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Smallholder Supply Response to Marketing Board Activities in a Dual Channel Marketing System: The Case of Zambia

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Abstract

In recent years, parastatal grain marketing boards have re-emerged as important elements of grain markets in eastern and southern Africa, yet little is known about how farmers are responding to their scaled up activities. This article develops a conceptual model of farmers' production decisions in the context of dual output marketing channels (government and private sector) when output prices at harvest time and the availability of one of the marketing channels are unknown at planting time. It then applies the model to the case of Zambia and uses nationally representative household-level panel survey data to estimate the effects of the Food Reserve Agency (FRA), the government parastatal maize marketing board, on smallholder crop production and fallow land. The FRA buys maize from smallholders at a pan-territorial price that typically exceeds market prices in major maize producing areas. Results suggest that increases in the farmgate FRA maize price raise farmer maize price expectations, which induces a supply response. Smallholders respond to an increase in the FRA price by extensifying their maize production. On average, a 1% increase in the FRA price is associated with 0.06% increases in smallholders' maize area planted and quantity harvested. There is also some evidence that farmers reduce the area of land under fallow in response to FRA incentives but there is no evidence of reductions in the area planted to other crops.

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Keywords: *Grain marketing boards*; *maize*; *price expectations; strategic grain reserves*; *sub-Saharan Africa*; *supply response*; *Zambia*.

JEL classifications: *Q12, Q13, Q18*.

1. Introduction

More than two decades after the initiation of agricultural market reforms in eastern and southern Africa, most governments in the region continue to participate directly in staple food marketing (Jayne *et al*., 2002, 2010; World Bank, 2008). In recent years, parastatal grain marketing boards (GMBs) and strategic grain reserves (SGRs) have re-emerged as important elements of grain markets in Kenya, Malawi, Zimbabwe, Ethiopia, Tanzania and Zambia (Jayne *et al*., 2010). Governments in the region are devoting substantial budgetary resources to GMB/SGR operations. In Zambia, for example, gross expenditures on the maize marketing activities of the FRA, a parastatal maize marketing board/strategic reserve, were equivalent to 1.6% and 1.8% of GDP in 2010 and 2011, respectively (IMF, 2012).

The ramping up of GMB/SGR activities has often gone hand-in-hand with the expansion of government fertiliser subsidy programmes and in some cases (e.g. Zambia) government spending on GMBs/SGRs has swamped that on input subsidies. Nonetheless, there has been little empirical analysis of how smallholder farm households are responding to scaled-up GMB/SGR operations in Africa. This is in stark contrast to the rapid proliferation of studies on the effects of fertiliser subsidies on smallholder behaviour (see Xu *et al*., 2009; Ricker-Gilbert *et al*., 2011; Holden and Lunduka, 2012; Chibwana *et al*., 2012; and the articles in the November 2013 special issue of *Agricultural Economics* on Input Subsidy Programmes in sub-Saharan Africa, among many others).

In this article, we estimate the effects of the FRA on crop output supply (area planted, yields and quantities harvested) among smallholder farm households in Zambia using a nationally representative household panel survey covering years before and during the FRA scale-up of maize purchases.[2] Since 2003, the FRA has bought maize directly from smallholder farmers at a pan-territorial price that typically exceeds market prices in major maize producing areas (see Figure 1). Private maize trade remains legal and market prices are unregulated. Smallholders therefore face two potential marketing channels for maize: FRA and the private sector. Since 2005/06, the FRA has been the dominant single buyer of smallholders' maize in most years (Table 1). Furthermore, the FRA is currently the Zambian government's flagship agricultural sector programme: 61% and 56% of government agricultural sector spending was devoted to the FRA in 2010 and 2011, respectively (GRZ, various years). The FRA is also the Zambian government's leading agricultural Poverty Reduction Programme, having garnered approximately 2/3 of the funds for such programmes in both 2010 and 2011. (See Table 2 for a summary of government spending from 2002 to 2011 on the FRA and on fertiliser subsidies, the Zambian government's other major agricultural sector programme.) Such major expenditures on the FRA and the high opportunity cost of these resources warrant a careful examination of the effects of FRA policies.

In addition to being the first empirical study of the effects of the FRA on smallholder behaviour in Zambia, this article makes a number of other contributions to the

[2]Smallholder households are defined as those cultivating fewer than 20 hectares.

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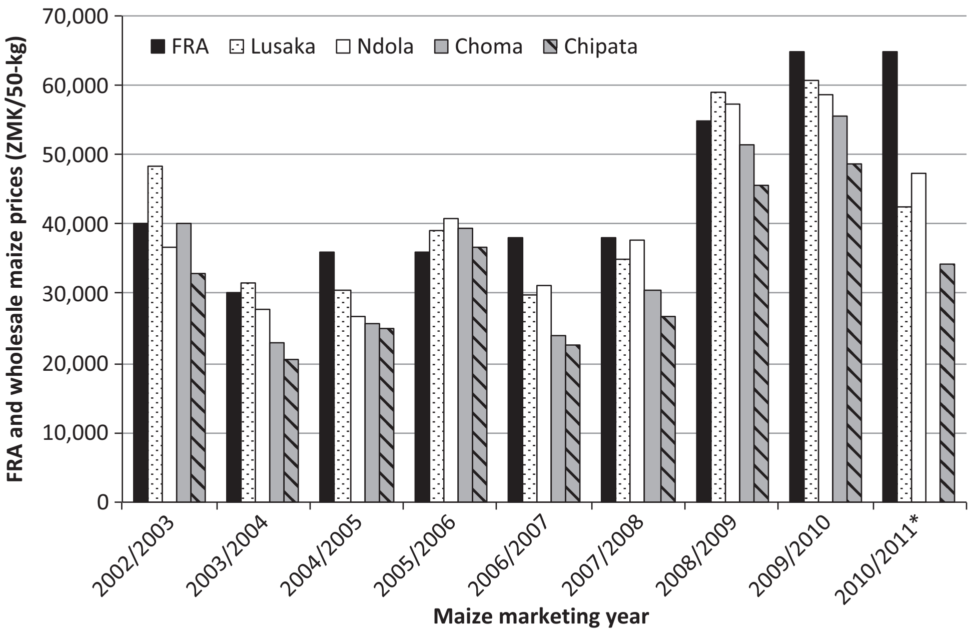

Figure 1. FRA buy price and wholesale market prices in Lusaka, Ndola, Choma and Chipata, 2002/03–2010/11 (ZMK/50-kg)
Notes: Lusaka and Ndola are major maize consumption areas; Choma and Chipata are major maize production areas. Wholesale prices are average marketing year into-mill prices.
*No Choma wholesale price data available for 2010/11.
Sources: Mason and Myers (2013); Zambia Agriculture Market Information Center.

literature. First, it broadens the knowledge base and informs policy debates on how smallholders are responding to the recent resurgence of GMB/SGR activities in Africa. Only one other study, Mather and Jayne (2011), has examined this issue. Mather and Jayne estimate the effects of maize purchases by the National Cereals and Produce Board (NCPB, a grain marketing board) on smallholder behaviour in Kenya. The FRA/Zambia case is distinct from the NCPB/Kenya case in significant ways. Most importantly, the NCPB buys virtually no maize directly from smallholders (it buys almost exclusively from large-scale commercial farmers and traders), whereas the FRA buys mainly from smallholders.[3] As a result, Kenyan smallholders face only one marketing channel (private sector) whereas Zambian smallholders face dual marketing channels for maize (private sector and FRA). Furthermore, the scale of NCPB maize purchases in recent years has generally been much smaller than that of the FRA (Mather and Jayne, 2011). Zambia thus offers an important comparison to the Kenya case.

A second contribution of the current article is that by using household panel survey data, we are able to explore dimensions of GMB effects on smallholder farmers that the earlier literature could not. Most of the previous literature is based on aggregate

[3]Smallholders account for approximately 98% of the maize area planted, 95% of the maize quantity harvested, and 92% of maize sales in Zambia (MAL, 2012). The FRA is technically supposed to buy only from smallholders but anecdotal evidence suggests that it occasionally buys from large-scale commercial farmers and traders. Data on FRA purchases from smallholders versus other sellers are not available.

