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Smallholder Market Participation and Choice of Marketing Channel in the Presence of Liquidity Constraints: Evidence from Zambian Maize Markets

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Abstract

Increasing smallholders' market participation as food grain seller is acknowledged as a potential pathway towards agricultural commercialization and structural transformation. Thus, governments of developing countries sometimes intervene in domestic grain markets through grain purchase programs with the aim of providing market access to small farmers in rural areas where agricultural markets are believed to be uncompetitive. However, the benefits of such programs may not reach farmers who face production constraints that inhibit their ability to produce a marketable surplus. Specifically, there is a gap in literature in understanding how liquidity constraints that limit smallholders' investments in productivity-enhancing agricultural inputs can affect their market participation and choice of marketing channel. In this article we explore this issue in context of smallholder maize growers in Zambia during a period when the country's parastatal marketing board – the Food Reserve Agency (FRA) – operated alongside private buyers and purchased large volumes of maize at a pan-territorial price that exceeded average market prices. We find that smallholders who were liquidity constrained during the production period produced lower maize output, were less likely to sell maize, and less likely to sell to the FRA, as compared to those who did not face liquidity constraints. The key takeaway is that market policies, like those of the FRA, are less likely to benefit smallholders if they do not possess the resources to expand production. Rather, the benefits of such policies can be disproportionately captured by relatively wealthier farmers.

JEL codes: Q12, Q13, Q18, O13

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Introduction

Uncompetitive markets and poor market access are identified as important reasons for limited market participation in agricultural markets by smallholder farmers in developing countries (Goetz 1992; Key et al. 2000; Heltberg and Tarp 2002). This perspective, while well supported by evidence, often overlooks the effect of constraints to production of a marketable surplus on market participation as a seller. This is especially relevant for staple food grains, which are primarily grown for consumption, and sale is often conditional on the production of a surplus beyond the household's consumption needs. A major constraint faced by smallholders in developing countries is the inability to invest adequately in crop productivity-enhancing inputs due to lack of liquidity during the production period (Duflo et al. 2011; Kusunose, Mason-Wardell, and Tembo 2020). This is known to reduce households' agricultural production (Feder et al. 1990; Foltz 2004; Winter-Nelson and Temu 2005) and consumption (Carter and Lybbert 2012) but there has not been a thorough investigation of its effects on smallholders' ability to participate in and benefit from lucrative agricultural output markets. In this article, we use nationally representative panel data from maize-growing smallholders in Zambia to empirically test the effect of liquidity constraints during the production period on maize marketing behavior. We find that, as compared to liquidity unconstrained households, liquidity constrained households are indeed less likely to sell maize. Moreover, when they do sell, they are less likely to take advantage of a marketing channel that offers a higher price but involves higher fixed costs.

Increased participation of smallholders in agricultural output markets can potentially shift farmers from high-risk and low-productivity subsistence farming to more profitable commercial agriculture (Timmer 1988; von Braun and Kennedy 1994; Heltberg and Tarp 2002), which in turn can stimulate the rural economy of developing countries (Binswanger and von Braun 1991; von Braun 1995). A first step in this direction is to increase their participation as sellers of staple food grains. Most smallholders grow staples for household consumption and investment in staple food production poses lower risk as compared to investment in cash crops or other high value crops (Pingali et al. 2005; Jaleta et al. 2009). Yet, less than 50% of smallholder farmers in many countries of sub-Saharan Africa (SSA) participate in staple food grain output markets as sellers (see, e.g., Alene et al. 2008 for Kenya; Barrett 2008 for a survey of the literature covering several countries in eastern and southern Africa; and Mather et al. 2013 for Kenya, Mozambique and Zambia). In their pioneering work, de Janvry et al. (1991) explain that low market participation by smallholders in agricultural markets is a household-specific market failure that results from high transaction costs of accessing markets. Subsequent literature has provided empirical evidence that high transaction costs arising from poor road infrastructure and inadequate market information can reduce market participation (Goetz 1992; Key et al. 2000; Heltberg and Tarp 2002). More recent evidence shows that improved access to public goods (roads, extension, and communication services) and private assets (land, labor, animal traction) can also facilitate market participation (Renkow et al. 2004; Cadot et al. 2006; Boughton et al. 2007). However, very few papers put this in perspective of imperfections in factor markets that can undermine the capacity of a household to generate a marketable surplus (Alene et al. 2008; Mather et al. 2013). We address some of this gap in the literature by focusing on the liquidity constraints faced by households during the production period.

Due to the seasonality of agriculture, farmers have competing demands for cash received at the time of harvest, with meeting consumption needs often being the most prominent (Stephens and Barrett 2011; Burke et al. 2019). This leaves limited resources to be spent on crop productivity-enhancing inputs (Duflo et al. 2011; Dercon and Christiaensen 2011), which in turn is expected to reduce output supply and thus the marketable surplus. The lack of well-functioning credit markets in many developing countries further exacerbates this problem. While prior literature shows that liquidity constraints lead to lower agricultural production (Feder et al. 1990; Foltz 2004; Winter-Nelson and Temu 2005), there is lack of rigorous research linking liquidity constraints *during the production period* to market participation as a seller.⁶

Another less explored aspect of smallholder market participation in the developing country context is the choice of marketing channel that households make when faced with several buyer types, such as private traders of various scales, government agencies, and other households in the community. The pioneering literature in this field has been dominated by discussion of the choice to sell at the farmgate versus at a distant market, and predominately

⁶ The literature on smallholder grain market participation has extensively investigated a slightly different aspect of the problem, i.e. the influence of liquidity constraints *during the marketing period* (i.e., after the marketable surplus has been realized) to explain the "sell low, buy high" phenomenon (Stephens and Barrett 2011; Dillon 2017; Burke, Bergquist, and Miguel 2019). Smallholder farmers are found to sell food grains relatively soon after harvest due to cash constraints and/or lack of quality storage facilities. At this time of the year, food grain prices tend to be at their lowest (i.e., "sell low"). Many of these households then purchase grain later in the marketing year, when grain prices tend to be higher (i.e., "buy high").

focuses on commercial crops or largely commercialized markets (Fafchamps and Hill 2005; Shilpi and Umali-Deininger 2008; Zanello et al. 2014; Negi et al. 2018). In reality, households may face several buyer types, each with their associated constraints and opportunities. Further, the discussion of semi-commercialized food grain markets requires recognition of nonseparability of production and consumption decisions if there are multiple market failures. Muamba (2011) and Takeshima and Winter-Nelson (2012) are the few papers that have studied the choice between selling at the farmgate versus at a distant market when production and consumption decisions are not separable. In this article, we examine whether the choice of marketing channel is affected by liquidity constraints faced during the production period. We argue that liquidity constraints will affect marketable surplus, which in turn will affect the household's ability to take advantage of relatively more remunerative marketing channels.

