
Full-time equivalent # of prime-age (15-59) adults	2.8	1.7	1.0	2.0	2.2	3.9	5.0
Age of household head	48.3	15.3	30.0	36.0	46.0	60.0	70.0
Kilometers from center of SEA to nearest (as of 2000):							
District town	34.5	22.6	9.8	16.0	28.9	47.0	70.2
Tarred/main road	25.5	35.7	0.9	4.0	12.0	29.2	69.8
Feeder road	3.3	3.3	0.6	1.1	2.4	4.3	7.7
Expected growing season rainfall (mm, 9-year MA)	896	184	660	757	877	1,059	1,167
Expected moisture stress (9-year MA)	1.8	1.0	0.6	0.9	1.9	2.4	3.1
Percentage point spread between MMD & lead opposition party in the last presidential election	41.8	23.6	11.6	21.2	41.1	61.4	74.4

Note: N=16,566.
Source: CSO/MACO/FSRP 2001, 2004, & 2008 Supplemental Surveys.

Table E.2. Summary statistics for binary explanatory variables

	Share of households (%)		
Explanatory variables	1999/2000	2002/2003	2006/2007
HH owns a water pump	0.7	0.7	0.8
Highest level of education completed by HH head:			
Lower primary (grades 1-4)	23.0	25.6	27.0
Upper primary (grades 5-7)	36.2	34.0	34.5
Secondary (grades 8-12)	19.3	18.3	19.4
Post-secondary education	2.5	2.7	1.8
Gender & residence of HH head (non-resident if <6 months):			
Female-headed with non-resident husband	0.6	0.9	0.4
Female-headed with no husband	20.8	21.8	23.6
Disease-related prime-age death in last 3-4 years:			
Male head/spouse	1.2	1.8	0.1
Female head/spouse	1.0	2.1	1.3
Male non-head/spouse	3.3	2.9	4.4
Female non-head/spouse	5.0	3.6	3.7
SEA suitable for low input management maize production	55.3	56.0	56.4
MMD won constituency in the last presidential election	92.8	44.0	59.1
Total number of households in sample	6,922	5,358	4,286

Source: CSO/MACO/FSRP 2001, 2004, & 2008 Supplemental Surveys.

Table E.3. Reduced form CRE Tobit estimates of factors affecting the kilograms of government-subsidized fertilizer acquired by the household

Explanatory variables	High PSA areas			Low PSA areas		
	APE	Sig.	p-val.	APE	Sig.	p-val.
IV: MMD won constituency in last presidential election (=1)	37.751	***	0.000	9.751	***	0.000
IV: Percentage point spread between MMD & lead opposition party	-0.242	**	0.031	-0.109	**	0.045
IV: Interaction effect (MMD won constituency $\times$ % point spread)	0.582	*	0.095	0.415	***	0.000
Expected effective maize price (ZMK/kg)	0.131		0.143	6.51E-03		0.791
Groundnut price (ZMK/kg, t-1)	0.0201		0.354	0.0112		0.204
Mixed bean price (ZMK/kg, t-1)	-0.161	***	0.000	-8.99E-04		0.939
Sweet potato price (ZMK/kg, t-1)	-0.187	***	0.000	-0.0129		0.449
Effective market fertilizer price (ZMK/kg)	0.0167		0.217	0.0142	***	0.001
Cattle price (ZMK/head)	1.28E-04	***	0.001	1.40E-06		0.940
Landholding size (cultivated+fallow, ha)	1.983	*	0.085	2.402	***	0.000
Plows & harrows ('00,000 ZMK)	0.291		0.722	-0.171		0.734
HH owns a water pump (=1)	-4.720		0.807	23.998		0.358
Full-time equivalent prime-age (15-59) adults	2.107		0.235	0.243		0.756
Age of HH head	-0.380		0.382	0.479	***	0.009
Highest level of education completed by HH head (base is no formal education):						
Lower primary (grades 1-4) (=1)	1.773		0.843	1.825		0.640
Upper primary (grades 5-7) (=1)	7.536		0.436	4.409		0.312
Secondary (grades 8-12) (=1)	1.061		0.927	15.935	**	0.017
Post-secondary education (=1)	-21.287		0.114	3.057		0.763
Gender & residence status of HH head (non-resident if <6 months; base is resident male):						
Female-headed with non-resident husband (=1)	-3.097		0.893	21.796		0.320
Female-headed with no husband (=1)	-7.995		0.356	0.356		0.944
Disease-related prime-age death in last 3-4 years:						
Male head/spouse death (=1)	20.229		0.442	-1.090		0.895
Female head/spouse death (=1)	16.789		0.379	13.373		0.320
Male non-head/spouse death (=1)	17.111		0.198	-2.186		0.607
Female non-head/spouse death (=1)	15.755		0.241	-3.510		0.361

Table E.3 (cont'd)

Explanatory variables	High PSA areas APE	Sig.	p-val.	Low PSA areas APE	Sig.	p-val.
Km from center of SEA to nearest (as of 2000):						
District town	-0.412	***	0.002	-0.0577		0.150
Tarred/main road	-0.328	***	0.000	-0.0543		0.138
Feeder road	-2.550	**	0.029	-1.005	***	0.000
Expected growing season rainfall ('00 mm, 9-year MA)	6.268		0.342	-6.931	*	0.083
Expected moisture stress (9-year MA)	26.659		0.106	-7.206		0.141
SEA suitable for low input mgmt. maize production (=1)	2.398		0.594	2.834		0.158
Agricultural year (base is 2006/2007):						
1999/2000 (=1)	-13.199		0.786	2.530		0.900
2002/2003 (=1)	-46.293	*	0.072	20.485	*	0.074
Province (base is Central Province):						
Copperbelt Province (=1)	174.921		0.141	-13.605	**	0.020
Eastern Province (=1)	-228.780		0.412	-28.254	**	0.022
Luapula Province (=1)				-18.067	***	0.004
Lusaka Province (=1)	-52.115	**	0.010	-16.062	***	0.000
Northern Province (=1)	-35.999		0.423	-22.827	**	0.046
Northwestern Province (=1)				-24.313	***	0.003
Southern Province (=1)	-18.044		0.638	-18.680	**	0.012
Western Province (=1)				-35.854	**	0.012
Overall model F-statistic	4.71	***	0.000	5.00	***	0.000
Pseudo R-squared	0.0397			0.0648		
Observations	5,919			9,036		

Notes: ***, **, * significant at the 1%, 5%, and 10% levels. Time averages of all time-varying explanatory variables also included in the regression. p-values based on Huber-White robust standard errors clustered at the household-level. MMD wins constituency and percentage point spread APEs include effects of interaction term.

Table E.4. Factors affecting the quantity (kg) of commercial fertilizer purchased by the household – high PSA areas

	-----Fixed Effects-----			-------CRE Tobit-------			-------CRE TNH-------		
Explanatory variables	APE	Sig.	p-val.	APE	Sig.	p-val.	APE	Sig.	p-val.
Kg of government-subsidized fertilizer acquired by HH	-0.354	***	0.000	-0.319	***	0.000	-0.239	***	0.000
Tobit residuals from gov't fertilizer reduced form	*Excluded (p=0.776)*			-0.0643	*	0.068	0.0376		0.451[a]
Effective market fertilizer price (ZMK/kg)	-0.0115		0.705	0.0111		0.569	0.0161		0.381
Expected effective maize price (ZMK/kg)	0.768	***	0.002	0.345	**	0.011	0.379	***	0.006
Groundnut price (ZMK/kg, t-1)	-0.0559	*	0.087	-0.0570	**	0.030	-0.037		0.236
Mixed bean price (ZMK/kg, t-1)	-0.0236		0.797	0.159	***	0.005	0.115	*	0.069
Sweet potato price (ZMK/kg, t-1)	-0.284	***	0.004	-0.0586		0.402	-0.114		0.156
Cattle price (ZMK/head)	1.05E-4		0.116	-7.18E-5		0.193	-3.48E-5		0.597
Landholding size (cultivated+fallow, ha)	18.809	***	0.000	8.617	***	0.000	4.173	***	0.000
Landholding size, squared	-0.245		0.101						
Plows & harrows ('00,000 ZMK)	7.832	***	0.002	4.464	***	0.008	2.783	***	0.002
Plows & harrows, squared	-0.0553		0.296						
HH owns a water pump (=1)	-6.673		0.864	-1.449		0.948	19.605		0.536
Full-time equivalent prime-age (15-59) adults	0.205		0.977	3.231		0.115	8.094	***	0.001
Full-time equivalent prime-age adults, squared	0.862		0.389						
Age of HH head	-0.0268		0.964	0.128		0.816	0.0594		0.939
Highest level of education completed by HH head (base is no formal education):									
Lower primary (grades 1-4) (=1)	-23.191	**	0.019	-10.488		0.272	-21.675	***	0.005
Upper primary (grades 5-7) (=1)	-34.542	***	0.006	-20.874	**	0.039	-26.843	**	0.025
Secondary (grades 8-12) (=1)	-35.005	**	0.048	-24.208	*	0.057	-26.332	**	0.046
Post-secondary education (=1)	-11.403		0.799	-1.703		0.955	-19.207		0.335
Gender & residence status of HH head (non-resident if <6 months; base is resident male):									
Female-headed with non-resident husband (=1)	55.494		0.274	37.878		0.405	-6.097		0.671[b]
Female-headed with no husband (=1)	6.245		0.661	-8.823		0.477			
Disease-related prime-age death in last 3-4 years:									
Male head/spouse (=1)	4.574		0.914	9.235		0.783	21.078		0.584
Female head/spouse (=1)	14.009		0.310	-5.226		0.727	28.462		0.305
Male non-head/spouse (=1)	-28.257	**	0.026	-21.298	*	0.054	-15.492		0.152
Female non-head/spouse (=1)	25.433	*	0.069	-0.269		0.981	32.497		0.141