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Table 1

FRA maize purchases and estimated smallholder maize production and sales, 1996/97–2012/13

Marketing year	No. of districts in which FRA purchased maize	FRA pan-territorial purchase price (ZMK/50-kg bag)*	FRA domestic maize purchases (MT) (A)	Estimated smallholder maize: Production (MT) (B)	Estimated smallholder maize: Sales (MT) (C)	FRA purchases as % of smallholder maize sales (D) = (A)/(C)	Key FRA policy changes and phases of involvement in maize markets in Zambia
1996/97	5	11,800	10,500	1,117,955	280,955	3.7	Phase I. First years of FRA involvement after its establishment in 1996 with the enactment of the Food Reserve Act of 1995; buys maize for strategic reserve through private traders at close to market price; minimal market share
1997/98	4	7,880	4,989	804,626	206,557	2.4	
1998/99	0	N/A	0	724,024	175,515	0	Phase II. No FRA purchases due to lack of funding
1999/2000	0	N/A	0	929,304	242,753	0	
2000/01	0	N/A	0	1,253,722	303,738	0	
2001/02	0	N/A	0	957,437	209,326	0	
2002/03	10	40,000†	23,535	673,673	143,453	16.4	Phase III. FRA starts buying directly from smallholders and engages in maize marketing activities beyond maintaining strategic reserve. FRA's market share increases over time but not yet dominant player
2003/04	36	30,000	54,847	970,317	260,885	21.0	
2004/05	46	36,000	105,279	1,364,841	331,006	31.8	

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Table 1
(*Continued*)

Marketing year	No. of districts in which FRA purchased maize	FRA pan-territorial purchase price (ZMK/50-kg bag)*	FRA domestic maize purchases (MT) (A)	Estimated smallholder maize: Production (MT) (B)	Estimated smallholder maize: Sales (MT) (C)	FRA purchases as % of smallholder maize sales (D) = (A)/(C)	Key FRA policy changes and phases of involvement in maize markets in Zambia
2005/06	50	36,000	78,667	652,414	151,514	51.9	Phase IV. Food Reserve Act amended in 2005 to give FRA an explicit maize marketing mandate. FRA becomes the dominant buyer of smallholders' maize. Maintains its dominant position except in 2008/09 and 2009/10 due to lower budget allocations, funding delays and stiffer competition from private traders
2006/07	53	38,000	389,510	1,339,479	454,676	85.7	
2007/08	58	38,000	396,450	1,419,545	533,632	74.3	
2008/09	58	45,000‡	73,876	1,392,180	522,033	14.2	
2009/10	59	65,000	198,630	1,657,117	613,356	32.4	
2010/11	62	65,000	883,036	2,463,523	1,062,010	83.1	
2011/12	68	65,000	1,751,660	2,786,896	1,429,911	122.5	
2012/13	—	65,000	1,046,000	2,731,843	1,440,944	72.6	

Notes: —, Data not available. N/A, not applicable. FRA was not buying from 1998/99 to 2001/02 so there was no FRA pan-territorial price in those years.
*Prices in 1996/97 and 1997/98 are averages across districts where the FRA was active.
†Initial price of K30,000 raised to K40,000 in Aug. 2002.
‡Increased to K55,000 in September 2008.
Sources: FRA; CSO/MACO Crop Forecast & Post-Harvest Surveys.

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Table 2

Zambian government spending on FRA activities and fertiliser subsidy programmes, 2002–11 budget years

Year	Spending on FRA	Spending on fertiliser subsidy programmes*	Total agricultural sector spending (FRA% in parentheses)		Total agricultural sector Poverty Reduction Programme spending (FRA% in parentheses)		Exchange rate (ZMK/US$)
Billion ZMK (nominal)							
2002	0.05	17.79	171.35	(0.03%)	—		4,399
2003	52.22	50.00	291.33	(17.93%)	—		4,733
2004	47.20	98.05	365.69	(12.91%)	—		4,779
2005	59.13	139.99	520.43	(11.36%)	—		4,464
2006	140.00	184.05	722.27	(19.38%)	334.81	(41.8%)	3,603
2007	205.00	204.54	1,135.71	(18.05%)	440.64	(46.5%)	4,003
2008	340.00	492.08	1,308.70	(25.98%)	—		3,746
2009	198.31	565.12	1,328.53	(14.93%)	819.54	(24.2%)	5,046
2010	1,204.09	589.01	1,967.68	(61.19%)	1,808.75	(66.6%)	4,797
2011	1,674.00	895.39	2,979.00	(56.19%)	2,609.21	(64.2%)	4,861

Notes: —, Data not available. *Fertiliser subsidy programmes refer to the Fertiliser Support Programme (2002–08) and the Farmer Input Support Programme (2009–11).
Sources: GRZ (various years); World Bank World Development Indicators database.

data and focuses on the decades prior to and during structural adjustment (e.g. Jansen, 1991; Krueger, 1991, 1996; Schiff and Valdés, 1991).[4] The use of household panel survey data facilitates an examination of the micro-level processes through which GMBs/SGRs affect smallholder behaviour. Moreover, it is widely known that African farmers are highly heterogeneous and the use of household panel survey data enables investigation of how GMB/SGR operations differentially affect smallholders with varying levels of land or other productive assets – something that was not feasible in the past due to lack of disaggregated data.

A third contribution of the article is that it develops and then operationalises a conceptual model of smallholder factor demand and output supply in the context of dual output marketing channels when harvest time prices in both channels, and the availability of one of the channels, are unknown at planting time.[5] To our knowledge, this article is the first to develop such a model. The main purpose of the conceptual model is to support our empirical model. However, the conceptual model and linked empirical strategy should have wide applicability beyond the Zambia/FRA case, for example

[4]Key exceptions are Mather and Jayne (2011), which is based on household panel survey data and Kutengule *et al.* (2006). The latter estimates the effects of proximity to Agricultural Development and Market Corporation (a GMB) facilities on household per capita expenditures in Malawi. However, the data used in Kutengule *et al.* are essentially cross-sectional, and so time invariant unobserved heterogeneity could not be adequately controlled for.

[5]The FRA, for example, does not announce its pan-territorial purchase price or where or how much it intends to buy until harvest time. Nor do farmers know at planting time what prices private traders will offer at harvest.

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to other countries where government entities buy products alongside private sector actors, or where there are multiple private sector marketing channels.

The article has four objectives. The first is to develop a conceptual model of smallholder factor demand and output supply in a dual channel marketing system. The second objective is to operationalise the conceptual model and use household panel survey data from Zambia to econometrically estimate the effects of the FRA's maize pricing and purchase policies on smallholder area planted, yields and quantities harvested of maize versus other crops. We test the hypotheses that FRA policies affect smallholders' expected maize price, which in turn stimulates a supply response.[6] We also test the conventional wisdom in Zambia that FRA-induced increases in maize production have come at the expense of other crops. The third objective of the article is to use the estimation results to explore how smallholders' supply response to FRA activities varies by landholding size, which is strongly positively correlated with household income (Jayne *et al.*, 2003). The fourth and final objective is to discuss the policy implications of the findings, including the implications of FRA's distributional effects by landholding size for its effectiveness as a poverty reduction programme.

The remainder of the article is organised as follows. The next section provides an overview of the Zambian government's role in maize marketing from independence to the present, with particular emphasis on the FRA's domestic maize purchases during the article's study period (1999/2000 to 2007/08). We then summarise smallholder maize sales to the FRA in the maize marketing years captured in the household panel survey data (2000/01, 2003/04 and 2007/08).[7] Subsequent sections describe the conceptual framework, data, empirical application and results. The final section of the article discusses the conclusions and policy implications.

2. The Zambian Government's Role in Maize Marketing

Grown by approximately 80% of smallholders and providing nearly 60% of the calories consumed in the country, maize is the dominant food crop in Zambia (Dorosh *et al.*, 2009). The Zambian government has been directly involved in maize marketing in almost every year from independence to the present. Until 1989, maize marketing in Zambia was controlled and subsidised by the government parastatal National Agricultural Marketing Board. While the controlled maize marketing system coupled with input and credit subsidies succeeded in increasing smallholder maize production in some areas, the system proved fiscally unsustainable and Zambia implemented a series of agricultural market reforms beginning in the late 1980s (Howard and Mungoma, 1996). The National Agricultural Marketing Board was abolished in 1989 and other restrictions on private sector participation in maize milling and trade were relaxed in the early 1990s (Jayne and Jones, 1997).

Following these market reforms, the Zambian government established the FRA in 1996 when it enacted the Food Reserve Act of 1995. FRA's original mandate was to establish and administer a national food reserve (GRZ, 1995). Table 1 summarises FRA's activities and major phases of its involvement in Zambian maize markets from

[6]Throughout the article we use the terms 'supply response' and changes in 'output supply' interchangeably and as shorthand for changes in area planted, yields and/or quantities harvested.

[7]The maize marketing year in Zambia is from May to April. The agricultural year is from October to September.

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its establishment in 1996 up to the 2012/13 maize marketing year. During its first two years in operation (1996/97 and 1997/98, 'Phase I' in Table 1), FRA purchased minimal quantities of maize and operated in only a handful of districts. In an attempt to be consistent with the government's general shift toward market-oriented policies, FRA procured maize through private traders at roughly the market price (C. Kabaghe, personal communication, 2010). It purchased no maize in Zambia in the following four years due to lack of funding (1998/99 to 2001/02, 'Phase II' in Table 1). The first wave of panel data used in this article covers the 1999/2000 agricultural year and the 2000/01 maize marketing year. Note that at the time planting decisions were made in 1999, the FRA had not purchased maize in Zambia for two years and had no plans to do so for the foreseeable future.