The article makes four main contributions to literature. First, it generates empirical evidence about whether and to what extent liquidity constraints during the production period affect food grain market participation and sellers' choice of marketing channel. Second, it adds to the thin literature on farmers' marketing channel choice when production and consumption (and thus marketing) decisions are non-separable. Third, it provides a rigorous conceptual framework that helps understand the mechanisms through which liquidity constraints during the production period may affect market participation and farmers' choice of marketing channel; this framework guides the specification of our empirical models. Finally, this paper provides empirical evidence on the link between constraints faced in agricultural production and accessing remunerative markets for agricultural goods in a developing country context.

We address the literature gaps noted above using Zambian smallholder maize-growing households as a case study. Zambia has a considerably large agricultural sector that employs 49% of the country's population (World Bank 2019a). Maize is the main staple food grain in Zambia, is grown by almost all smallholder households, and is an important source of income for many of them (Chapoto et al., 2015). However, maize market participation as a seller is far from universal.⁷ Credit markets in rural Zambia are poorly developed. In the 2013/14 agricultural season only 19% of rural households reported acquiring credit for agriculture from any formal or informal source. In a recent experimental study conducted by Fink, Jack, and Masiye (2020) for

⁷ In the maize marketing years covered in this analysis (2011/12 and 2014/15), the percentage of maize growers who sold more maize than they purchased (maize net sellers) was 52 and 42%, respectively.

rural Zambia, the authors find almost universal (98%) uptake of lean season loans at an implicit interest rate of 4.5% per month, indicating severe cash needs among agricultural households.

Smallholders' choice of marketing channel is of particular interest for Zambia given the important role played by the country's maize marketing board, the Food Reserve Agency (FRA).⁸ During the study period, the FRA bought maize from farmers at its depots throughout the country at a pan-territorial price that was higher than the average market price. Previous studies have shown that the FRA's activities have raised the mean level and reduced the variability of maize market prices (Mason and Myers 2013), which has induced farmers to bring more land under maize cultivation (Mason, Jayne and Myers 2015). Its effects on smallholder farmers' welfare have, however, been less promising. The FRA's activities have been found to benefit smallholders who sell to FRA but have very limited spillover effects on the remaining population and may in fact hurt maize buyers (Mason and Myers 2013; Fung et al. 2020).

Justifications made for grain marketing board activities, like those of the FRA, include the presence of uncompetitive grain markets and high transaction costs in remote areas. However, recent evidence shows that the argument of widespread uncompetitive food markets in rural SSA may be unsubstantiated and that market access has improved significantly (Chamberlain and Jayne 2013; Sitko and Jayne 2014; Dillon and Dambro 2017).⁹ On the other hand, long payment delays by the FRA to farmers is a perennial problem as is the significant uncertainty each year regarding the timing and scale of FRA's maize purchases, making it a less viable marketing channel for vulnerable and liquidity constrained households. The FRA has also been criticized for: (i) crowding out private maize traders, who provide an essential service to smallholders by providing timely maize market access and payments; and (ii) accounting for a large share of the scarce government resources available for the agricultural sector (Jayne et al. 2011; Sitko and Jayne 2014). Thus, this article has important implications for resource allocation

⁸ The FRA is a parastatal that serves as a strategic food reserve and maize marketing board; it seeks to raise and stabilize maize market prices as a means of improving national food security and farmer incomes. During the period of analysis for this study (2010-2015), the FRA played a major role in maize marketing in Zambia and purchased an average of 75% of the total volume of maize sold by smallholders each year (Fung et al. 2020).

⁹ Sitko and Jayne (2014) find that even the remotest villages in Zambia were visited by at least one private maize trader during the peak maize marketing season and that private traders made only small marketing margins through maize transactions, an important indicator of competitive markets. Similarly, Chamberlain and Jayne (2013) find that private trader activity was higher and distance travelled by smallholders for crop sales was lower in areas where public marketing boards reduced their activity.

and the maize market policies pursued by the Zambian government and other governments in the region.

Conceptual Framework

We use the framework of a non-separable agricultural household model and assume that production, consumption, and initial marketing decisions are made simultaneously at the time of planting (Singh, Squire, and Strauss 1986; Key et al. 2000). However, once agricultural output has been realized and harvest-time prices are revealed, the household can update its marketing decisions.

Let a (potentially risk-averse) agricultural household maximize its expected utility of consumption of maize (c_{mz}) , leisure (c_l) , and market-purchased goods (c_{mk}) , given household level characteristics (z^h) that affect consumption tastes and preferences and subject to several constraints (See Appendix A for complete model). For simplicity, we assume maize to be the only agricultural product produced by the household. We explicitly model liquidity constraints during the production period and assume that the liquidity constraints apply only to the variable production inputs (here: labor (l) and non-labor variable inputs (x)). Following de Janvry et al. (1992), the input purchase liquidity constraint can be represented as, $\eta(\mathbf{p}_x \mathbf{x} + wl - K) = 0$, where w and p_x denote the prices of labor and non-labor inputs, respectively. η is the shadow price of liquidity and K represents the cash available with the household. Thus, for liquidity constrained households (LC), liquidity is a binding constraint ($(p_x x + wl - K) = 0$ and $\eta > 0$) and the amount of agricultural inputs used will be limited by some upper limit K. On the other hand, if the household is not liquidity constrained (UC), the constraint is no longer binding $((\mathbf{p}_x \mathbf{x} + wl - K) < 0 \text{ and } \eta = 0)$ and purchases of inputs are not limited by K. LC and UC households will then maximize their expected utility under different sets of constraints, and thus have different input demand and output supply functions:

(1a) $q^{LC} = q^{LC}(p_e, p_{mk}, w(1 + \eta), p_x(1 + \eta), K, z^h, z^q)$ (1b) $q^{UC} = q^{UC}(p_e, p_{mk}, w, p_x, z^h, z^q)$