Table E.4 (cont'd)

Explanatory variables	-----Fixed Effects----- APE	Sig.	p-val.	-------CRE Tobit------- APE	Sig.	p-val.	-------CRE TNH------- APE	Sig.	p-val.
Km from center of SEA to nearest (as of 2000):									
District town				-1.086	***	0.002	-0.913	***	0.010
Tarred/main road				0.225		0.209	0.120		0.572
Feeder road				1.944		0.573	0.541		0.874
Expected growing season rainfall ('00 mm, 9-year MA)	196.932	*	0.085	-12.483		0.215	-10.930		0.306
Expected growing season rainfall, squared	-10.265	*	0.079						
Expected moisture stress (9-year MA)	17.987		0.521	-40.942		0.168	18.873		0.639
SEA suitable for low input mgmt. maize product. (=1)				6.267		0.512	21.155	***	0.008
Agricultural year (base is 2006/2007):									
1999/2000 (=1)	214.441	**	0.046	206.442	**	0.039	207.282		0.571
2002/2003 (=1)	7.354		0.877	77.029	**	0.042	44.169		0.294
Province (base is Central Province):									
Copperbelt Province (=1)				-116.148	***	0.001	-117.592		0.315
Eastern Province (=1)				233.187		0.331	2048.355		0.675
Luapula Province (=1)					*Empty*			*Empty*	
Lusaka Province (=1)				201.240		0.328	313.156		0.903
Northern Province (=1)				-79.946		0.238	-59.899		0.917
Northwestern Province (=1)					*Empty*			*Empty*	
Southern Province (=1)				106.705		0.268	587.812		0.537
Western Province (=1)					*Empty*			*Empty*	
Constant	-1182.24	**	0.040						
Time averages (CRE)	N/A			Yes			Yes		
Pseudo R-squared (Within R-squared for Fixed Effects)	0.145			0.0487					
Overall model F-statistic (Chi-squared for CRE TNH)	5.76	***	0.000	9.42	***	0.000	680.18	***	0.000

Notes: [a]Tobit residuals statistically significant at the 5% level in both the probit and truncated normal parts of the CRE TNH model. [b]Female-headed household (with or without resident husband). ***, **, * significant at the 1%, 5%, and 10% levels. p-values based on bootstrap standard errors (500 replications for FE and CRE Tobit, 275 replications for CRE TNH). CRE Tobit APEs include effects of associated squared terms. No squared terms included in CRE TNH model. N=5,919 (4,068 at corner).

Table E.5. Factors affecting the quantity (kg) of commercial fertilizer purchased by the household – low fertilizer PSA areas

	-----Fixed Effects-----			-------CRE Tobit-------			-------CRE TNH-------		
Explanatory variables	APE	Sig.	p-val.	APE	Sig.	p-val.	APE	Sig.	p-val.
Kg of government-subsidized fertilizer acquired by HH	-0.199	***	0.000	-0.0747	***	0.000	-0.0680	***	0.000
Tobit residuals from gov't fertilizer reduced form	-0.0800	***	0.007	-0.0354	***	0.009	*Stat. sig. in probit only*		
Effective market fertilizer price (ZMK/kg)	4.03E-4		0.964	9.89E-5		0.987	-2.61E-3		0.634
Expected effective maize price (ZMK/kg)	0.0626		0.114	0.0204		0.346	0.0496	*	0.055
Groundnut price (ZMK/kg, t-1)	0.002794		0.872	-0.00424		0.619	-8.77E-3		0.330
Mixed bean price (ZMK/kg, t-1)	0.0219		0.469	0.0100		0.347	0.0146		0.152
Sweet potato price (ZMK/kg, t-1)	0.0227		0.417	0.00847		0.558	0.0123		0.505
Cattle price (ZMK/head)	5.33E-5		0.189	4.19E-6		0.813	-1.42E-5		0.415
Landholding size (cultivated+fallow, ha)	0.969		0.723	1.445	*	0.059	0.898	**	0.037
Landholding size, squared	0.224		0.410						
Plows & harrows ('00,000 ZMK)	3.623		0.101	0.327		0.428	0.0898		0.813
Plows & harrows, squared	-0.04837		0.564						
HH owns a water pump (=1)	-33.106		0.390	-6.283		0.580	-4.417		0.616
Full-time equivalent prime-age (15-59) adults	2.431	*	0.060	1.913	**	0.015	2.066	**	0.012
Full-time equivalent prime-age adults, squared									
Age of HH head	-0.565		0.103	-0.297		0.128	-0.312		0.197
Highest level of education completed by HH head (base is no formal education):									
Lower primary (grades 1-4) (=1)	-5.916		0.188	-0.880		0.827	-4.376		0.235
Upper primary (grades 5-7) (=1)	-5.344		0.309	2.514		0.545	-0.345		0.939
Secondary (grades 8-12) (=1)	-12.349		0.147	-1.629		0.760	-3.851		0.418
Post-secondary education (=1)	18.843		0.325	16.042		0.351	10.354		0.393
Gender & residence status of HH head (non-resident if <6 months; base is resident male):									
Female-headed with non-resident husband (=1)	-25.571		0.275	-2.270		0.826	-5.277		0.267[a]
Female-headed with no husband (=1)	-0.730		0.920	-1.078		0.808			
Disease-related prime-age death in last 3-4 years:									
Male head/spouse (=1)	-2.001		0.843	-6.874		0.217	-3.472		0.643
Female head/spouse (=1)	-26.396	*	0.059	-7.691		0.141	-8.875	*	0.083
Male non-head/spouse (=1)	-1.222		0.884	1.509		0.794	4.046		0.517
Female non-head/spouse (=1)	1.642		0.773	-2.823		0.431	-3.403		0.335

Table E.5 (cont'd)

Explanatory variables	-----Fixed Effects----- APE	Sig.	p-val.	-------CRE Tobit------- APE	Sig.	p-val.	-------CRE TNH------- APE	Sig.	p-val.
Km from center of SEA to nearest (as of 2000):									
District town				-0.0533		0.264	-0.0615		0.257
Tarred/main road				-0.110	**	0.014	-0.0603		0.263
Feeder road				-0.475		0.181	-0.154		0.654
Expected growing season rainfall ('00 mm, 9-year MA)	47.430		0.311	4.759		0.180	6.988	**	0.043
Expected growing season rainfall, squared	-1.807		0.459						
Expected moisture stress (9-year MA)	7.668		0.369	4.259		0.431	7.399		0.173
SEA suitable for low input mgmt. maize production (=1)				1.188		0.584	0.923		0.707
Agricultural year (base is 2006/2007):									
1999/2000 (=1)	98.905	**	0.012	27.886		0.562	10.207		0.687
2002/2003 (=1)	31.075		0.114	6.464		0.600	0.866		0.923
Province (base is Central Province):									
Copperbelt Province (=1)				-9.979		0.977	-13.649		0.379
Eastern Province (=1)				-13.446		0.208	-5.505		0.782
Luapula Province (=1)				-25.309	***	0.001	-29.880	**	0.028
Lusaka Province (=1)				1.525		0.905	3.025		0.870
Northern Province (=1)				-21.661	*	0.067	-38.760		0.101
Northwestern Province (=1)				-21.583	***	0.005	-29.719	**	0.028
Southern Province (=1)				-13.033		0.119	-7.701		0.259
Western Province (=1)				-21.102	**	0.025	-21.338	*	0.072
Constant	-323.3218		0.114						
Time averages (CRE)	N/A			Yes			Yes		
Pseudo R-squared (Within R-squared for Fixed Effects)	0.0775			0.0771					
Overall model F-statistic	3.51	***	0.000	6.77	***	0.000	759.66	***	0.000