The FRA's role in maize marketing began to change dramatically in 2002 (the beginning of 'Phase III' in Table 1). That July, following drought-related poor harvests in many areas, the Zambian government allocated 12 billion Zambian Kwacha (ZMK) to the FRA to buy 15,000 MT of maize directly from smallholders in eight surplus districts (FEWSNET and WFP, 2002).[8] FRA set up satellite depots to which smallholders delivered their maize. Sourcing maize directly from smallholders rather than through private traders marked a distinct change in FRA procurement practices. By the end of October 2002, the FRA had purchased 9,059 MT in eight districts. Thus, at planting time in the 2002/03 agricultural season (captured in the second wave of the panel data used in this article), the FRA was buying maize directly from smallholders for the first time since its establishment but in only 8 of Zambia's 72 districts.

Despite an improved harvest in 2003, that May the FRA announced plans to purchase 205,700 MT of maize directly from smallholders in 37 districts at a pan-territorial price. This was the first time since 1992 that the Zambian government announced a pan-territorial price for maize (FEWSNET, 2003a,b). FRA ultimately purchased only 54,847 MT (21% of smallholder maize sales) due to funding shortfalls but its ambitious purchase target signaled its intention to become a major player in the Zambian maize market.

By 2005/06 (the beginning of 'Phase IV' in Table 1), FRA's share of smallholder maize sales exceeded 50%, making it the dominant buyer of maize in Zambia. Its purchases escalated in 2006/07 to 389,510 MT (equivalent to 86% of smallholder maize sales). Thus, at planting time in the 2006/07 agricultural year (captured in the third wave of the panel survey), the FRA was the dominant buyer of smallholder maize in Zambia and had purchased maize directly from smallholders for five consecutive years. At 38,000 ZMK per 50-kg bag, the FRA 2006/07 buy price was well above wholesale maize market prices, which ranged from approximately 23,000–31,000 ZMK (Figure 1; Mason and Myers, 2013). The Agency's buying presence had expanded from 10 districts in 2002/03 to 53 districts in 2006/07 (Table 1). The FRA purchased nearly 400,000 MT again in 2007/08. FRA purchases were lower in 2008/09 and 2009/10 due to a combination of lower budget allocations, slow release of funds from the Treasury, and stiffer competition from private traders (Mason and Myers, 2013). The lull was short-lived, and FRA purchases surged to nearly 900,000 MT in 2010/11 following a bumper maize harvest, and have remained very high since then.

Although the FRA first became directly involved in maize marketing in 2002, it was only in 2005 that maize marketing became an official FRA function (GRZ, 2005).

[8]The exchange rate in July 2002 was 4,527 ZMK per US$.

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Since then, the Agency's objectives have been to raise rural incomes, improve national food security and stabilise crop prices (FRA, n.d.). Poverty reduction is at least an implicit objective, as FRA activities are funded through the Zambian government's Poverty Reduction Programmes facility.

What does the FRA do with the maize it purchases from farmers? It stores the maize and later sells most of it to large industrial millers and trading firms via a tender process. FRA occasionally sells maize directly to consumers at a pan-territorial price or exports it. Although the FRA typically buys maize at above-market prices, it often sells maize on the domestic market at below-market prices.

In this article, we focus on the effects of the FRA's maize purchase price and quantities purchased on smallholder behaviour. The FRA may also affect smallholder behaviour through its maize storage and sales activities, and through general equilibrium effects.[9] However, such effects are beyond the scope of this article.

3. Smallholder Maize Sales to the FRA and Household Characteristics

Although the FRA purchased as much as 86% of smallholders' marketed maize during the study period, smallholder sales to the FRA were highly concentrated among a small number of wealthier households. Table 3 summarises smallholder maize sales to the FRA during the marketing years captured in the second and third waves of the panel survey (2003/04 and 2007/08) and compares the socio-economic characteristics of sellers and non-sellers.[10] Less than 1% of smallholder households sold maize to the Agency in 2003/04. This percentage rose to nearly 10% in 2007/08 as the FRA scaled up its activities. In 2007/08, participating households sold an average of 2.76 MT to the FRA. Households that sold maize to the Agency had considerably larger landholdings, more farm assets, and heads with higher educational attainment, and were less likely to be female-headed than households that did not (Table 3). Households with larger landholdings and more farm assets are expected to produce a larger marketable surplus of maize, and hence be more likely to sell to the FRA. Educational attainment is positively correlated with landholding size and farm assets, while female-headed households tend to have smaller landholdings and fewer farm assets.

4. Conceptual Framework

FRA policies influence the maize price that smallholders expect to receive at the next harvest, which, in turn, affects farmers' factor demand and output supply. In modeling these effects, four key features of the farmers' decision environment need to be taken into account. First, at planting time they do not know the prices at which the FRA and private traders will buy at the next harvest. Second, households do not know if the FRA will be buying maize in their area. Third, the FRA pan-territorial buy price is *not* a floor price. Private traders can legally buy maize for more or less. Fourth, the *farmgate* FRA price (i.e. the FRA pan-territorial price adjusted for transfer costs from the homestead to an FRA satellite depot) varies across households.

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[9]See Mason and Myers (2013) and Jayne *et al*. (2008) for analyses of the effects of the FRA and NCPB on equilibrium maize prices in Zambia and Kenya, respectively.

[10]The FRA did not buy maize in Zambia during the marketing year captured by the first wave of the panel survey (2000/01).

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Table 3
Smallholder socio-economic characteristics by participation in FRA

Descriptive result	Marketing year	Sold maize to FRA? Yes	No
Percentage of smallholder	2003/04	0.8%	99.2%
households	2007/08	9.7%	90.3%
Mean (median) kg of maize	2003/04	2,315 (600)	0
sold to FRA	2007/08	2,764 (1,250)	0
Mean landholding size (ha)	2003/04	3.65	2.11
	2007/08	3.65	1.84
Mean value of farm assets	2003/04	59.4	23.1
(100,000 ZMK, 2007/08 = 100)	2007/08	65.7	18.8
Percentage of female-headed	2003/04	8.6%	21.9%
households	2007/08	14.0%	25.0%
Median education of HH head	2003/04	8	5
(highest grade completed)	2007/08	7	5

Note**:** Farm assets are ploughs, harrows and ox carts. FRA, Food Reserve Agency; HH, household.
Sources**:** CSO/MACO/FSRP 2004 and 2008 Supplemental Surveys.

With these features in mind, the starting point for our conceptual framework is a separable model of the agricultural household, i.e. we assume household production and consumption decisions are made recursively rather than simultaneously (Singh *et al.*, 1986). Separability is assumed because our focus is on the effects of the FRA on household production decisions, not consumption decisions. As will become apparent below, focusing on production decisions separately from consumptions decisions is a useful simplification because, even in this case, modeling the effects of a dual marketing channel introduces considerable complexities to both theoretical and empirical models. Assuming separability allows us to highlight the key features and household decisions of interest, while maintaining the tractability of the model.

To our knowledge, this article is the first to model household production decisions in a dual marketing channel framework with price uncertainty. Articles by Goetz (1992) and Key *et al.* (2000), while useful for highlighting the role of transactions costs in household foodgrain supply and market participation decisions, both assume a single marketing channel and perfect foresight with respect to output prices. Here we relax the assumptions of a single marketing channel and perfect foresight but abstract away from transactions costs and non-separability in order to highlight the price expectations and dual marketing channel issues that are the focus of the paper.