Here, q^{LC} and q^{UC} denote the vector of input demand and output supply functions for LC and UC households, respectively; p_e is the household's expectation, as of planting time, of the maize price that will prevail at harvest time; p_{mk} is the vector of prices for other market purchased consumption goods, and z^q is vector of fixed and quasi-fixed factors affecting production. $(1 + \eta)$ represents an implicit input price markup for households that are liquidity

constrained. An important implication of this result is that LC households would be using less inputs and producing less output than unconstrained households, ceteris paribus ($q^{LC} < q^{UC}$). Let p_m be the realized price of maize at harvest and τ be household-specific transaction costs involved in marketing maize such that $\tau > 0$. These transaction costs are added to the market price of maize if the household is a buyer of maize and subtracted from the price of maize received if the household is a seller of maize (Key et al. 2000). Thus, the household-specific buyer and seller prices can be represented as $p_b = (p_m + \tau)$ and $p_s = (p_m - \tau)$, respectively. Let $p_a(q_{mz}, \cdot)$ be the household's shadow price of maize that is a function of the household's maize output (q_{mz}) and other household characteristics (·). We assume that $p_a(q_{mz}, \cdot)$ is a function strictly decreasing in q_{mz} . Thus, since LC households produce less maize output ($q_{mz}^{lc} < q_{mz}^{uc}$), they would have a higher shadow price of maize than UC households (i.e., $p_{lc}^a > p_{uc}^a$). The household's maize market position will be determined as follows: Household sells maize if $p^{s} \geq p^{a}$; household buys maize if $p^{b} \leq p^{a}$; household is autarkic with respect to maize if $p^b > p^a > p^s$. Based on this discussion, we state the following hypotheses: Hypothesis 1: Liquidity-constrained maize-producing households are less likely to become maize sellers, all else remaining constant, as compared to unconstrained households since $\Pr[p_{lc}^a \le p^s] < \Pr[p_{uc}^a \le p^s].$

Hypothesis 2: A liquidity-constrained household's probability to sell maize will be less responsive to changes in expected prices. We expect this because the liquidity constraint limits a household's capacity to increase production in response to higher expected prices, i.e.

$$\frac{\partial \Pr[p_{lc}^a \le p^s]}{\partial q_{mz}^{lc}} \cdot \frac{\partial q_{mz}^{lc}}{\partial p_e} < \frac{\Pr[p_{uc}^a \le p^s]}{\partial q_{mz}^{uc}} \cdot \frac{\partial q_{mz}^{uc}}{\partial p_e}, \text{ because } \frac{\partial q_{mz}^{lc}}{\partial p_e} < \frac{\partial q_{mz}^{uc}}{\partial p_e}.$$

The third hypothesis links liquidity constraints during the production period with the marketing channel chosen by maize sellers. Similar to the case of market position, we assume that the choice of marketing channel is determined after maize output has been realized. Further, we assume that the choice of marketing channel is conditional on the decision to participate in the maize market as a seller. We continue to assume (as we did above) that the household is potentially risk-averse and thus motivate the problem from an expected utility maximization perspective instead of a profit maximization one. Let $V_j(p_j^s m - F_j; \mathbf{z}^h)$ be the expected utility obtained from selling to marketing channel *j*. Here, p_j^s represents the *effective price* received from selling maize to channel *j*. The effective price incorporates transaction costs incurred in

transporting and handling per unit of maize and also discounts the price by the expected delay in market entry and/or in payment by the buyer. *m* is the quantity of maize marketed by household to channel *j*. F_j is a fixed transaction cost associated with use of channel *j*. This may include search and negotiation costs specific to that channel, such as membership of a cooperative or farmer group that facilitates the collection and transport of maize in bulk from the village to market or FRA depot, and uncertainty related to specific channels (like the FRA). This essentially implies that to be able to sell to channel *j*, a household must be marketing enough maize such that $p_j^s m > F_j$, *ceteris paribus*. If F_j is higher for a channel *j*, a higher effective price (p_j^s) or marketable surplus (*m*) will be required to compensate for the higher fixed cost. Given this background we state our third hypothesis as follows:

Hypothesis 3: Since LC households are expected to be producing a smaller marketable surplus $(q_{mz}^{lc} < q_{mz}^{uc})$, they are less likely to be able to overcome high fixed costs incurred in selling to channels such as the FRA, i.e., $\Pr[V_{FRA} - V_j > 0|LC] < \Pr[V_{FRA} - V_j > 0|UC]$, where *j* is any other marketing channel.

Data

The main data source used in this analysis is the Rural Agricultural Livelihoods Survey (RALS), a three-wave nationally representative panel survey dataset of smallholder farm households in Zambia. We utilize the first and second waves of the RALS data.¹⁰ These waves were implemented in June-July of 2012 and 2015, respectively, by the Indaba Agricultural Policy Research Institute (IAPRI) in collaboration with the Zambian Central Statistical Office (CSO) and the Ministry of Agriculture (MoA). See CSO (2012) for details on the RALS sample design. The dataset contains detailed information on household demographics, crop and livestock production and marketing, off-farm employment and own business activities, distances to roads, markets, and public services. The 2012 survey covered the 2010/11 agricultural year (October 2010–September 2011) and the associated crop marketing year (May 2011–April 2012). The 2015 survey covered the 2013/14 agricultural year and the 2014/15 crop marketing year. A total of 8,839 households were interviewed in the 2012 RALS. Of these, 7,254 (82%) were successfully re-interviewed in 2015. Our analytical sample consists of the balanced panel of 6,063 RALS households that grew maize in both 2012 and 2015, which amounts to a total of

¹⁰ Data from the third wave, which was conducted in June-July 2019, were not available for analysis at the time of this study.

12,126 households (84% of the total balanced sample and 73% of the total households surveyed). Tests for attrition bias based on a procedure recommended by Wooldridge (2010) fail to reject the null of no attrition bias for all dependent variables except one. We suspect that this exception may be due to our inability to control for unobserved heterogeneity in the tests (which we otherwise control for in all our main analysis). Thus, we do not consider attrition bias to be a major cause of concern for our analysis. Details of the attrition test can be found in Appendix B. The explanatory variables obtained from RALS are briefed here. The price of inorganic fertilizer and seed and agricultural wage rate (the price to weed 0.25 ha) are used to control for agricultural input prices (p_x and w in the conceptual framework). These prices were recorded at the household level in the RALS but we compute district level medians to remove outliers and alleviate concerns about incidental truncation (fertilizer prices were only captured for households that used fertilizer). Distances to important points of market access such as the nearest paved and unpaved roads, and agricultural market are used as proxies for transaction costs (τ). We also include the number of maize traders that arrived in the village during the peak maize marketing season (May-October) to capture the competitiveness and market access within the village (as suggested by Chamberlain and Jayne (2013) and Sitko and Jayne (2014)). Dummy variables that indicate the household's ownership of a bicycle, radio, and cellphone are included to represent the household's capacity to reduce fixed transaction costs such as those associated with obtaining price and buyer information. Land, livestock (measured as tropical livestock units (TLUs)), and number of plows, harrows, and ox-carts owned by the household are used to control for the household's quasi-fixed factors of production (\mathbf{z}^q) .¹¹ Controls for household characteristics affecting consumption (\mathbf{z}^h) include household size (the number of full-time adult equivalent household members) and various characteristics of the household head (age, education, and sex). We use district-level data on retail maize prices collected by the CSO (CSO 2018) to compute maize market prices. Even though the RALS records price data for each maize transaction made by a household, we refrain from using this information to avoid bias due to incidental truncation.¹² Maize market prices in Zambia are also significantly affected by the government's

¹¹ TLU's were calculated with the following FAO formula: cattle = 0.70, sheep and goats = 0.10, pigs = 0.20 and chickens = 0.01 (FAO 2007).