Notes: [a]Female-headed household (with or without resident husband). ***, **, * significant at the 1%, 5%, and 10% levels. p-values based on bootstrap standard errors (500 replications for FE and CRE Tobit, 275 replications for CRE TNH). CRE Tobit APEs include effects of squared terms. No squared terms included in CRE TNH model. N=9,036 (8,278 at corner)

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CHAPTER 6: CONCLUSION

Grain marketing boards (GMBs), strategic grain reserves (SGRs), and fertilizer subsidies have experienced a renaissance in eastern and southern Africa (ESA) over the last decade. Relatively little is known about how the re-emergence of GMBs/SGRs as major players in grain markets in the region is affecting smallholder behavior and grain market outcomes. The revival of fertilizer subsidies has received considerably more attention from researchers and policymakers but knowledge gaps remain. Beyond the disciplinary contributions highlighted in Chapter 1, a main goal of this dissertation is to provide empirical evidence on the effects of GMBs/SGRs and targeted fertilizer subsidies that can inform policy debates in ESA and elsewhere. The empirical work focuses on the case of Zambia. Maize is the dominant crop there and the Government of the Republic of Zambia (GRZ) has become increasingly involved in maize marketing in recent years through the Food Reserve Agency (FRA), an SGR/GMB. Every year since 2003/04, the FRA has announced a pan-territorial price for maize and purchased the crop from smallholders at satellite depots throughout the country. The FRA pan-territorial price tends to be higher than wholesale market prices in major maize-producing areas in Zambia. The scale of GRZ targeted fertilizer subsidy programs has also increased since the late 1990s.

The dissertation highlights six key findings on the impacts of the FRA on smallholder behavior and maize market prices. First, analysis in Chapter 2 based on a nationally-representative household-level panel survey data set covering the 1999/2000, 2002/03, and 2006/07 agricultural years suggests that an increase in the quantity of maize purchased by the FRA in a household's district in previous years has a positive and statistically significant marginal effect on the household's expected maize price at the next harvest. The estimated elasticity of the expected maize price with respect to past FRA purchases in the household's district is 0.10 for the 2006/07 agricultural year. Second, for smallholders cultivating two hectares of land or more, an increase in the effective (i.e., farmgate) FRA maize price faced by the household at the previous harvest has a positive and statistically significant marginal effect on the expected maize price. The estimated elasticity of the expected maize price with respect to the lagged effective FRA price is 0.19 for the 2006/07 agricultural year.

Third, other factors constant, an increase in a household's expected maize price has a statistically significant positive marginal effect on maize area planted (elasticity 0.64) but a statistically significant negative marginal effect on maize yield (elasticity -0.87), the net effect being no significant change in maize quantity harvested. The marginal effect on total crop output is also not statistically different from zero. The maize yield decline does not appear to be driven by reduced fertilizer application, as an increase in the expected maize price does not have a statistically significant effect on the intensity of fertilizer use on maize. The additional land brought under maize in response to a higher expected maize price may be of poorer quality and/or in areas less agro-ecologically suited for maize production. Even with the same intensity of fertilizer use, one would expect lower maize yields on such land. The negative marginal effect on maize yield may also be due to constraints on other inputs such as cash or credit to buy improved seed for the additional maize area, or family time or money to hire in labor to weed and otherwise manage the additional maize acreage.

Fourth, together the aforementioned findings suggest that increases in past FRA purchases in a household's district and in the effective FRA maize price faced by the household at the previous harvest do not have a statistically significant marginal effect on household-level maize quantity harvested or total crop output. Thus at the household level, past FRA activities do not appear to have stimulated a significant smallholder supply response.

Fifth, simulation results in Chapter 3 based on a vector autoregression model using monthly data from July 1996 through December 2008 suggest that the FRA's maize buying and selling price policies and net maize purchases between July 2003 and December 2008 raised mean wholesale maize prices in Lusaka and Choma by 17% and 19%, respectively. These findings are consistent with the conventional wisdom in Zambia that the FRA's involvement in the maize market has led to an increase in maize prices (Govereh et al., 2008). Sixth, FRA activities reduced the variability of maize market prices during the sample period. Between July 2003 and December 2008, the standard deviation of maize market prices was 22-25% lower and the coefficient of variation was 34-36% lower than it would have been had the FRA not been involved in maize marketing in Zambia. These results are similar in direction and magnitude to the estimated effects of the National Cereals and Produce Board on maize market prices in Kenya between July 1995 and October 2004 (Jayne et al., 2008).

The FRA's strategic goal is "to significantly contribute to the stabilization of national food security and market prices of designated crops through the establishment and sustenance of a sizable and diverse national strategic food reserve in Zambia by 2010" (FRA, n.d.) Among potential 'designated crops', the FRA has focused almost exclusively on maize. What do the results in this dissertation suggest about the extent to which the FRA has achieved its strategic goal? The Agency's activities appear to have improved the stability of equilibrium maize market prices. I do not measure the effects of the FRA's activities on national food security *per se*. However, I find that increases in past FRA effective maize prices and maize purchases have no statistically significant marginal effect on household-level maize quantity harvested or total crop output, outcomes that are likely to be positively correlated with food security for many small farm households. Maize accounts for approximately 60% of national calorie consumption in Zambia (Dorosh et al, 2009). *Ceteris paribus*, the mean market price-raising effects of the FRA's activities adversely affect the maize purchasing power of net maize buying households, which include urban consumers and more than 1/3 of smallholder farm households (Nkonde et al., 2011). The findings in this study are therefore not suggestive of major improvements in food security as a result of the FRA's involvement in the domestic maize market. That said, the household-level analysis in Chapter 2 measures only the *marginal* effects of *changes* in past FRA effective maize prices and maize purchases on smallholder behavior, and not the *equilibrium* effects of FRA policies. For example, FRA activities may affect smallholder maize and other crop production levels through effects on equilibrium maize market prices.

Five key findings related to the targeting of GRZ-subsidized fertilizer and to the household-level effects of these fertilizer subsidy programs also emerge from the analysis. First, as shown in Chapter 4, past constituency-level election outcomes appear to have considerable bearing on the allocation of GRZ-subsidized fertilizer across smallholder households. (There are 150 total constituencies in Zambia's 72 districts.) Estimation results suggest that, other factors constant, households in constituencies won by the ruling party (the Movement for Multi-Party Democracy, MMD) in the last presidential election receive 25.6 kg more government-subsidized fertilizer than households in constituencies lost by the MMD. Second, households in constituencies won by the MMD receive 0.7 kg more subsidized fertilizer for each percentage point increase in the MMD's margin of victory. These general results hold whether presidential or parliamentary election results are used and whether only Fertilizer Support Programme (FSP) fertilizer is used or fertilizer received through any of the three major GRZ fertilizer subsidy programs in place between 1999/2000 and 2006/07 is used. The MMD appears to use subsidized fertilizer to reward its supporters, and the reward is greater the stronger the support.

These findings are consistent with the "core supporter" theory of Cox and McCubbins (1986), where the ruling party targets subsidized fertilizer or other transfers to areas where it has strong support from voters. In contrast, Banful (2011) finds that in Ghana in 2008 fertilizer subsidy vouchers were allocated across districts in a manner consistent with the "swing voter" theory (Lindbeck and Weibull, 1993; Dixit and Londregan, 1996 and 1998). This theory predicts that politicians will target transfers to areas with large numbers of undecided voters or where the margin of victory is likely to be small.

As Zambian taxpayer and donor resources are used to fund GRZ fertilizer subsidy programs, it is important that political considerations not drive subsidy allocation across constituencies and households. Politicization of fertilizer subsidy targeting is also likely to be deleterious from an efficiency standpoint (Banful, 2011). More transparency in and better monitoring of subsidized fertilizer targeting is clearly needed. Under the Farmer Input Support Programme (FISP), which replaced FSP in 2009/10, GRZ has already made some changes to the way fertilizer subsidy beneficiaries are selected. The panel data used in Chapter 4 only cover through 2006/07 but a fourth wave of panel data covering the 2010/11 agricultural season is to be collected in June/July 2012. These data should help evaluate the extent to which reforms under FISP have diminished the role of past election outcomes in the targeting of GRZ-subsidized fertilizer.

The third set of findings related to fertilizer subsidies in Zambia is that an increase in the quantity of GRZ-subsidized fertilizer received by a smallholder household has a positive and statistically significant marginal effect on its intensity of fertilizer use on maize and its total (17 crops), maize, and non-maize area planted, crop output per hectare, and crop output (Chapter 2). Other factors constant, a household's maize quantity harvested increases by 2.2-2.6 kg for each additional kg of government-subsidized fertilizer that it receives. The positive effects on total, maize, and non-maize area planted suggests that, at the margin, GRZ fertilizer subsidies are not incentivizing smallholders to plant more maize at the expense of other crops. Additional analysis is needed to determine if the benefits from GRZ fertilizer subsidies exceed program costs and if such programs are the most cost-effective way of increasing smallholder incomes and food security.