Consider an expected profit-maximising producer with implicit production function $G(q, \boldsymbol{q_0}, \boldsymbol{x}; \boldsymbol{z}) = 0$, where q is the quantity of maize produced, $\boldsymbol{q_0}$ 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 variables not under direct control of the producer (e.g. rainfall). We assume a single (private sector) marketing channel for non-maize crops but two potential marketing channels for maize: private sector and FRA. The private sector channel is always available but the FRA channel may or may not be available. Let γ be a Bernoulli random variable equal to one if the FRA channel is available at

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harvest, and zero otherwise. Let p_f, p_p, and $\boldsymbol{p_0}$ be, respectively, the farmgate FRA, private sector maize prices and a vector of other crop prices at the next harvest. These prices and γ are unobserved random variables at planting time. Assume that the household sells maize to only one marketing channel (the one with the higher farmgate price) and that variable input prices ($\boldsymbol{w}$) are known at planting time.[11] Then, the household's expected profit maximisation problem is:

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

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

Assuming that γ is independent of p_f and p_p but allowing p_f and p_p to be correlated, equation (1a) can be simplified to:

$$\max_{q,\boldsymbol{q_o},\boldsymbol{x}} \{E(\gamma)E[\max(p_f, p_p)] + [1 - E(\gamma)]E(p_p)\}q + \boldsymbol{q_o}E(\boldsymbol{p_0}) - \boldsymbol{xw} \tag{1a'}$$

Let $\boldsymbol{y} = [q,\ \boldsymbol{q_0},\ \boldsymbol{x}]'$ be a vector of output and variable input quantities and let

$$p^* \equiv E(\gamma)E[\max(p_f, p_p)] + [1 - E(\gamma)]E(p_p) \tag{2}$$

be the household's expected farmgate maize price. Then solving equation (1a′) subject to (1b) gives factor demand and output supply functions of the form:

$$\boldsymbol{y} = \boldsymbol{y}(p^*, E(\boldsymbol{p_0}), \boldsymbol{w}; \boldsymbol{z}). \tag{3}$$

There is no general expression for the expected value of the maximum of two random variables, so to evaluate p^* we need an assumption on the joint distribution of (p_f, p_p). Two distributions commonly used in the commodity price literature are bivariate normal and lognormal (see, e.g., Myers, 1989; Chavas and Holt, 1990). We assume bivariate lognormality as an approximation.[12]

Let $E(\ln p_j) = \mu_j$, $Var(\ln p_j) = \sigma_j^2$, $j = f, p$, 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 $\ln p_p$. Following Lien (2005), then under bivariate lognormality:

$$\begin{aligned} E[\max(p_f, p_p)] = {} & \exp[\mu_f + (\sigma_f^2/2)]\left\{1 - \Phi\left[\frac{\mu_p - \mu_f - \sigma_f^2 + \sigma_{fp}}{\sqrt{\sigma_f^2 + \sigma_p^2 - 2\sigma_{fp}}}\right]\right\} \\ & + \exp[\mu_p + (\sigma_p^2/2)]\left\{1 - \Phi\left[\frac{\mu_f - \mu_p - \sigma_p^2 + \sigma_{fp}}{\sqrt{\sigma_f^2 + \sigma_p^2 - 2\sigma_{fp}}}\right]\right\} \end{aligned} \tag{4a}$$

$$E(p_p) = \exp[\mu_p + (\sigma_p^2/2)]. \tag{4b}$$

[11]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 sector buyers and the FRA.

[12]The lognormal is selected over the normal distribution because: (i) it is used more frequently in the commodity price analysis literature; (ii) empirical tests suggest that the lognormal distribution is preferred to the normal distribution when modeling crop prices (Goodwin *et al.*, 2000); and (iii) the lognormal distribution ensures that there is zero probability of negative prices.

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Given data, appropriate functional forms, and producers' subjective assessments of μ_f, μ_p, σ_f^2, σ_p^2, σ_{fp}, $E(\gamma)$ and $E(\boldsymbol{p_0})$, then the supply and factor demand equation (3) can be estimated subject to the specifications in equations (2) and (4).

5. Data

The data are from a three-wave, nationally representative longitudinal survey of rural smallholder households in Zambia. The first wave was done in two parts: the 1999/2000 Post-Harvest Survey conducted by the Zambian Central Statistical Office and Ministry of Agriculture and Cooperatives in August–September 2000, and the linked Central Statistical Office/Ministry of Agriculture and Cooperatives/Food Security Research Project Supplemental Survey conducted in May 2001. The second and third waves were the Supplemental Surveys conducted in May 2004 and June–July 2008.

A total of 7,699 rural households were interviewed for the 1999/2000 Post-Harvest Survey. See Megill (2005) for details on the sampling design. For the 2001 Supplemental Survey, 6,922 (89.9%) of the 1999/2000 Post-Harvest Survey households were successfully revisited to collect additional information on household demographics, off-farm income, remittances and other details. Of the 6,922 households interviewed for the 2001 Supplemental Survey, 5,358 (77.4%) were successfully re-interviewed for the 2004 Supplemental Survey, and 4,286 (80.0%) of the 2004 Supplemental Survey households were successfully re-interviewed for the 2008 Supplemental Survey. Unless otherwise noted, we use the unbalanced panel of households that were interviewed in at least the 2001 and 2004 Supplemental Surveys, if not the 2008 Supplemental Survey.

Given non-trivial attrition rates between survey rounds, attrition bias is a potential problem. However, tests for attrition bias as described in Wooldridge (2010, p. 837) fail to reject the null hypothesis of no attrition bias in all cases ($0.27 < P < 0.94$).

Other data used in the analysis are: (i) FRA administrative records on yearly district-level maize purchases; (ii) rainfall data from the Zambia Meteorological Department; (iii) crop prices from Central Statistical Office/Ministry of Agriculture and Cooperatives Post-Harvest Surveys for 1998/99, 2001/02 and 2005/06; and (iv) wholesale maize prices from the Ministry of Agriculture and Cooperative's Agriculture Market Information Center.

6. Empirical Models and Estimation Strategy

To operationalise the conceptual framework, we first need to estimate households' subjective values for μ_f, μ_p, σ_f^2, σ_p^2, σ_{fp} and $E(\gamma)$. We hypothesise that these values are influenced by past FRA policies and other factors. We then use the estimated subjective values to construct a household's expected farmgate maize price as per equations (2) and (4), and include this as an explanatory variable in the crop area planted, yield and quantity harvested regressions. FRA policies are hypothesised to influence smallholder output supply through the expected maize price. If (i) a given FRA policy has a statistically significant marginal effect on farmers' expected maize price, and (ii) the expected maize price has a statistically significant marginal effect on a given dimension of farmers' supply response (area, yield or quantity harvested), then we conclude that the FRA policy affects that behaviour. The marginal effect of the FRA policy is computed by applying the chain rule to (i) and (ii).

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6.1. Estimating subjective values for μ_f and μ_p

Similar to Nerlove and Fornari's (1998) quasi-rational expectations approach, estimates of households' subjective values for expected log maize prices in the FRA and private sector channels are obtained by first estimating:

$$\ln p_{j,i,t} = \mathbf{\Omega}_{i,t-1}\boldsymbol{\beta}_j + c_{j,i} + \varepsilon_{j,i,t} \quad \text{for } j = f, p \tag{5}$$

where $p_{j,i,t}$ is the channel j farmgate maize price received by household i in harvest year t; $\mathbf{\Omega}_{i,t-1}$ is a vector of information observed by the household at planting time; $\boldsymbol{\beta}_j$ is a vector of parameters to be estimated; $c_{j,i}$ is time invariant 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, *inter alia*, maize prices in the private sector and FRA marketing channels at the previous harvest and the volume of maize purchased by the FRA in the household's district during the previous marketing year. See Tables A1 and A2 in online Appendix A for a full list of the variables included in $\mathbf{\Omega}_{i,t-1}$ and associated summary statistics.[13]

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. Estimating equation (5) poses two main econometric challenges. First, the unobserved heterogeneity ($c_{j,i}$) may be correlated with the observed covariates in equation (5) (call them $\boldsymbol{X_{i,t}}$). In order to use the CRE approach to control for $c_{j,i}$ and consistently estimate the parameters in equation (5), we first need to assume strict exogeneity of $\boldsymbol{X_{i,t}}$ conditional on $c_{j,i}$, i.e. $E(\varepsilon_{j,i,t}|\boldsymbol{X_i}, c_{j,i}) = 0$, $t = 1, 2, \ldots, T$. If in addition to strict exogeneity we assume that $c_{j,i} = \psi_j + \overline{\boldsymbol{X_i}}\boldsymbol{\xi}_j + a_{j,i}$ and $c_{j,i}|\boldsymbol{X_i} \sim Normal(\psi_j + \overline{\boldsymbol{X_i}}\boldsymbol{\xi}_j, \sigma^2_{j,a})$, where $\overline{\boldsymbol{X_i}}$ is the time average of $\boldsymbol{X_{i,t}}$, $t = 1,\ldots,T$, and $\sigma^2_{j,a}$ is the variance of $a_{j,i}$, then we can control for $c_{j,i}$ by including $\overline{\boldsymbol{X_i}}$ as additional explanatory variables in the POLS regression (Mundlak, 1978; Chamberlain, 1984; Wooldridge, 2010).

Although equation (5) is estimated using data from households that sold maize to marketing channel j, once estimated, equation (5) can be used to obtain predicted values for *all* households in the sample. This is possible because the variables in $\mathbf{\Omega}_{i,t-1}$ are observed for all households whether or not they sold maize to marketing channel j. These predicted values are used as measures of households' subjective values for μ_f and μ_p, i.e.,

$$\hat{\mu}_{j,i,t} = \mathbf{\Omega}_{i,t-1}\hat{\boldsymbol{\beta}}_j + \hat{c}_{j,i} \quad \text{for } j = f, p. \tag{6}$$

The second econometric challenge is that although roughly 80% of Zambian smallholder households grow maize, only approximately 30% sell the crop in any given year. An even smaller percentage of households sell maize to the FRA (Table 3). Predicted log maize prices obtained for all smallholder households from parameter estimates based on data for those that sold maize to marketing channel j could therefore be subject to selection bias. However, tests as described in Wooldridge (2010, p. 815) fail to reject the null hypothesis of no sample selection bias in all cases ($P > 0.10$).