¹² Since the price information in RALS was only recorded for households that sold maize, these prices may not accurately reflect the prices faced by all households. The resulting measurement errors may in turn be systematically correlated with unobservables that determine market participation.

market interventions through the FRA (Mason and Myers 2013). We do not explicitly model the interdependence of market and FRA prices; rather we include separate variables for the FRA and market prices. For each of these, we compute estimates of each household's expected (p_e) and realized post-harvest maize price (p_m). For computing expected maize price we assume that households make the naïve expectation that next period's prices will be similar to last period's prices. Thus, we use the market price as of August of the marketing season just before the agricultural season as the expected market price of maize.¹³ Similarly, the FRA price during the previous marketing year is used as a proxy for a household's expected FRA price. On the other hand, the district-level maize retail price in August of each harvest year is used as the realized post-harvest maize market price. The post-harvest FRA price is simply that paid by the FRA during each harvest year. All prices are adjusted to household level transport costs (obtained from the RALS) to generate farmgate prices. See Appendix C for further details on the computation of prices.

Rainfall is an important determinant of agricultural production in the context of Zambia where smallholder agriculture is almost exclusively rainfed. Thus, we include information on rainfall and moisture shock during the growing season as well as their long-term averages (a 16-year moving average).¹⁴ A moisture shock in the season before the planting season of interest was used as the exclusion restriction for liquidity status. These variables were obtained from data compiled by Snyder et al. (2019) using geospatial data from Tropical Applications of Meteorology using Satellite data and ground-based observations (TAMSAT) (Maidment et al. 2014; Tarnavsky et al. 2014; Maidment et al. 2017). Snyder et al. (2019) matched the TAMSAT data to GPS locations of RALS households and created rainfall estimates using the Raster Calculator tool in ArcGIS Model Builder. The TAMSAT data has a spatial resolution of approximately 0.0375 x 0.0375 degrees, which is approximately 4 x 4 kilometers, or 16 square

¹³ Zambia's marketing season runs from May to April and agricultural season runs from October to September. Thus, the expected prices as of October, 2010 would be the market price of maize as of August, 2010. We used the prices as of August because in our sample the largest share of maize transactions (46%) were made during the month of August, followed by July (20%) and September (14%). It could be a matter of concern that August prices do not represent the true price faced or expected by the household. We conduct sensitivity analysis using two other measures of prices. These are discussed later in the article.

¹⁴ Moisture shock here is defined as the presence of more than one moisture stress period during the maize growing season. Moisture stress is defined as in Snyder et al. (2019) as the number of overlapping 20-day periods with less than 40 mm of rainfall. Kusunose et al. (2020) use a similar weather shock variable as an instrument for liquidity.

kilometers (Snyder et al. 2019). In practical terms, these estimates are therefore village-level measures.

Finally, the consumer price index from the World Bank (2019b) was used to convert all prices from nominal to real terms (with base year 2017=100). This implicitly controls for variation in the prices of consumer goods (p_{mk}). Descriptive statistics for all variables can be found in the table D1 of Appendix D.

Important definitions

In this section we describe three variables that are an integral part of the analysis: the household's liquidity status during the production period, their maize market position, and the maize marketing channel chosen by net sellers for their largest transaction.

Liquidity status

Liquidity is a difficult concept to measure because it is not easily observable. It is often also confused with a similar but slightly different concept of credit constraint/access (Winter-Nelson and Temu, 2005). Further, different types of liquidity constraints can affect different household decisions, such as, production of farm and non-farm goods and consumption of market and home-produced goods (Sadoulet and de Janvry 1995). In this article, liquidity constraints imply lack of readily available cash in adequate amount to enable the household to invest in productivity enhancing agricultural inputs. We follow an approach similar to Winter-Nelson and Temu (2005) and exploit unique data available in RALS to define a household to be liquidity constrained during the production period if one or both of the following conditions are met: (1) The household claims to not have acquired fertilizer from the market due to a lack of cash; and/or (2) the household claims to not have obtained fertilizer from the Farmer Input Support Program (FISP) due to - (a) not being able to afford the farmer's down payment for obtaining fertilizer through FISP, and/or (b) lack of cash for the mandatory cooperative membership payment required for participation in the program.^{15, 16}

¹⁵ FISP is a large-scale government program designed to enable eligible farmers to obtain farm at subsidized prices. Eligibility is primarily determined by landholding, membership in a farmer cooperative and payment for part of the cost for inputs received (Mason, Jayne, and Mofya-Mukuka 2013). During the study period, the program focused on maize inputs (inorganic fertilizer and improved seed). Since the 2015/16 agricultural year, the FISP has been partially converted into a flexible electronic voucher program (Kuteya, Chinmaya, and Malata 2018) with aims to crowd-in private sector participation in Zambia's agricultural input value chains and give farmers more flexibility in terms of the farm inputs or equipment for which they can use the e-voucher.