Fourth, each additional kg of GRZ-subsidized fertilizer received by a household decreases its fertilizer purchases from commercial retailers by 0.14 kg (Chapter 5). The estimated "displacement" or "crowding out" rate at the household level is 0.24 in areas where the private sector was initially relatively active in fertilizer retailing (high PSA areas) and 0.07 in low PSA areas. The displacement rate is also higher among households that cultivate two or more hectares of land (0.20) than among households cultivating smaller areas (0.12), and higher among male-headed households (0.15) than among female-headed households (0.09). Ricker-Gilbert et al. (2011) estimate the displacement rate among Malawian smallholders at 0.22 kg. The finding that the displacement rate in Zambia is greater in high PSA areas than in low PSA areas is consistent with *a priori* expectations and with the general insight from Xu et al. (2009) that displacement rates differ substantially between high and low PSA areas.

Finally, Central Statistical Office/Ministry of Agriculture and Cooperatives/Food Security Research Project household survey data-based estimates suggest that approximately 67% of fertilizer delivered to the district level for GRZ subsidy programs in 1999/2000, 2002/03, and 2006/07 reached smallholders through the government distribution channel. This is consistent with anecdotal evidence of diversion and resale of FSP fertilizer. Assuming that the remaining 33% leaked out of the government channel and was resold through commercial channels and using the overall household-level displacement estimate of 0.14, total fertilizer acquisition is estimated to increase by 0.53 kg for each additional kg of subsidized fertilizer injected into the system. This estimate would have been 0.86 kg had no adjustment been made for leakage, highlighting the potentially large difference that such an adjustment can make.

These findings suggest that GRZ may be able to add more to total fertilizer use through its fertilizer subsidy programs by reducing leakage and by reducing displacement of household-level fertilizer purchases from commercial retailers. Targeting households in low PSA areas, households with smaller landholdings, and/or female-headed households may be one way to achieve the latter.

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APPENDIX F

APPENDIX F: BACKGROUND ON THE FOOD RESERVE AGENCY AND GOVERNMENT FERTILIZER PROGRAMS IN ZAMBIA

F1. Overview of the Food Reserve Agency, 1996-2010

The Food Reserve Agency, a parastatal, was established in 1996 with the enactment of the Food Reserve Act of 1995. At that time, private maize trade remained legal in Zambia and maize prices were not regulated. No maize marketing board existed, as the National Agricultural Marketing Board (NAMBOARD) had been abolished in 1989 as part of food market and pricing reforms in Zambia (Jayne and Jones, 1997).

The FRA's original primary functions were to establish and administer a national food reserve, the purposes of which were: (i) to "ensure a reliable supply of designated commodities for the country"; (ii) to "meet local shortfalls in the supply of a designated commodity"; (iii) to "meet such other food emergencies caused by drought or flood, or by such other natural disaster…as may be declared by the President"; and (iv) to "correct problems relating to the supply of designated commodities which result from the manipulation of prices or monopolistic trading practices" (GRZ, 1995). Secondary functions of the FRA were to manage storage facilities, to establish and operate a market information system, to promote the use of weighing and grading standards, and to assess storage requirements for marketing (FRA, n.d.). According to the Food Reserve Act of 1995, the FRA did not have an explicit crop marketing mandate; it was to be involved in crop marketing only as necessary to administer the national food reserve. Direct participation in crop marketing and market facilitation were added to the FRA's official functions when the Food Reserve Act was amended in 2005 (GRZ, 2005).[38] The FRA's stated

[38] The events that precipitated the 2005 Amendment of the Food Reserve Act are discussed further below.

objective (referred to as its “strategic goal” on the Agency’s website) is “to significantly contribute to the stabilization of national food security and market prices of designated crops through the establishment and sustenance of a sizable and diverse national strategic food reserve in Zambia by 2010” (FRA, n.d.). The Agency’s “strategic mission” is “to be an organization that efficiently manages sustainable National Strategic Food Reserves, ensuring National Food Security and Income through the provision of complementary and high quality marketing and storage services, in line with international standards” (ibid).

Although the Food Reserve Act does not constrain the national food reserve to be comprised of maize only, maize is the most important crop in Zambia and the FRA’s emphasis has been almost exclusively on maize.[39] In the next three subsections, I focus on the FRA’s activities in the maize market, discussing first the FRA’s maize purchases on the domestic market, then FRA maize sales in Zambia, followed by FRA maize imports and exports. The fourth and final subsection presents information on government spending on the FRA.

F1.1 FRA maize purchases on the domestic market

Table F.1 summarizes the tonnage of maize purchased on the domestic market by the FRA each year from 1996/97 through 2010/11 as well as the number of districts from which maize was purchased, the price at which it was purchased, and the estimated tonnage of maize produced and sold by smallholders in each year. FRA’s purchases on the domestic market can be divided into roughly three periods: 1996/97-1997/98, when it bought small quantities of maize from smallholders via private traders; 1998/99-2001/02, when it purchased nothing on the

[39] For example, in the 2005/06 marketing year, of the K91.3 billion allocated to the FRA for crop purchases, K86.4 billion or 95% was to be used to purchase 120,000 MT of maize. The remaining 5% was for the purchase of rice (1,600 MT), cassava (2,000 MT), groundnuts (500 MT), soybeans (400 MT), and sugar beans (200 MT) (FRA, 2005).

domestic market; and 2002/03 to present, when it has purchased maize directly from smallholder farmers.

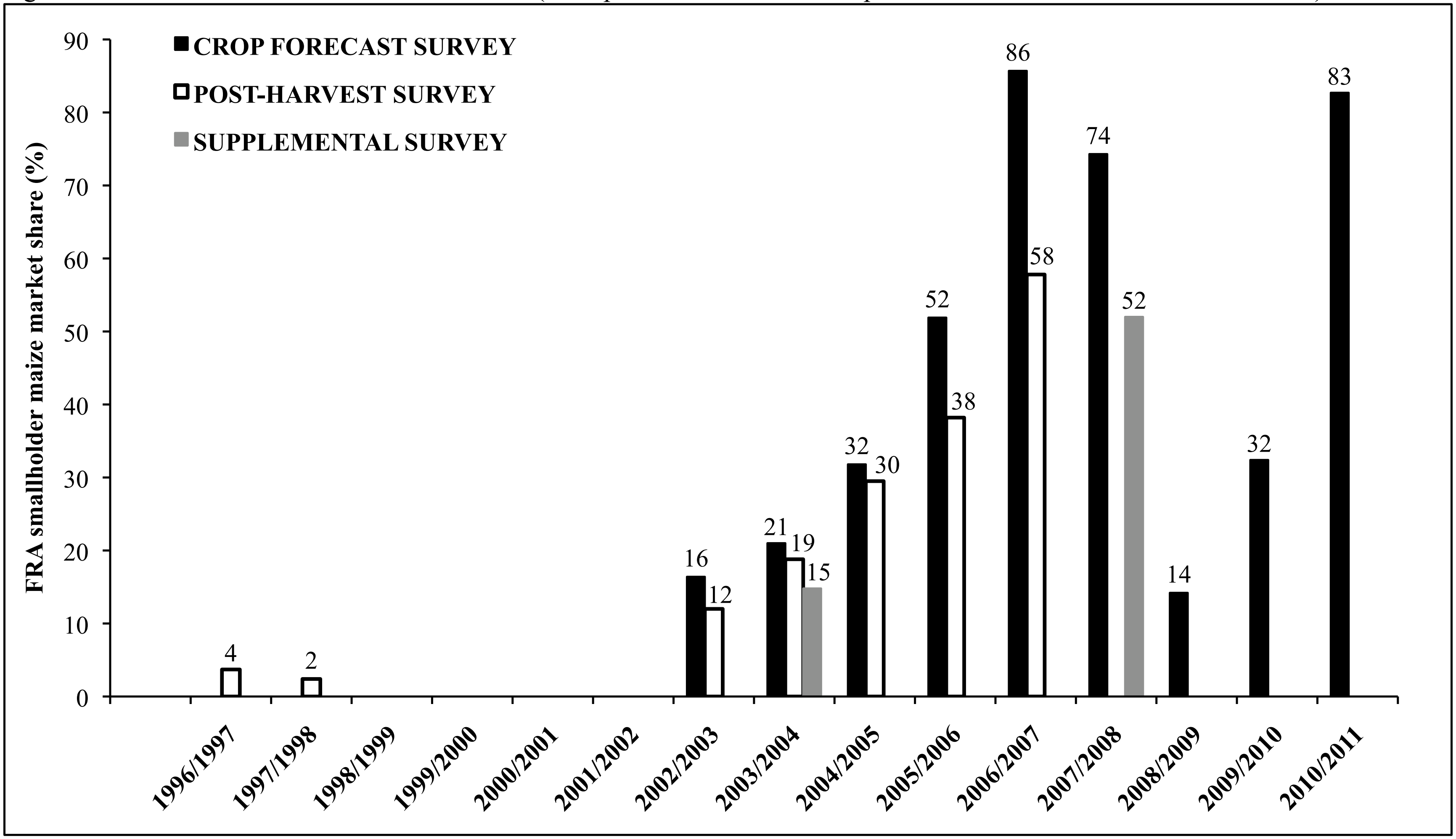
In the first two marketing years in which it bought maize (1996/97 and 1997/98), the FRA contracted small-scale traders to buy maize from smallholders on its behalf in four to five districts that the Agency had identified as 'surplus but uneconomic', i.e., areas with surplus production but where few private traders currently operated (Kabaghe, 2010). FRA's goal in procuring maize in this way was to help foster the development of private sector maize trading in the liberalizing environment. FRA buy prices in 1996/97 and 1997/98 were uniform within a given district but differentiated across districts to better reflect market price levels. The FRA established one main holding depot in each targeted district; no satellite depots were set up because the FRA was not buying directly from smallholders. The FRA owned the main depots but management of the depots was contracted out, again in an effort to stimulate private sector activity. The quantities of maize purchased by the FRA in these first two years were small relative to the total amount of maize produced and sold by smallholders, and the maize it purchased was for strategic reserve purposes only. The FRA purchased no maize on the domestic market during the 1998/99-2001/02 marketing years due to lack of funding.