[13]Many of the covariates in $\mathbf{\Omega}_{i,t-1}$ are similar to the explanatory variables in Bwalya *et al.*'s (2013) study of the factors affecting smallholder maize market participation in Zambia. Bwalya *et al.* do not, however, investigate the effects of the FRA or maize prices on smallholder market participation (or supply response).

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6.2. *Estimating subjective values for σ_f^2 and σ_p^2*

From equation (5), note that:

$$\sigma^2_{j,i,t} = E(\varepsilon^2_{j,i,t}), \quad \text{for } j = f, p. \tag{7}$$

To obtain subjective variances we first estimate:

$$\ln \hat{\varepsilon}^2_{j,i,t} = \Omega_{i,t-1}\boldsymbol{\delta}_j + b_{j,i} + v_{j,i,t} \quad \text{for } j = f, p, \tag{8}$$

using CRE-POLS where $\hat{\varepsilon}^2_{j,i,t}$ are the squared residuals from equation (5), $\boldsymbol{\delta}_j$ is a vector of parameters to be estimated, $b_{j,i}$ is time invariant unobserved heterogeneity, and $v_{j,i,t}$ is the error term. We obtain predicted values $\widehat{\hat{\varepsilon}^2_{j,i,t}}$ for each household in the sample and use this as the household's subjective value for $\sigma^2_{j,i,t}$, i.e. $\hat{\sigma}^2_{j,i,t} \equiv \widehat{\hat{\varepsilon}^2_{j,i,t}}$. The econometric challenges and estimation strategy for equation (8) are similar to those described in the previous sub-section. We find no evidence of selection bias.

6.3. *Estimating subjective values for σ_{fp}*

We assume that the correlation coefficient between ln p_f and ln p_p is a constant ($\bar{\rho}$) and estimate it as the sample correlation between $\hat{\varepsilon}_{f,i,t}$ and $\hat{\varepsilon}_{p,i,t}$. A household's subjective value for σ_{fp} is then estimated as $\hat{\sigma}_{fp,i,t} \equiv \bar{\rho}\hat{\sigma}_{f,i,t}\hat{\sigma}_{p,i,t}$.

6.4. *Estimating subjective values for $E(\gamma)$*

The 2004 and 2008 Supplemental Surveys did not ask respondents if the FRA channel was available in their area 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, $\gamma_{i,t} \equiv 1$ 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 probit model:

$$E(\gamma_{i,t}|\Omega_{i,t-1}, e_i) = \Pr(\gamma_{i,t} = 1|\Omega_{i,t-1}, e_i) = \Phi(\Omega_{i,t-1}\boldsymbol{\omega} + e_i), \tag{9}$$

where $\boldsymbol{\omega}$ is a vector of parameters to be estimated and e_i is time invariant unobserved heterogeneity.[14] Equation (9) is estimated by CRE-probit to control for e_i. (Wooldridge, 2010). There is no selection bias issue because $\gamma_{i,t}$ is observed for all households. All 1999/2000 households and 2002/03 households outside of the eight districts where the FRA had purchased maize as of planting time in 2002 are excluded from the probit and assigned zero probability of selling to the FRA at the next harvest.

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[14]Estimating γ as the predicted probability that the household will sell maize to the FRA at the next harvest based on information available at planting time is consistent with the survey sampling design. The survey data are representative at the household- and provincial-levels. During the study period there were nine provinces in Zambia, and each contained an average of about 120,000 smallholder households in the first wave of the survey. Estimating γ as the predicted probability that any household in the household's province will sell maize to the FRA would greatly overestimate the probability that the FRA channel will be available to a given household. Unfortunately, the data are not representative at an intermediate level of aggregation, such as the ward, or else we could use, for example, the predicted probability that any household in the household's ward will sell maize to the FRA as our estimate of γ. (There were 1,422 wards in Zambia during the study period.)

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Having obtained estimates 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 $\hat{\gamma}_{i,t}$, the expected farmgate maize price ($\hat{p}^*_{i,t}$) is constructed according to equations (2) and (4). We also compute the average partial effects (APEs) of FRA policies on the expected maize price by taking the partial derivative of the expected maize price (equations (2) and (4)) with respect to the farmgate FRA price or FRA district-level maize purchases in the previous year. (Recall that these two variables are included in $\boldsymbol{\Omega}_{i,t-1}$ and are therefore explanatory variables in all of the auxiliary regressions used to construct the expected maize price.) Standard errors for these APEs are obtained via bootstrapping to account for the multiple stage estimation.

6.5. Empirical output supply equations

The empirical output supply equations are specified as:

$$y_{i,t} = \alpha_0 + \alpha_1 \hat{p}^*_{i,t} + \boldsymbol{p}_{\mathbf{0},k,t-1}\boldsymbol{\alpha}_{\mathbf{2}} + \boldsymbol{w}_{i,t}\boldsymbol{\alpha}_{\mathbf{3}} + \boldsymbol{z}_{i,t}\boldsymbol{\alpha}_{\mathbf{4}} + \alpha_5 govtfert_{i,t} + r_i + u_{i,t} \tag{10}$$

where $y_{i,t}$ is a measure of crop output (discussed further below), $\hat{p}^*_{i,t}$ is the expected farmgate maize price (ZMK/kg); $\boldsymbol{p}_{\mathbf{0},k,t-1}$ is a vector of provincial (k) level prices for other crops at the previous harvest in ZMK/kg; $\boldsymbol{w}_{i,t}$ includes an agricultural wage rate (ZMK to weed a 0.25 ha field) and the farmgate fertiliser market price in ZMK/kg; $\boldsymbol{z}_{i,t}$ 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-subsidised fertiliser acquired by the household; r_i is time invariant unobserved heterogeneity; and $u_{i,t}$ is the error term. We include $govtfert_{i,t}$ as a regressor because along with the FRA, the fertiliser subsidy programme is the other major government initiative that is likely to affect farmers' crop production decisions. Excluding it from the regression would be likely to cause omitted variables bias.[15] Following Ricker-Gilbert *et al.* (2011), $govtfert_{i,t}$ is treated as a quasi-fixed factor because households cannot freely choose how much subsidised fertiliser they acquire.

In equation (10), expected prices for non-maize crops ($E(\boldsymbol{p}_{\mathbf{0}})$) in harvest year t are proxied by prices in $t-1$. While this naïve price expectations assumption is much simpler than the specification of households' maize price expectations, insufficient data are available to estimate households' other price expectations in a similar way to maize. The commonly marketed crops for which lagged prices are available are groundnuts and sweet potatoes. (See Tables A1 and A2 in online Appendix A for summary statistics for all explanatory variables.)

Output supply equations are estimated for area planted and yield. Because quantity harvested is equal to area planted times yield, we apply the product rule to results for area planted and yield to compute the APEs of key variables of interest on quantity harvested. Area and yield equations are estimated for maize and 'other crops', namely, the 16 non-maize crops covered by all three Supplemental Surveys: cassava, sweet potato, sorghum, millet, groundnut, mixed bean, cotton, rice, sunflower, soybean, Irish potato, ground bean, cowpea, velvet bean, tobacco and coffee. An index of the quantity harvested of other crops is computed as the Fisher-Ideal Quantity Index for those 16 crops (FIQI) (Diewert, 1992, 1993). Theoretically consistent quantity indexes such as the FIQI are generally preferred to *ad hoc* methods of quantity

[15] See Mason and Jayne (2013) for details on Zambia's fertiliser subsidy programmes.

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aggregation over crops, such as computing the gross value of crop production.[16] The FIQI for the 16 other crops divided by the total hectares planted to those 16 crops also provides an index of the land productivity of those 16 crops. For simplicity, we refer to this as the 'yield of other crops' measured in FIQI/ha. Because changes in index values can be difficult to interpret in absolute terms, we also report changes in elasticity terms in the next section. See Table A3 in online Appendix A for summary statistics for the various dependent variables.

Two econometric challenges associated with estimating equation (10) are controlling for the unobserved heterogeneity (r_i) and testing and controlling for the potential endogeneity of $govtfert_{i,t}$. We control for unobserved heterogeneity using the fixed effects (FE) estimator and the correlated random effects (CRE) approach. The FE estimator is used to estimate equation (10) for all dependent variables. We also use CRE-Tobit to estimate the area planted equations for maize and other crops because these dependent variables are both equal to zero for 20% of the sample. A Tobit model may therefore characterise the full distribution of these variables better than a linear model.