¹⁶ According to Burke, Jayne, and Sitko (2012) the cash outlays required for obtaining inputs from FISP could cost up to 20% of the annual gross income for 60% of the smallholders in Zambia, thus precluding many smallholders

A natural concern with a stated preference measure of liquidity such as the one used here is hypothetical bias -i.e., households overstating the liquidity constraints that they face. It may be that households imprecisely state other constraints, such as poor returns to or low profitability of fertilizer use, that keep them from purchasing fertilizer as 'lack of cash'. We alleviate these concerns through some additional analysis. First of all, the RALS survey instrument included a rich set of alternatives from which the respondent could choose his/her reason for not purchasing fertilizer from market or obtaining fertilizer from FISP. While lack of cash was the leading reason for not purchasing fertilizer (80%), low profitability (7%), and adequate soil fertility (6%) were the other most common reasons mentioned by these households. Similarly, apart from the lack of cash, not being eligible for FISP (17%) was the leading reason for not being able to obtain FISP fertilizer (See tables D2 and D3 in Appendix D). Secondly, we expect the scope for bias to be less for criterion 2 than criterion 1 because criterion 2 is based on relatively more objective questions, such as the household's down payment or cooperative membership. Thus, we use criterion 2 as an alternative definition of liquidity constrained households and conduct robustness checks to validate the results. Finally, we expect that being liquidity constrained is correlated with other characteristics of the household, such as ownership of land, livestock, assets, access to markets, non-farm income, and use of agricultural inputs. The better measure of liquidity status would be the one that provides a sharper separation between households based on these characteristics. We computed the differences in mean values for key variables between LC and UC households using criterion 1 only, 2 only, and criteria 1 or 2 (See table D4 in Appendix D). We note that using the latter gives the largest mean differences between LC and UC households in majority cases; these differences are statically significant at the 1% level of significance across all characteristics except for distance to unpaved road. We thus choose to employ criteria 1 or 2 as the main definition of liquidity status.

Approximately 62% and 52% of households were liquidity constrained in the RALS 2012 and 2015 waves, respectively, using this approach (table 1, column A). 13% of households that were UC in RALS 2012 became LC in the next round, whereas 23% of those that were LC in 2012 became UC in RALS 2015 (table D5, Appendix D). Most of the households were defined as LC as a result of meeting criterion 1; relatively fewer met criterion 2 (table 1, column C).

from being able to participate in FISP. In fact, evidence suggests that FISP has benefitted wealthier farmers proportionately more than poorer farmers (Mason, Jayne, and Mofya-Mukuka 2013).

Only 23% and 15% of sample households met both criteria in RALS 2012 and 2015 (table 1, column D), respectively.

RALS wave	Criteria 1 or 2	Criteria 1 only	Criteria 2 only	Criteria 1 & 2
	А	В	С	D
2012	62%	57%	26%	23%
2015	52%	47%	18%	15%

Table 1: Percentage of Liquidity Constrained Households, by RALS wave and Criteria

Notes: Sample consists of maize growing households in the balanced panel in each wave (N=6063). 368 households that claimed to be LC according to Criteria 2 purchased >100 kg of fertilizer. We re-defined these households as UC.

Maize market position

In our sample, a small percent of households (13%) both buy or sell some amount of maize grain and maize meal, and 21% of households neither sell nor buy any maize product.¹⁷ It is not straightforward to classify these households as sellers or buyers. Thus, following an approach similar to Bellemare and Barrett (2006) and Burke, Myers, and Jayne (2015), we define three mutually exclusive maize market positions as follows. A household is defined as a maize net seller if the quantity of maize sold is greater than the quantity of maize grain and maize meal purchased, autarkic if the household has no maize sales and purchases, and a net buyer if the quantity of maize sold is less than the quantity of maize grain and maize meal purchased.¹⁸ During the 2014/15 (2011/12) marketing year only 38% (42%) of LC households ended up as maize net sellers compared to 67% (67%) of UC households. (See table D6 in Appendix D). An alternative definition of maize market positions was computed using value of maize and maize meal sold and bought. Maize sold was valued at the district median maize producer price (computed from prices reported by maize-selling households) in order to minimize the effect of outliers. Similarly, maize grain and maize meal purchased by the household was valued at the district level median (computed from household-reported purchase price). According to this definition, only 31% (44%) of LC households were maize net sellers in 2014/15 (2011/12) as

¹⁷ Maize meal is a type of maize flour and is used to prepare *nshima*, the most common form in which maize is consumed in Zambia.

¹⁸ To compute the maize market positions, the maize meal bought by a household was first converted to its equivalent maize grain value using conversion factors from Mwiinga et al., 2002.

compared to 56% (68%) for UC households (See table D7 in Appendix D). This value based maize market position was used for conducting robustness check.

Maize marketing channels

Smallholder households in Zambia sell maize to a wide variety of buyers and may make more than one transaction in a marketing year. For tractability, we focus on the largest maize transaction made by each household and group maize marketing channels into four categories: the FRA, small scale private traders, large scale private traders, and other households. ¹⁹

In 2014/15 (2011/12) marketing year, 48% (64%) of households chose to sell to FRA, 26% (17%) to small scale traders, 16% (10%) to large scale traders, and 11% (9%) to other households. A smaller percentage of LC households sold to the FRA as compared to UC households in both years (table D8 in Appendix D). Almost 90% of the households selling to the FRA had to travel >1 km to make the maize sale. In contrast, 74% (64%), 33% (30%), and 87% (85%) of the transactions made to small scale traders, large scale traders, and other households in 2011/12 (2014/15) were made at the farmgate, respectively (tables D9 and D10 in Appendix D). The median farmgate price received from the FRA was 42% (24%) higher than the price received for sales to other households was also slightly higher (1% and 8% for 2011/12 and 2014/15 respectively) than that for small scale traders (tables D9 and D10 in Appendix D). This is probably because maize sales to other households were spread more evenly over the maize marketing season and thus the prices received from this channel would reflect, in part, the higher maize prices that prevail later in the marketing season.²⁰

Even though during our period of analysis, the price offered by the FRA was higher than private market prices on average, there was considerable uncertainty related to when FRA would start buying maize and when farmers would be paid. Almost 50% of farmers who sold to FRA had to wait for at least two months to be paid. In contrast, more than 90% of those who sold to private traders or another household that year received payment at the time of the sale (Figure 1). Further, even though harvesting begins in May, farmers typically have to wait until July or

¹⁹ A large majority of maize net sellers (87% in 2011/12 and 88% in 2014/15) had only one maize sale transaction in the given marketing year.

²⁰ Figure D2 in Appendix D shows that >50% of the largest maize transactions to other households occur in months *other than* July, August, and September (the peak maize marketing months). This is in comparison to <10% for FRA and <40% for small and large scale private traders.

August for the FRA to start buying maize. This, coupled with the delayed payments, would likely lead to considerable discounting of the price offered by the FRA, especially for households that may be in urgent need of cash. Another potential hurdle to selling to the FRA that households may have to overcome is that, officially, 500 kg is the minimum amount of maize that the FRA will buy from an individual or cooperative (Mason 2011). In contrast, the median quantity of maize sold by LC households in our sample was only 50 kg; however, farmers can overcome this hurdle by bulking their product with that of other farmers.



Figure 1: Number of months between sales transaction and payment to farmer for the largest maize transaction

Estimation method

We break down the estimation method into several smaller and simpler steps.