Table F.1. FRA maize prices and purchases, and estimated smallholder maize production and sales, 1996/97-2010/11 marketing years

Marketing year	FRA pan-territorial price (ZMK/50 kg)	# of districts in which FRA purchased maize[d]	FRA domestic maize purchases (MT)	Estimated smallholder maize:[e]		FRA purchases as % of smallholder maize sales	Production & sales data source
				Production (MT)	Sales (MT)		
1996/1997	11,800[a]	5	10,500	1,117,955	280,955	3.7	PHS
1997/1998	7,880[a]	4	4,989	804,626	206,557	2.4	PHS
1998/1999	N/A	0	0	724,024	175,515	0	PHS
1999/2000	N/A	0	0	929,304	242,753	0	PHS
2000/2001	N/A	0	0	1,253,722	303,738	0	PHS
				1,282,352	323,387	0	SS
2001/2002	N/A	0	0	957,437	209,326	0	CFS
				938,539	197,915	0	PHS
2002/2003	40,000[b]	10	23,535	673,673	143,453	16.4	CFS
				947,825	195,407	12.0	PHS
2003/2004	30,000	36	54,847	970,317	260,885	21.0	CFS
				1,126,316	291,462	18.8	PHS
				1,365,538	370,332	14.8	SS
2004/2005	36,000	46	105,279	1,364,841	331,006	31.8	CFS
				1,216,943	356,750	29.5	PHS
2005/2006	36,000	50	78,667	652,414	151,514	51.9	CFS
				800,574	206,092	38.2	PHS
2006/2007	38,000	53	389,510	1,339,479	454,676	85.7	CFS
				1,388,311	674,020	57.8	PHS
2007/2008	38,000	58	396,450	1,419,545	533,632	74.3	CFS
				1,960,692	762,093	52.0	SS
2008/2009	45,000[c]	58	73,876	1,392,180	522,033	14.2	CFS
2009/2010	65,000	59	198,630	1,657,117	613,356	32.4	CFS
2010/2011	65,000	62	878,570	2,463,523	1,062,010	82.7	CFS

Notes: [a]Not a pan-territorial price but the average price paid by FRA to private traders, who procured from smallholders. [b]Not a pan-territorial price but the price paid by FRA directly to smallholder farmers in the districts where it was purchasing; initial FRA price of K30,000 was raised to K40,000 in August 2002. [c]FRA price increased to 55,000 in September 2008. [d]There are 72 districts in Zambia. [e]Smallholder maize production and sales based on CFS data are expected, not realized, levels.
Sources: FRA; CSO/MACO Crop Forecast Surveys (CFS); CSO/MACO Post-Harvest Surveys (PHS); CSO/MACO/FSRP Supplemental Surveys (SS).

Figure F.1. FRA smallholder maize market share (FRA purchases as share of expected and actual smallholder maize sales)



Note: Crop Forecast Survey estimates of smallholder maize sales are based on farmers' expected sales prior to harvest. Post-Harvest and Supplemental Survey estimates are based on recall data of smallholders' actual maize sales during the previous marketing year.
Sources: FRA; CSO/MACO Crop Forecast Surveys; CSO/MACO Post-Harvest Surveys; CSO/MACO/FSRP Supplemental Surveys.

After six marketing years in operation (1996/97-2001/02), the FRA was perceived as not having adequately addressed the crop marketing constraints faced by smallholders and in 2002 a Crop Marketing Authority (CMA) Bill was introduced in parliament (Nijhoff et al., 2003). The proposed CMA was to replace the FRA. Like the FRA, the CMA would administer the national food reserve but unlike the FRA, the CMA would have an explicit crop marketing mandate. Ultimately, parliament did not ratify the CMA Bill; instead, the Food Reserve Act was amended in 2005 to add crop marketing and market facilitation as official FRA functions (GRZ, 2005).

Even prior to the 2005 amendment, beginning in the 2002/03 marketing year, the FRA began to participate more directly in maize marketing. Following the drought-related failed harvest in large swathes of the country in 2002, the FRA made plans to purchase roughly 15,000 MT of maize directly from smallholders in eight 'surplus' districts (FEWSNET and WFP, 2002). By the end of the 2002/03 marketing year, the FRA had purchased more than 23,500 MT from 10 districts. At the beginning of the next marketing year (2003/04), the FRA announced its plans to purchase 205,700 MT of maize directly from smallholders in 37 districts at a pan-territorial price of K30,000 per 50-kg bag; this was the first time since liberalization in 1992 that the government set a pan-territorial price for maize (FEWSNET, 2003a; FEWSNET, 2003b).[40] In addition to its main holding depots, the FRA set up satellite depots in outlying areas in targeted districts. Although the Agency only managed to purchase approximately 55,000 MT in 36 districts in 2003/04 due to funding shortfalls, its message was clear: the FRA intended to be a major player in the Zambian maize market. From the 2004/05 to 2010/11 marketing years, FRA local purchases ranged from a low of approximately 74,000 MT in 2008/09, to nearly 400,000

[40] Even with the announcement of the FRA's pan-territorial price, private maize trade remained legal in Zambia and private traders and other buyers were free to buy at prices above or below the FRA price. The government has, however, consistently encouraged farmers not to sell below the FRA price.

MT in 2006/07 and 2007/08, to a high of 878,570 MT in 2010/11 (Table F.1). FRA's share of actual smallholder maize sales increased steadily from 12% in 2002/03 to more than 50% in both 2006/07 and 2007/08 before dropping off in 2008/09 and 2009/10 (Figure F.1). Based on the expected quantity of maize to be sold by smallholders in 2010/11, FRA is estimated to have captured 83% of the market. The spatial coverage of FRA's purchases increased steadily over time from 36 districts in 2003/04 to 62 districts in 2010/11 (Table F.1).[41]

Farmers wishing to sell their maize to the FRA are officially required to be small-scale farmers that belong to a cooperative or other farmer group; beneficiaries of the Fertilizer Support Programme are also targeted (FRA, various years). Farmers are encouraged to sell to the FRA through their farmer organizations. The minimum quantity of maize that the FRA will purchase directly from a given farmer or cooperative/farmer group is 500 kg and all sales to FRA are to be made at satellite depots at the primary cooperative society level in designated districts (FRA, various years). Upon delivery of their crop to an FRA satellite depot, participating farmers are not paid in cash but rather are issued a receipt (a Produce Received Note, PRN). Once the maize is transported to the main holding depot in the district, the farmer is issued a second receipt (a Goods Received Note-Crop Purchases, GRN). With these two receipts (PRN and GRN) in hand along with their national registration card, the farmer can recoup their payment at a participating bank (FRA, various years). The FRA aims to pay farmers within 10 days of when they deliver their crop but payment often takes much longer than that.

According to the FRA, the following factors are considered in the selection of locations for satellite depots: (i) "ensure that the principle of buying in surplus but disadvantaged areas is adhered to; (ii) being present in as many areas as possible within available resources; (iii) FRA

[41] There are 72 total districts in Zambia.

operations should not disrupt operations of [the] private sector where they already exist; and (iv) FRA will play a supplementary role to the private sector marketing operations" (FRA, 2008: 2). The FRA crop purchasing exercise typically commences in June or July, depending on the moisture content of maize. The end of the FRA crop purchasing exercise has varied from year to year, ending as early as the end of September in the 2007/08 marketing year, and as late as the end of February in 2003/04.