With the exception of the quantity of subsidised fertiliser acquired by the household, all explanatory variables in equation (10) are assumed to be strictly exogenous (as required for CRE and FE to be consistent). $govtfert_{i,t}$ may be endogenous because subsidised fertiliser beneficiaries are not randomly selected. $govtfert_{i,t}$ is also a corner solution variable: most households acquire zero subsidised fertiliser, and the quantity acquired by recipients is approximately continuous. We follow Ricker-Gilbert *et al.* (2011) and Mason and Jayne (2013) and use the control function approach to test and control for the potential endogeneity of $govtfert_{i,t}$ (Rivers and Vuong, 1988; Vella, 1993). We employ the same instrumental variables (IVs) as Mason and Jayne: (i) a dummy variable equal to one if the household's constituency was won by the ruling party in the last presidential election; (ii) the absolute value of the percentage point spread between the ruling party and the lead opposition in the constituency; and (iii) the interaction of (i) and (ii). As shown in Table B1 in online Appendix B, (i) and (iii) are strongly related to the kg of subsidised fertiliser allocated to a household ($P < 0.001$). We maintain (and tests for over-identifying restrictions suggest) that the IVs are exogenous to a household's output supply after controlling for the observed covariates and unobserved heterogeneity in equation (10). Test results suggest that $govfert_{i,t}$ is indeed endogenous in all equations except for the other crops area equation estimated via FE. See Tables B2 and B3 in online Appendix B for details. Standard errors for equation (10) are computed using bootstrapping to account for the first-stage estimation of the expected maize price and the control function residuals (Wooldridge, 2010).

7. Results

We begin by presenting first stage results: the estimated marginal effects of the lagged farmgate FRA maize price and lagged FRA district-level maize purchases on a smallholder household's expected farmgate maize price. We then report the second stage results: the estimated marginal effects of the expected maize price on smallholders'

[16]See Diewert (1992) for a discussion of why the FIQI is preferred to other quantity indexes.

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crop output supply. Finally, we discuss the combined first and second stage results: the marginal effects of FRA policies on smallholder output supply.[17]

7.1. The marginal effects of FRA policies on a smallholder's expected farmgate maize price

Estimation results in Table 4 suggest that, of the two FRA policy variables (the lagged FRA farmgate maize price and lagged FRA purchases in a household's district), only the lagged FRA price has a statistically significant effect on a smallholder's expected maize price ($P < 0.10$).[18] The average elasticity (AE) of the lagged FRA price is positive and highly significant in the 2006/07 agricultural year (AE = 0.088, $P = 0.005$), when the FRA was a major player in the maize market (Table 4). However, as anticipated, the lagged FRA price had no statistically significant effect on smallholders' expected maize price in 2002/03. Recall that as of planting time that year, the FRA had only purchased maize in 8 of 72 districts and the quantities purchased were small. Moreover, the FRA had been dormant the four previous years (Table 1). Therefore, at planting time in 2002/03, smallholders would have had little reason to expect the FRA to be a major buyer of maize at the next harvest, and thus little reason for the lagged FRA price to influence their maize price expectations.

What are the channels through which the lagged FRA price affects smallholders' expected maize price? As shown in Table 5, increases in the lagged FRA price raise farmers' expected maize price by increasing the probability of their selling to the FRA at the next harvest and by raising their expected FRA price. The latter is consistent with the fact that it has proven difficult politically for the FRA to lower its buy price from one year to the next. Indeed, the FRA price has either increased or stayed the same every year since 2003/04 (Table 1).

7.2. Marginal effects of the expected farmgate maize price on smallholder output supply

APEs and AEs of crop output supply with respect to the expected farmgate maize price are summarised in Table 6. Results suggest that Zambian smallholders respond to an increase in the expected maize price by extensifying their maize production. A 1% increase in the expected maize price is associated with a 0.67% increase in the area planted to maize ($P = 0.023$, row B) but no statistically significant change in maize yield ($P = 0.245$). The area expansion combined with no change in yield result in an increase in maize quantity harvested of 0.67% for each 1% increase in the expected maize price ($P = 0.023$, row E). Changes in the expected maize price have no statistically significant effect on the area planted, yields or quantity harvested of other crops ($P > 0.10$, rows F–I).

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[17]Although we control for government fertiliser subsidies in the regressions, a detailed discussion of fertiliser subsidy effects is beyond the scope of the paper. See online Appendix B for the estimation results.

[18]Table 5 shows that lagged FRA maize purchases have marginally significant effects on the mean and variance of the farmgate private sector price, and on the probability of selling maize to the FRA. However, these effects are too weak to affect the overall expected farmgate price. After bootstrapping to take into account the multiple auxiliary regressions used to construct the expected maize price, lagged FRA maize purchases have no statistically significant effect on smallholders' expected maize price ($P = 0.172$).

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Table 4

AEs of the expected maize price with respect to FRA policies

AE of the expected maize price with respect to:	FRA farmgate maize price (t–1)		FRA district-level maize purchases (t–1)	
	AE	*P*	AE	*P*
Overall	**0.0415**	**0.053**	0.0241	0.172
By agricultural year:				
2002/03	0.00433	0.800	–9.15E-5	0.926
2006/07	**0.0882**	**0.005**	0.0546	0.167

Notes: *P*-values are based on 500 bootstrap replications. Results in bold are statistically significant at the 10% level or lower. Overall refers to both the 2002/03 and 2006/07 agricultural years. AE, average elasticity; FRA, Food Reserve Agency.
Source: Authors' calculation.

7.3. Marginal effects of the FRA farmgate maize price ($t-1$) on smallholder output supply

The positive marginal effect of the lagged FRA price on farmers' expected maize price coupled with the positive marginal effect of the expected maize price on their maize area planted and maize quantity harvested suggest that increases in the lagged FRA price result in statistically significant ($P < 0.10$) increases in these two dimensions of smallholder supply response. More specifically, based on the CRE-Tobit results, a 1% increase in the lagged FRA price raises smallholders' maize area planted and quantity harvested by 0.06%. The expected maize price has no statistically significant effect on the area, yield or quantity harvested of other crops; consequently, the lagged FRA price has no statistically significant effect on these behaviours. The empirical evidence is therefore consistent with the conventional wisdom in Zambia that FRA policies have encouraged an increase in maize production. The evidence does not suggest that the expansion of maize area has come at the expense of area planted to other crops in *absolute* terms. However, the fact that area devoted to maize increases but area planted to other crops does not change implies an increase in total area planted, and thus that FRA activities incentivise an increase in the *share* of total area planted to maize. Area planted to other crops declines in share of total area terms. These results are consistent with the aggregate data, which indicate that as the FRA has ramped up its activities since 2002/03, maize area planted has increased in both absolute terms and as a share of total area planted. In contrast, the share of area planted to other crops has declined but total area planted to these crops has not changed markedly (Tembo and Sitko, 2013).

If FRA activities are incentivising an expansion of maize area without reducing the (absolute) area planted to other crops, what are the effects of FRA activities on fallow and virgin land? We find some evidence that, other factors constant, smallholders reduce the area under fallow in response to an increase in the expected maize price, and hence in response to an increase in the lagged FRA price. We estimated FE and CRE-Tobit models for hectares under fallow similar to equation (10).[19] The FE

[19]Approximately 39% of the observations in our sample have some fallow land. See Table A3 in online Appendix A for summary statistics and Table B4 in online Appendix B for the full regression results for hectares under fallow. Survey respondents reported the area of fallow fields in addition to the area of cropped fields, allowing us to estimate expected maize price and FRA effects on area under fallow just as we have done for maize and other crops area planted.