Step 1

We first estimate the effect of being liquidity status and expected maize prices on maize output using a linear switching regression. This approach allows the parameter estimates to differ between LC and UC households, in line with the conceptual framework where LC and UC households were found to be solving different optimizing problems and with similar previous work (Feder et al. 1990; Foltz 2004; Winter-Nelson and Temu 2005).²¹ The availability of panel data enables us to control for unobserved time-invariant household-level heterogeneity. Given the non-linear-in-parameters nature of our estimators in the second step regression (discussed below), we use a correlated random effects (CRE) approach (Mundlak 1978; Chamberlain 1984) throughout the paper for consistency.^{22 23} In our analysis we operationalize CRE by including the means of all time varying exogenous variables as additional regressors in our model. There may be time-varying unobservables (such as an unreported access to productive resources from family or friends) that are correlated with a household's liquidity status as well as their maize output leading to potential omitted variable bias. To overcome this problem, we use a two-step control function endogenous switching CRE-pooled OLS (CRE-POLS) procedure as suggested by Wooldridge (2015) and Murtazashvili and Wooldridge (2016). The two-step approach entails estimating a first stage regression of liquidity status to obtain residuals that are used as an additional regressor in the main equation. Details of the approach are discussed below. Equation 2 represents the main equation to be estimated:

(2) $q_{mz,it} = LC_{it} \times X_{1it}\beta_1 + X_{1it}\beta_0 + LC_{it} \times c_i + c_i + LC_{it} \times v_t + v_t + \tau_1 LC_{it} \times \widehat{u_{it}} + \tau_0 \widehat{u_{it}} + \epsilon_{it}$

Here, $q_{mz,it}$ is the maize output of household *i* in agricultural year *t*, LC_{it} is an indicator variable that equals 1 if the household was LC during the production period, and 0 if UC. X_{1it} is the vector of explanatory variables (including the vector of expected harvest-time maize prices (p_e), prices of agricultural inputs (p_x and w), household characteristics (z^h), quasi-fixed factors (z^q), and rainfall and moisture shocks in the growing season). c_i is the household-specific time invariant unobserved heterogeneity, v_t is the year fixed effect, $\widehat{u_{it}}$ are the residuals from the first stage regression of the liquidity status and ϵ_{it} is the idiosyncratic error specific to each household

²¹ We also estimate the equation using a 2SLS approach as a robustness check, as will be discussed later.

²² The fixed effect approach is not recommended for non-linear-in-parameters panel estimation when the number of observations of the individual (N) tends to infinity but the number of time periods (T) is very small. Using a fixed effects approach would require estimating parameters for each of the N units which are known be inconsistent. This is known as the incidental parameters problem (Greene et al. 2002; Arellano and Hahn 2007).

²³ Like a fixed-effects or (regular) random effects approach, a key assumption underlying the CRE approach is strict exogeneity of the observed covariates conditional on the unobserved household-level time constant heterogeneity. However, the CRE approach allows the observed covariates to be correlated with the unobserved heterogeneity like the fixed effects approach, whereas the regular random effects approach assumes these two to be uncorrelated.

and time period. β_1 , β_0 , τ_1 , and τ_0 are the parameter values to be estimated.²⁴ The estimates of interest are the marginal effect of LC ($E(q_{mz}|LC = 1) - E(q_{mz}|LC = 0)$) and marginal effect of expected prices on maize output for LC and UC households ($E\left[\frac{\partial q_{mz}}{\partial n_1}\right] LC =$

1] and
$$E\left[\frac{\partial q_{mz}}{\partial p_e} \mid LC = 0\right]$$
).

Identification

The first stage regression that is used to control for potential endogeneity is estimated using CRE-linear probability model of liquidity status (LC_{it}) on the full set of exogenous variables (X_{1it}) and an exclusion restriction (z_{it}) and can be represented as follows:

(3) $LC_{it} = X_{1it}\alpha_1 + \alpha_2 z_{it} + c_i + v_t + u_{it}$

Identification hinges on the availability of a strong exclusion restriction – i.e., a variable that has a strong statistically significant effect on the household's selection into one of the two regimes, yet which we can confidently assume is not correlated with the household's maize output through any channel other than its effect on liquidity. Our exclusion restriction is an indicator variable that equals one if the village in which the household resides experienced a moisture shock in the growing season prior to the planting season in which we measure liquidity constraint. A moisture shock in year t-1 is expected to lead to poor crop output and thus a higher chance of being liquidity constrained in the following year. We find that a moisture shock in year t-1 is strongly partially correlated with being liquidity constrained in year t (F-statistic = 16.27, p-value = 0.0001; see table E1 in Appendix E for the full results). Additionally, a moisture shock in year t-1 should not affect maize output in year t through any channel other than its effect on liquidity, particularly after controlling for rainfall conditions and the other covariates in year t, as well as time-constraint unobserved heterogeneity via CRE. The validity of the instrument is further discussed later in the article by conducting robustness checks.

Step 2

²⁴ Failure to reject that $\tau_0=0$ and $\tau_1=0$ indicates that we fail to reject that liquidity status is exogenous to maize output and can choose to use an exogenous version as the main analysis (we call this CRE-exogenous switching regression). Alternatively, rejecting that at least one of the τ is equal to zero, would imply that liquidity status is endogenous; the inclusion of the first stage residuals corrects for this endogeneity (conditional on the validity of the exclusion restriction). We call this version the CRE-endogenous switching regression.

In the second step we estimate the effect of maize output on the household's maize market position using a CRE-ordered Probit approach. The respective probabilities of being a net buyer and net seller of maize are given as follows:

(4)
$$Pr(M_{it} = 1 | q_{mz,it}, X_{2it}, c_i, v_t) = \Phi(0 - (\delta q_{mz,it} + X_{2it}\gamma + c_i + v_t))$$

(5) $Pr(M_{it} = 3 | q_{mz,it}, X_{2it}, c_i, v_t) = \Phi(\delta q_{mz,it} + X_{2it}\gamma + c_i + v_t)$

where, M_{it} is the household's maize market position ($M_{it} = 1$ if net buyer, =2 if autarkic, and =3 if net seller); X_{2it} is the vector of explanatory variables consisting of post-harvest farmgate price of maize (p_m); proxies for transaction costs or access to markets, and household characteristics. δ and γ are parameters to be estimated. The estimate of interest is the marginal effect of maize output on market position ($E\left[\frac{\partial \Pr(M=3)}{\partial q_{mz}}\right]$).