F1.2 FRA maize sales on the domestic market

The FRA has not made publicly available comprehensive data on its maize sales. In this section, I summarize the information obtained to date. Most FRA maize sales are done via tender but maize is periodically sold on the market at a pan-territorial price. In the latter case, the FRA sell price is determined in consultation with stakeholders such as the Zambia National Farmers Union, the Grain Traders Association of Zambia, and the Millers Association of Zambia. Thus the FRA sell price may vary from transaction to transaction within a given marketing year.[42]

Table F.2 summarizes information on FRA sales quantities, prices, and buyers. It is unlikely that the sales data obtained from FRA are comprehensive, so the sales totals in the table should be considered lower bounds. Available evidence indicates that millers are the largest buyer of FRA maize sold in Zambia, followed by traders, the Government of Zambia (GRZ) Disaster Mitigation and Management Unit (DMMU), and, to a lesser extent, the World Food Programme (WFP) (Table F.2). Over 80% of the FRA's maize sales occur during the hungry season months of December through March. For maize sold by the FRA between December 1997 and February 2002 (the only period for which details on the location of the sales are

[42] Beginning in October 2010, the FRA also sold small quantities of maize (20,000 MT) through an auction-like mechanism on the Zambia Agricultural Commodity Exchange.

available), 64% was sold in Lusaka and 7%-9% was sold in each of Central, Copperbelt, Eastern, and Southern Provinces. Comparing the weighted average sell price to FRA's buy price in the same marketing year, note that in 2004/05, 2005/06, and 2007/08 the FRA sell price was nearly identical to its buy price, which suggests heavy FRA losses on the maize it sold (Table F.2).

F1.3 FRA/GRZ maize imports and exports

In addition to buying and selling maize on the domestic market, the FRA is also involved in international maize trade. Table F.3 shows FRA/GRZ net maize imports in the 1996/97 to 2010/11 marketing years. Maize imported by GRZ through FRA is typically sold to large-scale millers at prices below the cost of commercial importation (Govereh et al., 2008). Permits are required to import and export maize and, particularly since 2005, these permits have been allocated mainly to FRA and select millers and traders or not issued to private firms at all, effectively banning formal commercial cross-border maize trade (ibid). In most marketing years since 2002/3, the FRA buy price has been higher than average wholesale prices, particularly those in major maize-producing areas such as Choma, Kabwe, Chipata, and Kasama. The above-market prices that the FRA pays for maize make it difficult for the Agency to export maize – the FRA essentially prices itself out of export markets. When the Agency does export maize, it is sometimes at a loss, as in the 2007/08 and 2010/11 marketing years (Govereh et al., 2008; Nkonde et al., 2011).

Table F.2. Estimated FRA maize sales and weighted average sell price, and shares of FRA sales to different buyers, 1996/97-2008/09 marketing years

Marketing year	FRA maize sold on the domestic market (MT)	Weighted average FRA maize sell price (ZMK/ 50-kg)[a]	FRA maize buy price (ZMK/ 50-kg)	% of total FRA maize sold in Zambia purchased by:					
				Millers	Traders	DMMU	WFP	Other buyers	Buyer not specified
1996/1997	0		11,800						
1997/1998	34,722	16,876	7,880						100
1998/1999	178,863	22,357	N/A	1.3	0	0	0	0.5	98.2
1999/2000	0		N/A						
2000/2001	17,421	15,811	N/A	66.7	22.5	0	0	0.3	10.5
2001/2002	11,690	13,392	N/A	9.1	51.7	0	0	2.6	36.6
2002/2003	739	49,000	40,000[b]						100
2003/2004	53,920	44,471	30,000						100
2004/2005	25,051	35,332	36,000						100
2005/2006	82,479	36,202	36,000	57.1	9.7	24.4	4.4	4.0	0.4
2006/2007	15,152	43,184	38,000	29.9	38.2	25.8	0	5.2	0.9
2007/2008	195,277	39,821	38,000	77.8	9.4	0.4	9.0	1.2	2.2
2008/2009	23,381	63,000	45,000[c]	92.6	7.4	0	0	0	0

Notes: FRA sales began in December 1997. 2008/09 marketing year sales are through December 2008. “Other buyers” are consumers, District and Province Cooperative Unions, within-FRA sales (among depots), and NGOs. [a]Weighted average sell price based on the share of total marketing year FRA maize sales on the domestic market sold at a given price. [b]Initial FRA price of K30,000 was raised to K40,000 in August 2002. [c]FRA price increased to 55,000 in September 2008. Source: FRA.

Table F.3. FRA/GRZ net maize imports, 1996/97-2010/11

Marketing year	FRA/GRZ net maize imports (MT)
1996/1997	109,000
1997/1998	70,000
1998/1999	150,000
1999/2000	0
2000/2001	0
2001/2002	150,103
2002/2003	41,608
2003/2004	0
2004/2005	-22,098
2005/2006	36,245
2006/2007	-230,000
2007/2008	-285,856
2008/2009	34,325
2009/2010	0
2010/2011	-78,177

Sources: Govereh et al. (2008); FRA.

F1.4 Government of Zambia spending on the FRA

The Government of Zambia has devoted a substantial share of its agricultural sector and Poverty Reduction Programme resources to the FRA, particularly since 2003. Table F.4 summarizes, for budget years 2001 through 2011, the government budget allocation and funds released to the Strategic Food Reserve/FRA (SFR/FRA). Over budget years 2003-2011, the GRZ budget allocation to the SFR/FRA averaged over K86 billion, and accounted for, on average, 18.5% of the GRZ budget allocation to the Ministries of Agriculture and Cooperatives (MACO) and Livestock and Fisheries Development (MLFD), and 23.7% of the GRZ budget allocation for Poverty Reduction Programmes (PRPs).

Table F.4. GRZ funding for the SFR/FRA and the Fertilizer Support Programme/Farmer Input Support Programme (FSP/FISP), budget years 2001-2011

Budget	Budget allocation ---------- (K billion) ----------		Funds released ---------- (K billion) ----------		Budget allocation as % of total budget allocation to ------- MACO/MLFD -------		Budget allocation as % of total budget allocation to Poverty -- Reduction Programmes --	
year	SFR/FRA	FSP/FISP	SFR/FRA	FSP/FISP	SFR/FRA	FSP/FISP	SFR/FRA	FSP/FISP
2001	0.00	40.00	0.00	40.00	0.0%	40.5%	0.0%	61.8%
2002	0.05	17.79	0.05	17.79	0.1%	24.2%	0.1%	22.8%
2003	50.00	50.00	52.22	50.00	25.7%	24.6%	14.4%	14.4%
2004	47.00	70.00	47.20	98.05	19.9%	41.4%	33.0%	49.2%
2005	50.00	100.00	59.13	139.99	17.9%	42.5%	22.6%	45.2%
2006	50.00	199.00	140.00	184.05	30.6%	40.2%	18.5%	73.7%
2007	150.00	205.00	205.00	204.54	23.0%	31.2%	38.1%	52.1%
2008	80.00	185.00	340.00	492.08	15.5%	36.2%	28.3%	65.4%
2009	100.00	435.00	198.31	565.12	10.9%	47.3%	17.4%	75.6%
2010	100.00	430.00			8.7%	37.4%	18.1%	78.0%
2011	150.00	485.00			14.1%	45.6%	22.6%	73.0%

Source: GRZ

F2. The Fertilizer Support Programme and other major government fertilizer programs in Zambia, with a focus on the period 1999/2000 to 2009/2010

F2.1 Fertilizer subsidies prior to the Fertilizer Support Programme

Fertilizer subsidies have a long and varied history in Zambia. During the 1980s, fertilizer was subsidized at a rate of 50% and sold at uniform prices throughout the country (MACO et al., 2002). All fertilizer was handled and marketed by NAMBOARD. As part of the market reforms initiated in 1991, fertilizer marketing and pricing were liberalized and direct subsidies to farmers were eliminated. Between 1992/93 and 1996/97, GRZ experimented with a number of different facilities and programs to build private sector capacity for fertilizer importation, handling, and financing, none of which proved particularly effective or sustainable.[43]

Then, beginning in the 1997/98 agricultural season, GRZ tasked the FRA with importing fertilizer and running a fertilizer credit scheme, despite this not being a core FRA function according the 1995 Food Reserve Act. Under the FRA Fertilizer Credit Programme (FRA-FCP), which ran from 1997/98 through 2001/02, private fertilizer trade and pricing remained legal but fertilizer distributed on credit to small-scale farmers by the FRA was uniformly priced throughout the country (MACO et al., 2002). The quantities of subsidized fertilizer distributed under the FRA-FCP from 1997/98 through 2001/02 and the number of participating districts are summarized in Table F.5.