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Table 5

Results from auxiliary regressions used to construct the expected maize price

Dependent variable:	(A) Log farmgate private sector maize price		(B) Log sqd. residuals from (A)		(C) Log farmgate FRA maize price		(D) Log sqd. residuals from (C)		(E) HH sold maize to FRA = 1;= 0 otherwise	
Estimator:	CRE-POLS		CRE-POLS		CRE-POLS		CRE-POLS		CRE-Probit	
Explanatory variables:	Coef.	*P*	Coef.	*P*	Coef.	*P*	Coef.	*P*	APE	*P*
Log farmgate FRA maize price (ZMK/kg, $t-1$)	0.106	0.277	0.612	0.371	0.345***	0.000	−3.203	0.299	0.286***	0.001
Log farmgate FRA maize price × 1999/2000 agricultural year	0.329**	0.021	−0.335	0.915						
FRA district-level maize purchases (‘000 MT, $t-1$)	0.00437*	0.089	−0.0819*	0.087	−0.00213	0.357	0.0172	0.790	0.0101*	0.082
FRA district-level maize purchases, squared			0.00331	0.135						
Log maize producer price (ZMK/kg, $t-1$)	0.0528	0.424	−3.167	0.887	0.00921	0.828	−2.070	0.200	−0.144**	0.027
Log maize producer price, squared			0.155	0.929						
Log regional wholesale maize price, Oct. current agric. year (ZMK/kg)	0.0374	0.287	0.551	0.101					0.0410	0.567
Log farmgate market price of fertiliser (ZMK/kg)	0.0219	0.663	−0.353	0.285	0.0302	0.360	−2.024	0.111	−0.118**	0.016
Log wage to weed 0.25 ha field (‘000 ZMK)	−0.0332	0.355	−0.147	0.590	−0.0137	0.362	0.342	0.642	−0.0353	0.184
Landholding size (ha)	−6.74E-4	0.786	−0.0109	0.151	8.98E-4	0.332	−0.0361	0.337	0.0101***	0.000
Landholding size, squared	−9.90E-6	0.352								

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Table 5
(*Continued*)

Dependent variable:	(A) Log farmgate private sector maize price		(B) Log sqd. residuals from (A)		(C) Log farmgate FRA maize price		(D) Log sqd. residuals from (C)		(E) HH sold maize to FRA = 1;= 0 otherwise	
Estimator:	CRE-POLS		CRE-POLS		CRE-POLS		CRE-POLS		CRE-Probit	
Explanatory variables:	Coef.	*P*	Coef.	*P*	Coef.	*P*	Coef.	*P*	APE	*P*
Adult equivalents	0.00280	0.448	0.0208	0.515	−0.00155	0.433	0.0221	0.757	3.55E-4	0.878
Age of household head	6.09E-4	0.702	−0.157***	0.001	7.96E-4	0.237	0.00983	0.764	4.26E-4	0.611
Age of household head, squared			0.00140***	0.001						
Highest level of education completed by HH head (base is none):										
Lower primary (grades 1–4) (=1)	0.0330	0.263	0.447**	0.038	0.0504**	0.011	0.0163	0.985	−0.0187	0.274
Upper primary (grades 5–7) (=1)	0.0443	0.124	0.450**	0.049	0.0364*	0.082	0.0860	0.928	−0.0117	0.520
Secondary (grades 8–12) (=1)	0.0267	0.482	0.259	0.320	0.0633***	0.003	0.688	0.477	0.00101	0.965
Post-secondary education (=1)	0.0977*	0.085	0.456	0.301	0.0249	0.329	−0.0957	0.937	−0.0163	0.616
Female-headed household (=1)									−0.0138	0.443
Gender & residence status of HH head (non-resident if <6 months; base is resident male):										
Female-headed with non-resident husband (=1)	−0.0849	0.262	−0.0371	0.930	−0.0603**	0.023	0.465	0.634		

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Table 5
(*Continued*)

Dependent variable:	(A) Log farmgate private sector maize price		(B) Log sqd. residuals from (A)		(C) Log farmgate FRA maize price		(D) Log sqd. residuals from (C)		(E) HH sold maize to FRA = 1;= 0 otherwise	
Estimator:	CRE-POLS		CRE-POLS		CRE-POLS		CRE-POLS		CRE-Probit	
Explanatory variables:	Coef.	*P*	Coef.	*P*	Coef.	*P*	Coef.	*P*	APE	*P*
Female-headed with no husband (=1)	0.00235	0.938	0.235	0.386	0.0437***	0.003	0.419	0.503		
HH owns radio (=1)	0.0260	0.123	−0.00644	0.957	0.0103	0.194	0.402	0.391	0.0132	0.198
HH owns cell phone (=1)	−0.0202	0.461	0.305	0.256	0.00472	0.585	0.451	0.267	0.0265*	0.052
HH does not own but has access to cell phone (=1)	−0.00944	0.675	0.0779	0.754	0.00167	0.838	−0.279	0.417	0.0202**	0.043
HH owns bicycle (=1)	0.0184	0.251	−0.00859	0.944	−0.00991	0.271	0.365	0.379	0.0240**	0.039
HH owns motorcycle (=1)	0.00696	0.906	0.742**	0.036	0.0488	0.295	0.468	0.749		
HH owns car, pick-up, van, truck/lorry, or tractor-trailer (=1)	0.0136	0.837	0.509	0.211	0.00352	0.826	−0.794	0.248	0.0268	0.568
HH owns ox-cart (=1)	5.93E-5	0.998	0.223	0.291	−7.71E-4	0.932	−0.0736	0.903	0.0316	0.155
Km from center of SEA to nearest district town (as of 2000)	8.16E-4	0.859	0.00918***	0.000	2.53E-4	0.246	0.0128	0.192	2.43E-4	0.423
Km from center of SEA to nearest tarred/main road (as of 2000)	−4.76E-4	0.260	−0.00617**	0.017	3.21E-5	0.719	−0.00443	0.358	−3.58E-5	0.835
Km from center of SEA to nearest feeder road (as of 2000)	−0.00535*	0.054	−0.0157	0.200	6.48E-4	0.601	−0.0696	0.347	−0.00690	0.000

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Table 5
(*Continued*)

Dependent variable:	(A) Log farmgate private sector maize price		(B) Log sqd. residuals from (A)		(C) Log farmgate FRA maize price		(D) Log sqd. residuals from (C)		(E) HH sold maize to FRA = 1;= 0 otherwise	
Estimator:	CRE-POLS		CRE-POLS		CRE-POLS		CRE-POLS		CRE-Probit	
Explanatory variables:	Coef.	*P*	Coef.	*P*	Coef.	*P*	Coef.	*P*	APE	*P*
Expected growing season rainfall ('00 mm)	0.268**	0.013	−0.186	0.368	−0.00780	0.529	0.127	0.818	0.0252	0.171
Expected growing season rainfall, squared	−0.0163***	0.003								
Expected moisture stress	0.0537	0.116	0.417	0.119	−0.0344	0.190	−0.161	0.871	0.0933**	0.015
SEA suitable for low input management rainfed maize production (=1)	0.0116	0.531	−0.174*	0.081	0.00817	0.103	0.465	0.128	0.00267	0.799
Agricultural year (2006/07 is base):										
Agricultural year 1999/2000 (=1)	−2.561***	0.003	1.375	0.942						
Agricultural year 2002/03 (=1)	−0.277***	0.000	0.172	0.616	−0.219***	0.000	1.848*	0.087	−0.0827***	0.000
Constant	7.478*	0.059	−124.628	0.364	3.989***	0.000	−14.622	0.616		
District dummies	Yes		Yes		No		No		No	
Provincial & agro-ecological region dummies	No		No		Yes		Yes		Yes	
Time averages (CRE)	Yes		Yes		Yes		Yes		Yes	
Observations	3,969		3,969		492		492		5,441	
R-squared (Pseudo *R*-squared for probit)	0.678		0.076		0.605		0.112		0.277	

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Table 5
(*Continued*)

Dependent variable:	(A) Log farmgate private sector maize price		(B) Log sqd. residuals from (A)		(C) Log farmgate FRA maize price		(D) Log sqd. residuals from (C)		(E) HH sold maize to FRA = 1;= 0 otherwise	
Estimator:	CRE-POLS		CRE-POLS		CRE-POLS		CRE-POLS		CRE-Probit	
Explanatory variables:	Coef.	*P*	Coef.	*P*	Coef.	*P*	Coef.	*P*	APE	*P*
Overall model *F*-test	73.04***	0.000	3.57***	0.000	20.17***	0.000	4.29***	0.000	17.74***	0.000
Theil's U	0.809				0.543					
Unbiasedness of forecast	0.000	1.000	0.00	1.000	0.00	1.000	0.00	1.000		

***Notes*:** See Tables A1 and A2 in online Appendix A for more complete explanatory variable descriptions. ***, **, *Significant at the 1%, 5%, and 10% levels. Complex survey weights & Huber-White robust variance matrix estimator used in computation of standard errors. SEA is standard enumeration area. An SEA contains approximately 150–200 households and 2–4 villages. APE, average partial effect; CRE, correlated random effect; FRA, Food Reserve Agency.