Step 3

The effect of maize output on the household's maize marketing channel choice is estimated using a CRE-Multinomial Logit (MNL) regression.²⁵ The choice of marketing channel can be represented as:

(6)
$$Pr(V_{jit} - V_{kit} > 0 | q_{mz,it}, W_{it}, c_i, v_t) =$$

 $\exp(\lambda_j q_{mz,it} + W_{it} \pi_j + c_i + v_t) / (1 + \sum_{j=1}^4 \exp(\lambda_j q_{mz,it} + W_{it} \pi_j + c_i + v_t)))$

Here V_{jit} - V_{kit} is the difference in utilities obtained from choosing channel *j* vs. channel *k*. $q_{mz,it}$ is as defined before and W_{it} is a vector of control variables consisting of X_{2it} (same as in Step 2) and residuals from a selection equation described below. λ_j and π_j are parameters associated with marketing channel *j*. The estimate of interest to us is the marginal effect of maize output on choice of marketing channel ($E\left[\frac{\partial \Pr(V_j - V_k > 0)}{\partial q_{mz}}\right]$).

The CRE-MNL is estimated for the subset of maize net sellers only which can introduce selection bias if the net selling maize growers are non-randomly different from other maizegrowing households in the full sample based on unobservable, time-varying characteristics. To address this potential problem, we first estimate a CRE-Tobit selection equation for the net maize quantity sold using the full sample, where net maize sales are zero for autarkic and net-

²⁵ MNL is chosen over Multinomial Probit because the former is known to be computationally less cumbersome and easier to interpret (Wooldridge 2010).

buying households. The generalized residuals from this Tobit regression are then used as an additional regressor in the CRE-MNL to control for sample selection. The use of Tobit instead of Probit as a selection equation allows us to solve the selection problem without the need of an exclusion restriction. ²⁶

Test of Hypothesis

The estimates from Step 1 and Step 2 are multiplied as shown in table 2 to test the hypothesis 1 and 2. Similarly, the product of estimates from Step 1 and Step 3 are used to test the hypothesis 3. Standard errors are computed by bootstrapping over 500 replications.

Hypothesis	Statement	Estimates
1	LC maize-producing households are less likely to become maize net sellers	$E[(q_{mz} LC = 1) - (q_{mz} LC = 0)] *$ $E\left[\frac{\partial \Pr(M = 3)}{\partial q_{mz}}\right] < 0$
2	A LC household's probability to sell maize will be less responsive to changes in expected prices	$E\left[\frac{\partial q_{mz}}{\partial p_e} \mid LC = 1\right] * E\left[\frac{\partial \Pr\left(M = 3\right)\right)}{\partial q_{mz}}\right] < E\left[\frac{\partial q_{mz}}{\partial p_e} \mid LC = 0\right] * E\left[\frac{\partial \Pr\left(M = 3\right)\right)}{\partial q_{mz}}\right]$
3	Net seller LC households are less likely to sell to FRA	$E[(q_{mz} LC = 1) - (q_{mz} LC = 0)] *$ $E\left[\frac{\partial \Pr(V_{FRA} - V_k > 0)}{\partial q_{mz}}\right] < 0$

 Table 2: Estimates to be Computed for Testing the Hypotheses

Results

Table 3 reports the Average Partial Effects (APEs) from the CRE-POLS switching regressions for maize output by liquidity status for key variables of interest (See table E2 and E3 in Appendix E for full results). The residuals in the endogenous switching regression are not statistically significant (at 10% level of significance); thus, we conclude that, controlling for the observables and time invariant unobserved heterogeneity via CRE, liquidity status at planting time is exogenous to maize output. In the subsequent discussion and computations, we focus on

²⁶ Using a Probit selection equation without an exclusion restriction could lead to severe collinearity between the generated residuals and explanatory variables. Identification in such a case relies on the nonlinearity of the inverse mills ratio. In contrast, because the variation in the quantity of maize sold among net sellers is leveraged in the Tobit selection equation, the Tobit residuals have separate variation from the explanatory variables of the main regression (here, CRE-MNL), thus alleviating concerns of collinearity and providing a way to control for sample selection bias even in the absence of an exclusion restriction. (See Wooldridge (2010) for details).

the results from the exogenous switching regression only and interpret our results as associations. We find that liquidity constraints in the production period are associated with an average 1272 kg reduction in maize output (p<0.01). This is approximately equivalent to 1,700 ZMW at the FRA's 2014/15 marketing year price (or 280 USD at the exchange rate during that period).

Variables	Exogenous Switching CRE-POLS		Endogenous switching CRE-POLS	
	UC	LC	UC	LC
Household is liquidity constrained-1		-1272.0***		-1389.8
Thousehold is inquidity constrained-1		(70.98)		(1508.1)
Expected farmgate FRA maize price	524.2	123.6	523.5	131.4
(ZMW/kg, 2017=100)	(793.0)	(243.8)	(794.0)	(243.6)
Expected farmgate maize market price	-38.6	-19.5	-37.8	-27.6
(ZMW/kg, 2017=100)	(211.6)	(63.83)	(219.4)	(67.62)
Residuals			815	286
			(0.785)	(0.802)
Other controls	Yes		Ŋ	les
Time fixed effects	Yes		Yes	
District fixed effects	Yes		Y	les
CRE time averages	Yes		Y	les
Observations	12,126		12	,126

Table 3. Average	Partial Effects	of Kev V	ariables on	Maize Out	put (kg)
Lable et li telage		01 110, 1		maile out	

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses LC= Liquidity Constrained; UC= Unconstrained; HH=household. ZMW=Zambian Kwacha; FRA= Food Reserve Agency

However, we find no statistically significant relationship between expected FRA and market prices of maize and household maize output for both LC and UC households. This may in fact be the case, but it is also possible that there is measurement error in our expected maize price variables, which would bias their estimated effects toward zero. The measurement error may arise due to our use of naïve expectations (for tractability) instead of a more sophisticated construct of price expectations. Secondly, while the use of district level retail prices in lieu of producer prices collected from smallholder maize sellers helps us avoid incidental truncation concerns, the adjustments for transport costs to convert the district-level retail prices to farmgate prices are rough approximations at best. This entailed making some potentially strong assumptions about the nature of transport costs (as discussed in the Data section briefly and in Appendix C in detail). Finally, the variance inflation factor (VIF) for the expected FRA price and the year dummy is greater than 10, signalling a multicollinearity issue.²⁷ The correlation coefficient between these two variables is also very high (0.90). This is expected because there is relatively little variation in FRA farmgate prices within a year due to the pan-territorial nature of FRA depot-level price. We therefore interpret with caution the estimated effects of the expected maize prices on maize output.