[43] See MACO et al., 2002, for additional details.

Table F.5. FRA Fertilizer Credit Programme fertilizer tonnage distributed and number of participating districts, 1997/98-2001/02

Agricultural year	Quantity of fertilizer distributed (MT)	# of participating districts
1997/1998	15,495	16
1998/1999	50,001	23
1999/2000	34,999	45
2000/2001	23,227	42
2001/2002	28,985	45

Note: Information on the number of farmers participating in the program each year is not available. Source: FRA Agro Support Department.

During the 1999/2000 agricultural season, approximately 35,000 MT of fertilizer were distributed on loan through the FRA-FCP (Table F.5). Under this program, farmers applied for fertilizer on loan in November 1999 and made a down payment of K5,000 per 50-kg bag of fertilizer; the balance of K40,000 per bag was to be repaid either in cash or in maize in June 2000 (MACO et al., 2002). According to the program guidelines, farmers could apply for 200 to 800 kg of fertilizer for the cultivation of one half to two hectares of maize, respectively. Each 100 kg "pack" consisted of one 50-kg bag of basal and one 50-kg bag of top dressing fertilizer (FRA Agro Support Department, 1999).

The FRA-FCP was implemented through farmer cooperatives. The FRA pre-selected cooperatives with which it wished to work in each district. Then, at meetings convened by the (pre-selected) Cooperative Boards and respective Camp Extension Officers, and attended by prospective farmer applicants, village headmen, and Village Farmers' Committees, the modalities of the program were explained. Farmers completed application forms and obtained endorsements from their village headman and Camp Extension Officer at this meeting. These applications were subsequently reviewed by the Village Farmers' Committees, who were to ensure that applicants met the program criteria. These criteria stated that a participating farmer must be: (i) “a bona fide resident and is farming within the village area; (ii) credible and able to pay back the loan; and (iii) not indebted to FRA as regards seasonal loans” in previous seasons (FRA Agro Support Department, 1999: 3). After additional levels of approvals, selected farmer participants were informed by their Cooperative Boards as to the location and time at which inputs could be picked up. Forty-three main fertilizer depots were operated throughout the country in 1999/2000 and there was an average of six satellite depots per main depot. The FRA-FCP was implemented in collaboration with the Ministry of Agriculture, Food, and Fisheries extension staff (FRA Agro Support Department, 1999). The loan recovery rate in the 1999/2000 agricultural season averaged 34.5% and recovery rates in subsequent years continued to be low (MACO et al., 2002). It is therefore not surprising that the government moved to a cash-only (no credit) system with the establishment of the Fertilizer Support Programme in the 2002/03 agricultural season.

F2.2 The Fertilizer Support Programme, 2002/03-2008/9, and the Farmer Input Support Programme, 2009/10

The Zambian government’s rationale for establishing the Fertilizer Support Programme in 2002 is best summarized in its own words from the 2008 FSP Internal Evaluation: “From 1990 to 2001, government failed to provide adequate facilities and infrastructure to enable expanded private sector participation in input marketing. As a result, the FRA continued to be a key player in input marketing. Unfortunately, farmers continued to face chronic problems of timeliness in input delivery, inadequate quantity and inferior quality. Input dealers operated in an unpredictable policy environment leading to uncertainties about long-term sustainability. Therefore, the private sector could not effectively fill up the gap left by the government in fertilizer markets. In order to address the dynamic constraints experienced in fertilizer markets during the 1990s, in 2002, Government developed the Fertilizer Support Programme (FSP). It was justified that Government runs a managed transition to full market liberalization to build the capacities of both the private sector and small-scale farmers" (MACO, 2008: 3). The major drought in the 2001/02 agricultural season may have also contributed to pressure on the GRZ to be perceived as 'doing something' to help its rural constituents to recover.

A key feature of FSP that distinguished it from earlier fertilizer subsidy programs in Zambia was that farmers were required to pay cash for inputs. FSP marked the end of the provision of agricultural inputs on credit to small-scale farmers by GRZ (MACO, various years).[44] The stated objectives of FSP, which ran from 2002/03 through 2008/09 and was implemented by the Ministry of Agriculture and Cooperatives (MACO), were: (i) "to increase private sector participation in the supply of agricultural inputs to smallholder farmers, thereby reducing government involvement; (ii) to ensure timely, effective and adequate supply of agricultural inputs in the country; (iii) to improve access of smallholder farmers to agricultural inputs [fertilizer and hybrid maize seed]; (iv) to ensure competitiveness and transparency in the distribution of inputs, thereby breaking monopolies; (v) to serve as a risk-sharing mechanism for smallholder farmers to cover part of the costs for improving agricultural productivity; (vi) to expand markets for private sector input suppliers [dealers] and increase their involvement in the distribution of agricultural inputs in rural areas, thereby reducing the direct role of Government; and (vii) to facilitate the process of farmer organization, dissemination of knowledge and

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[44] In addition to the FSP cash program, there was a small, transitional FSP "loan" program in 2002/03, the first year of FSP. In this program, a limited number of farmers that did not get subsidized fertilizer through the FSP cash program received fertilizer from FSP on credit and were expected to pay back the loan to cover the full (unsubsidized) price of the fertilizer. Only about 10% of the total amount of fertilizer distributed through FSP in 2002/03 was through this credit program. Repayment rates under the FSP fertilizer loan program were low and the loan component of FSP was not continued after 2002/03 (Govereh, 2010).

creation of other rural institutions that will contribute to the development of the agricultural sector" (MACO, various years). Additional goals of FSP as articulated in the 2008 FSP Internal Evaluation were "improving household and national food security, incomes, [and] accessibility to agricultural inputs by small-scale farmers through a subsidy", "building the capacity of the private sector to participate in the supply of agricultural inputs", and "rebuilding the resource base of smallholder farmers and instilling their sense of self-reliance" (MACO, 2008: 3).

Like its predecessor program, the FRA-FCP, only farmers that were members of cooperatives or other farmer organizations were technically eligible for FSP. Beneficiary cooperatives and other farmer organizations in each participating district were pre-selected by the District Agriculture Committee in collaboration with other local leaders including Members of Parliament, the District Administrator, NGOs, and village headmen. Pre-selected cooperatives/farmer organizations were then verified and approved by the FSP Programme Coordination Office (MACO, various years).[45] Within a pre-selected cooperative/farmer organization, individual farmer beneficiaries were to be selected based on the following criteria: "(i) should be a small scale farmer and actively involved in farming within the cooperative coverage area; (ii) has the capacity to grow 1-5 hectares of maize; (iii) should be able to meet 50% of the cost of inputs [or the farmer contribution in that year]; (iv) should not concurrently benefit from the Food Security Pack; and (v) should not be a defaulter, from Food Reserve Agency and/or any other agricultural credit program whether belonging to an eligible cooperative or not" (MACO, various years).

[45] In order to be eligible, participating cooperatives and other farmer organizations had to meet a number of selection criteria, such as having written by-laws, an executive committee, a bank account, and knowledge of cooperative and agribusiness management, being a registered cooperative or other farmer organization, being located in an agricultural area and engaged in agricultural activities, and having no outstanding loans with FRA or other lenders (MACO, various years).

Selection of individual farmer beneficiaries was to be done by Cooperative Boards in conjunction with Camp Extension Officers. (The latter are MACO employees.) Village Farmers' Committees, village headmen, and other local leaders were to be involved in the process of verifying that applicants met the selection criteria (ibid). After additional levels of approvals, selected individual farmer beneficiaries paid their share of the input costs to their cooperative/farmer organization, which in turn deposited the funds at a participating bank, with the balance due deposited by the government. When inputs were positioned at the depots, individual farmers reported to their designated depot and collected the inputs upon showing their national registration card (ibid). From 2002/03 through 2008/09, there were an average of eight FSP satellite depots per district, but many of these satellite depots appear not to have been used (MACO, various years; CSPR, 2005; CDFA, 2008).

Under FSP, the official "pack" consisted of four 50-kg bags of basal fertilizer, four 50-kg bags of top dressing fertilizer, and 20 kg of hybrid maize seed. These inputs were to be used to plant one hectare of maize. In theory, each participating farmer was to receive only one pack. In practice, however, the quantities of subsidized fertilizer received by participating farmers varied greatly.