***Source*:** Authors' calculation.

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Table 6

APE and AE of output supply with respect to the expected maize price

Row	Dependent variable	Estimator	APE	AE	Bootstrap *P*-value
A	Maize area planted (ha)	FE	**0.000813**	**0.896**	**0.026**
B		CRE-Tobit	**0.000667**	**0.674**	**0.023**
C	Maize yield (kg/ha)	FE	−0.574	−0.354	0.245
D	Maize quantity harvested (kg)	Derived from A & C	**1.271**	**0.888**	**0.026**
E		Derived from B & C	**1.186**	**0.670**	**0.023**
F	Area planted to other crops (ha)	FE	5.10E-6	0.005	0.978
G		CRE-Tobit	2.01E-5	0.019	0.932
H	Yield of other crops (FIQI/ha)	FE	−0.0150	−0.671	0.295
I	Quantity harvested of other crops (FIQI)	*No stat. sig. effect on area or yield, so no stat. sig. effect on quantity harvested*			
J	Area under fallow (ha)	FE	**−0.00131**	**−1.165**	**0.008**
K		CRE	−3.45E-4	−0.307	0.197

***Notes*:** Results in bold are statistically significant at the 10% level or lower. See Tables B2 and B3 in online Appendix B for the full regression results. FIQI is Fisher-Ideal Quantity Index. APE, average partial effects; AE, average elasticities; FE, fixed effects; CRE, correlated random effects.
***Source*:** Authors' calculation.

results suggest statistically significant, negative effects of the expected maize price on fallow area (Table 6, AE = −1.16, P = 0.008). The CRE-Tobit results, however, suggest that the expected maize price has no statistically significant effect on fallow area (Table 6, AE = −0.31, P = 0.197).[20] FRA activities may also be negatively affecting virgin land but data on virgin land are not available in all three waves of the survey, so we could not estimate these effects directly.

We next investigate the differential effects of FRA policies on smallholders with different landholding sizes, and then relate these results to the amount of fallow and virgin land under the households' control. In Zambia, and in sub-Saharan Africa more broadly, landholding size is highly positively correlated with smallholder farm household incomes (Jayne *et al*., 2003). As shown in Table 7 and based on the third wave of the panel survey, approximately 65% of Zambian smallholders have landholdings of less than 2 ha (column (A)). The supply responsiveness of these farmers to changes in the lagged FRA price is considerably lower in both elasticity and absolute terms than the nearly 35% of farmers that control 2 ha of land or more (columns (B)

[20]These CRE-Tobit results are treating subsidised fertiliser as endogenous, as supported by the control function tests for endogeneity. If subsidised fertiliser is treated as exogenous, the CRE-Tobit results, like the FE results, suggest that the expected maize price has a statistically significant, negative effect on area under fallow (AE = −0.62, P = 0.025). We fail to reject the exogeneity of subsidised fertiliser in the FE models.

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Table 7

Smallholder maize supply responsiveness to the lagged FRA farmgate price, sales to the FRA, and summary statistics on fallow and virgin land, by landholding size, 2006/07 agricultural year

Landholding size (cultivated + fallow)	% of HHs	Maize supply response to increase in FRA farmgate price ($t-1$): Average elasticity* (%)	Maize supply response: Estimated changes per 100 ZMK/kg increase: Ha planted	Kg harvested	% of HHs with fallow land (mean fallow ha for HHs with it in paren.)	% of HHs with virgin land (mean virgin ha for HHs with it in paren.)	% of HHs selling maize to FRA (2007/08 marketing year)	% of total sales to FRA (2007/08 marketing year)	% of HHs selling maize to FRA and/or private sector (2007/08 marketing year)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
0–0.99 ha	30.6	0.047	0.00203	4.29	8.7 (0.31)	8.6 (3.80)	2.2	1.4	15.7
1–1.99 ha	34.7	0.056	0.00441	8.47	26.5 (0.62)	14.8 (4.09)	7.9	10.3	30.0
2–4.99 ha	28.2	0.069	0.01037	19.28	45.6 (1.34)	21.2 (5.80)	15.8	35.2	44.0
5+ ha	6.5	0.082	0.02117	41.24	61.8 (4.21)	23.7 (10.39)	28.1	53.2	58.8
Overall	100.0	0.060	0.00647	13.21	28.7 (1.41)	15.3 (5.34)	9.7	100.0	31.4

Notes: All figures refer to smallholder households. FRA, Food Reserve Agency; HH, household.
*The average elasticity is the percentage change in maize area planted and quantity harvested given a 1% increase in the lagged FRA farmgate price. Results are based on CRE-Tobit estimates of the maize ha planted equation and associated derived effects on maize kg harvested. For column (H), the sum of the percentages slightly exceeds 100% due to rounding. Weighted results based on 4,286 panel households.
Sources: 2008 CSO/MACO/FSRP Supplemental Survey and authors' calculation.

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through (D)).[21] For example, households in the smallest landholding category (0–0.99 ha) have an average elasticity of supply that is only 57% that of farmers in the largest landholding category (5+ ha category, Table 7, column (B)). In absolute terms, the smallest farms' increase in maize area planted and quantity harvested in response to an increase in the lagged FRA price is only 10% that of the largest farmers' supply response (Table 7, columns (C) and (D)).

Farmers increase their maize production in response to an increase in the FRA price by devoting more land to maize. Two reasons that households with larger landholdings are able to be more responsive to FRA incentives (even without reducing area to other crops) are: (i) they are more likely to have fallow or virgin land; and (ii) those that do have fallow or virgin land have more of it (Table 7, columns (E) and (F)).

Not only are farmers with smaller landholdings less able to increase their maize production in response to FRA price increases, they are also much less likely to sell to the FRA than are households with larger landholdings. For example, only 2.2% of farmers with landholdings of less than 1 ha sold maize to the FRA during the 2007/08 marketing year, whereas 28.1% of smallholders with landholdings of 5 ha or more sold to the FRA that year (Table 7, column (G)). Moreover, smallholder sales to the FRA are highly concentrated in the hands of households with larger landholdings. Although farmers cultivating 5 ha or more make up only 6.5% of the smallholder population, they account for 53.2% of smallholder maize sales to the FRA (Table 7, column (H)). In contrast, farmers with landholdings smaller than 1 ha make up 30.6% of the smallholder population but account for just 1.4% of smallholder sales to the FRA. The direct benefits of the high price the FRA pays for maize therefore accrue disproportionately to households with more land (and presumably higher incomes). These relatively better-off households also benefit more from increases in the FRA price through a larger supply response.

8. Conclusions and Policy Implications

The main conclusions of this article are that increases in the lagged FRA price raise farmers' expected maize price, which, in turn, induces them to increase their maize production by planting more area to maize. Farmers do not reduce area planted to other crops in response to an increase in the FRA price (although the *share* of area planted to other crops declines). Rather, we find some evidence that FRA activities incentivise a reduction in area under fallow. FRA activities may also be encouraging farmers to bring virgin land under cultivation. These findings raise important questions about the extent to which FRA policies can continue to stimulate maize production before it begins to negatively affect the production of other crops, reduce soil fertility (through reduced fallows), or promote deforestation or land degradation (through bringing more land, including virgin forested or marginal land, under agricultural production). These questions warrant further analysis.

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[21]Columns C and D of Table 7 show the estimated changes in maize ha planted and kg harvested given a 100 ZMK/kg increase in the lagged FRA price. To put this price change in perspective, the FRA pan-territorial price during the 2006/07 and 2007/08 marketing years was 760 ZMK/kg. This price rose to an average of 1,000 ZMK/kg during the 2008/09 marketing year, an increase of 240 ZMK/kg. The average exchange rate in 2007 was 4,006 ZMK/US$.

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Zambian smallholder responses to FRA activities contrast with those of their Kenyan counterparts to National Cereals and Produce Board activities. Whereas Zambian smallholders respond to an increase in the FRA price by *extensifying* their maize production, Kenyan smallholders respond to an increase in the National Cereals and Produce Board price by *intensifying* their maize production (Mather and Jayne, 2011). Kenyan farmers are generally much more land-constrained than Zambian farmers, which is a likely explanation for the differential responses of farmers in the two countries.

Although our results indicate that FRA policies have indeed stimulated a maize supply response in Zambia, as of 2006/07 the increase in maize production was very small (0.06% increase per 1% increase in the FRA price). Additional research is needed to assess the cost-effectiveness of FRA policies, especially given the high level of public resources devoted to the Agency. For example, in 2010 and 2011, spending on the FRA averaged 1.7% of GDP, 59% of total agricultural sector government spending, and 65% of total agricultural sector Poverty Reduction Programme spending (IMF, 2012; Table 1).

Despite these large expenditures on FRA activities, rural poverty rates have remained stubbornly high at roughly 80% since the early 2000s, and there has been no substantive reduction in rural poverty since the FRA was established in 1996 (CSO, 2010, 2011). Results presented here cast doubt on the effectiveness of FRA maize purchase policies as poverty reduction strategies. In particular, we show that although poorer households with relatively small landholdings make up the vast majority of the smallholder population, these households sell very little maize to the FRA. They also have a much smaller maize supply response to changes in the FRA price than larger, relatively better-off smallholders. Thus, although FRA is the Zambian government's main agricultural Poverty Reduction Programme, our results suggest that it is mainly relatively better-off smallholders, not the poorest households, who respond most to FRA's maize purchase policies.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix A. Summary statistics.

Appendix B. Full regression results.

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