Table F.6 summarizes the quantities of subsidized fertilizer delivered up to the district level under FSP from 2002/03 through 2008/09, and under the Farmer Input Support Programme (FISP, the successor program to FSP) in the 2009/10 agricultural year. The table also lists the subsidy level each year, the number of districts that were allocated FSP/FISP fertilizer, and the number of intended beneficiaries, as well as the estimated number of smallholder households that actually received the subsidized fertilizer and the estimated amount of subsidized fertilizer acquired by these households. This table highlights several important points. First, note that the

FSP/FISP subsidy level has increased over time, from 50% in 2002/03 through 2005/06, to 75% in 2008/09 and 2009/10 (Table F.6, column A). This is in contrast to the original plan for FSP, which was to last only three years, with a subsidy level of 50% in the first year, 25% in the second, and 0% in the third (MACO, 2002). Second, FSP/FISP covered all or nearly all districts in Zambia in each year of the program (Table F.6, column B). This is much broader coverage than achieved under FRA-FCP, which covered at most 45 districts (see Table F.5).

Third, the quantity of subsidized fertilizer distributed under FSP/FISP is more than double that under FRA-FCP. Over the 1997/98 to 2001/02 period, the annual quantity of fertilizer distributed under FRA-FCP ranged from 15,000 to 50,000 MT and averaged 30,500 MT. Between 2002/03 and 2009/10, the annual quantity of fertilizer distributed under FSP/FISP ranged from 48,000 to 106,000 MT and averaged 66,000 MT. Fourth, there is some evidence of leakage of FSP/FISP fertilizer, as the estimated quantity received by smallholders based on nationally-representative household survey data collected by the Central Statistical Office is 34% to 87% of the quantity of FSP/FISP fertilizer delivered by GRZ to the district level (Table F.6, column E).[46] These results may be consistent with widespread allegations in Zambia that some FSP/FISP fertilizer has been diverted from the program to be sold informally by program implementers.[47] Similarly, in all years except 2007/08 and 2008/09, the number of households receiving FSP/FISP based on household survey data is 52% to 85% of the number of beneficiaries according to FSP/FISP records (Table F.6, column F).

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[46] Dr. Michael T. Weber (Michigan State University), while on long-term assignment in Zambia with the Food Security Research Project, was the first to examine this relationship between official GRZ FSP distribution numbers and survey estimates.

[47] See, for example, Mulenga (2009), Sinyangwe (2009), and Chulu (2010), as well as http://www.aec.msu.edu/fs2/zambia/tour/FSP_Difficulties_Press_Clipping_Nov_Dec_2008.pdf for a compilation of Zambian newspaper articles from November and December 2008 related to this issue.

In the 2009/10 agricultural season, FSP was renamed the Farmer Input Support Programme. The objectives of FISP are similar to those of FSP discussed above with two main exceptions. First, FISP has an increased emphasis on targeting small-scale farmers, after FSP was criticized for problems with leakage and poor targeting. Second, the range of inputs subsidized under FISP is to be expanded beyond fertilizer and hybrid maize seed. Another major change under FISP is a reduction in the pack size from eight bags of fertilizer to four and from 20 kg of hybrid maize seed to 10 kg. These inputs are to be used to plant 0.5 ha of maize (MACO, 2009). The reduction in the pack size means that, in theory, for a given quantity of subsidized fertilizer, twice as many farmers benefit under FISP as under FSP.

Both FSP and FISP have attracted a substantial share of GRZ budgetary resources. The FSP/FISP budget allocation has generally grown over time, from K40 billion in the 2001 to K485 billion in 2011(Table F.4). Between 2004 and 2011, FSP/FISP accounted for, on average, 40% and 64% of the GRZ budget allocations to MACO/MLFD and PRPs, respectively. From 2009 to 2011, FSP/FISP garnered roughly 75% of the PRP budget allocation. And from 2006 to 2011, the FSP/FISP and SFR/FRA budget allocations combined accounted for more than 90% of the total resources available for PRPs in Zambia (Table F.4).

Table F.6. FSP/FISP subsidy level, number of participating districts, fertilizer tonnage, and number of beneficiaries, 2002/3-2009/10

			According to FSP/FISP records		Estimated from household survey data		
Agricultural year	Subsidy level	# of districts allocated FSP/FISP fertilizer	MT of fertilizer delivered to districts	Intended number of beneficiary households	MT of fertilizer received by smallholder households (as % of MT delivered to districts in parentheses)	# of beneficiary smallholder households (as % of # of intended beneficiary households in parentheses)	Data source
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
2002/2003	50%	72	48,000	120,000	31,722 (66%)	102,113 (85%)	SS04
2003/2004	50%	72	60,000	150,000	33,372 (56%)	101,139 (67%)	SS04
2004/2005	50%	67[a]	50,000	125,000	16,792 (34%)	64,854 (52%)	PHS0405
2005/2006	50%	72	50,000	125,000	23,595 (47%)	74,040 (59%)	PHS0506
2006/2007	60%	68[a]	84,000	210,000	58,404 (70%)	164,229 (78%)	SS08
2007/2008	60%	72	50,000	125,000	43,596 (87%)	140,612 (112%)	SS08
2008/2009	75%	72	80,000	200,000	55,114 (69%)	192,860 (96%)	CFS0809
2009/2010	75%	72	106,000	534,000[b]	69,103 (65%)	292,685 (55%)	CFS0910

Notes: Agricultural year refers to October-September. [a]Indicates number of districts allocated FSP in original allocations. Additional districts may have been added when FSP received supplemental funding. [b]Pack size reduced to four 50 kg bags under FISP.
Sources: FSP/FISP Implementation Manuals (FSP/FISP, various years); FSP Internal Evaluation (2008); the 2004/05 and 2005/06 Post-Harvest Surveys (PHS0405, PHS0506); 2004 and 2008 CSO/MACO/FSRP Supplemental Surveys (SS04 and SS08); and 2008/09 and 2009/10 Crop Forecast Surveys (CFS0809 and CFS0910).

F2.3 The Food Security Pack Programme/Programme Against Malnutrition

The last major fertilizer subsidy program operating in Zambia during the last decade is the Food Security Pack Programme (FSPP/PAM), which is funded by GRZ and was implemented for many years by the Programme Against Malnutrition, a Zambian NGO. FSPP/PAM has been in place since 2000/01 and provides inputs on grant to participating households. Whereas FSP (officially) targeted households capable of growing one to five hectares of maize, FSPP/PAM targets 'vulnerable but viable' farming households that cultivate less than one hectare of land. Groups considered 'vulnerable but viable' by FSPP/PAM are small-scale rural farming households headed by women or children, those with disabled persons or that are supporting orphans, those "affected by calamities", and unemployed youth (Tembo, 2007: 40). Beneficiaries are selected by community-level Satellite Food Security Committees. According to program documents, FSPP/PAM covers all 72 districts of Zambia.

A Food Security Pack consists of (i) 0.25 hectare's worth of cereal seed (maize, millet, rice, or sorghum, depending on the area); (ii) two 50-kg bags of fertilizer (one basal and one top dressing) for households that receive maize seed; (iii) 0.25 hectare's worth of legume seeds (groundnuts, beans, cowpeas, or soybeans); (iv) 0.25 hectare's worth of cassava or sweet potato planting materials; and (v) lime for beneficiary households in high rainfall areas. FSPP/PAM's main objectives are (i) to "promote crop diversification for increased food production"; (ii) to "promote farming methods that help restore soil fertility and productivity"; and (iii) to "encourage adoption of conservation farming (CF) technologies" (Tembo, 2007: 1). Table F.7 lists the number of households receiving FSPP/PAM grants from 2000/01 through 2006/07. The FSPP/PAM program has received less funding in recent years (as funding for FSP has increased), hence the precipitous drop in the number of participating households after 2003/04.

Table F.7. Number of households participating in FSPP/PAM, 2000/01-2006/07

Agricultural year	Number of households
2000/2001	60,000
2001/2002	135,000
2002/2003	140,399
2003/2004	145,000
2004/2005	24,867
2005/2006	31,797
2006/2007	21,700

Source: Tembo (2007)

F3. Summary

As evidenced in this Appendix, GRZ has become increasingly involved in Zambia's fertilizer and maize markets over the last decade. Fertilizer subsidies and direct state involvement in maize marketing were somewhat scaled back during the agricultural market reforms of the 1980s and 1990s. Maize and fertilizer are at the heart of the government's implicit social contract with Zambians. Under this social contract, the government is expected to support smallholder incomes and keep food prices low for urban consumers (Jayne and Jones, 1997; Jayne et al., 2007). Tembo et al. (2009: 1) argue that GRZ "sees as its moral mandate to ensure that … producers and consumers alike are not solely at the mercy of unpredictable market forces".

GRZ's return over the last decade to subsidizing fertilizer and buying maize from smallholders at a pan-territorial price typically above market prices has likely been driven by: (i) continued pressure to deliver on the social contract; (ii) a perception among government officials that the private sector failed to 'fill the gap' after government reduced its involvement in agricultural input and output marketing in the 1980s and 1990s; and (iii) the high visibility and political expediency of large-scale fertilizer subsidy programs and state maize purchases at high prices. Donors' transition from highly conditional to direct budget support has likely facilitated GRZ's return to these policies (Jayne et al., 2007).

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