A comparison of APEs of landholding size of LC and UC households reveals that UC households are able to produce, on average, 430 kg more maize from an additional hectare of land as compared to LC households (table E4 in Appendix E). This is what we would expect if LC households are constrained in their ability to invest in sufficient inorganic fertilizer or improved seed to use land productively. It is also plausible that the effect of liquidity constraints are heterogenous across different landholding categories. This is especially relevant given the recent rise in the prominence of medium scale farmers (i.e., those farming 5+ hectares of land) in Zambia and other land abundant countries in SSA. These farmers are found to have better access to resources and political leverage to influence agricultural policy (Jayne et al. 2019). Figure 2 shows that LC households across all landholding sizes produce less maize output than UC households, and more importantly, the difference in maize output between LC and UC households goes on increasing as the landholding size increases. A caveat worth noting here is that almost 90% of LC households in our sample owned 5 hectares or less of land compared to 75% of UC households.

We further use the CRE-POLS switching approach to interrogate the premise that the difference in maize output between LC and UC households is at least partly due to LC households' relatively lower capacity to invest in maize productivity-enhancing inputs – e.g., inorganic fertilizer and improved seed.²⁸ The results of these regressions (table E5 in Appendix E) suggest that being liquidity constrained is associated with a 113 kg/ha reduction in the rate of fertilizer application to maize and a 19 percentage point reduction in the probability of growing an improved maize variety, on average (p<0.01). These numbers represent a 55% and 25% reduction in use of fertilizer and improved seed, respectively. They further emphasize the losses incurred by the inability to use land productively through investment in inorganic fertilizer and improved seed.

 $^{^{27}}$ The VIF for all other variables was within the acceptable range (<=10).

²⁸ Improved seed refers to both hybrids and improved open pollinated varieties.



Figure 2. Predictive margins of liquidity status at planting time across different landholding sizes and with 95% Confidence Interval

Notes: UC: Liquidity unconstrained households; LC: Liquidity constrained households

The key results from the CRE-ordered Probit of maize market position are reported in table 4 (Full results in table E6 in Appendix E).²⁹ A one metric ton (=1000 kg) increase in maize output is associated with a 12 percentage point decrease and a 14 percentage point increase in the probability to be a maize net buyer and net seller, respectively (p<0.01). Maize market and FRA prices are not statistically significantly related to the maize market position. Additionally, we computed the effect of maize output on a household's net maize sales (using a CRE-POLS approach, table E8, Appendix E) and find that a 1 kg increase in maize output is associated with an average 0.86 kg increase in net maize sales (p<0.01).

²⁹ The CRE-ordered Probit failed to converge even though the estimates remain stable after the 15th iteration. We used estimates from 2000 iterations here. To ensure that results are robust, we repeated the analysis with the valuebased definition of maize market position. The model using this definition attains convergence and its results were robust to the main specification (See table E7 in Appendix E).

Variables	Net-buyer	Autarkic	Net-seller
Quantity of maiza produced kg	-0.00012***	-0.000020***	0.00014***
Qualitity of marze produced, kg	(0.000016)	(0.0000015)	(0.000016)
Farmgate maize price	-0.0021	-0.00036	0.0025
(ZMW/kg, 2017=100)	(0.012)	(0.0020)	(0.014)
Farmgate FRA maize price	-0.061	-0.010	0.071
(ZMW/kg, 2017=100)	(0.106)	(0.018)	(0.124)
Other controls		Yes	
Time fixed effects		Yes	
District fixed effects		Yes	
CRE time averages		Yes	
Observations		12126	

 Table 4. Average Partial Effects of Key Variables on the Maize Market Position (CREordered Probit)

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses

LC= Liquidity Constrained; UC= Unconstrained; HH=household. ZMW=Zambian Kwacha; FRA= Food Reserve Agency

Table 5 summarizes key results of the CRE-MNL for net selling households' choice of maize marketing channel for the largest transaction of maize (See tables E9 and E10 in Appendix E for the first-stage CRE-Tobit for the quantity of maize sold and the full CRE-MNL results, respectively). An additional unit of maize produced does not have any statistically significant relation with choosing to sell to small scale traders. However, a one metric ton increase in maize produced is associated with a 4 percentage point increase in probability to sell to FRA, a 1.2 percentage point increase in probability to sell to large scale traders, and a 5.4 percentage point decrease in probability to sell to other households (p<0.01). These results support our exposition that households that produce a larger maize surplus would be more likely to sell to marketing channels that entail larger fixed costs (such as uncertainty and delay for FRA, negotiation and search costs for large scale sellers, and transport for both).

The estimates computed above are used to test the hypotheses as detailed in table 2 and the results are summarised in table 6. In support of hypothesis 1, LC households are found to be 18 percentage points less likely to be a net seller of maize due the inability to produce a marketable surplus (p<0.05). We do not find evidence of statistically significant effect of expected maize price on households' probability of being net sellers for either LC or UC households. However, as discussed earlier, due to caveats about measurement error in expected prices we are unable to make a confident conclusion about hypothesis 2. Lastly, consistent with

hypothesis 3, being liquidity constrained is found to be associated with 5 percentage point reduction in the probability of selling to FRA. LC households are also found to be 2 percentage points less likely to sell to large scale traders but 7 percentage points more likely to sell to other households (p<0.05). There is no statistically significant relationship between being liquidity constrained and selling to small scale traders.

Variables	Average Partial Effects				
	Small scale traders	FRA	Large scale traders	Other households	
Quantity of maize produced,	0.0000030	0.000039***	0.000012***	-0.000054***	
kg	(0.0000081)	(0.000089)	(0.000036)	(0.000013)	
Residuals from CRE-Tobit selection equation [§]	Yes				
Time fixed effects	Yes				
Province fixed effects [#]	Yes				
CRE time averages	Yes				
Observations		7	108		

Table 5. Average Partial Effects of Maize Output on Choice of Marketing Channel made
for the Largest Transaction of Maize by Net Seller Households (CRE-Multinomial Logit)

Notes: *** p<0.01, ** p<0.05, * p<0.1; standard errors are clustered at household level and bootstrapped with 500 replications to account for the generated regressor (CRE-Tobit residuals). [§]The CRE-Tobit residuals are significant at 1% level of significance, implying that the sample of net sellers was non-random and our estimates would have been biased if we had not corrected them through inclusion of the residuals; [#]Province fixed effects were used in place of district fixed effects because the model failed to converge when using the latter.

Finally, to alleviate concerns about the hypothetical bias in the definition of liquidity status, we re-conduct the analysis using the alternate definition of liquidity (criteria 2 only). Results from the analysis are presented in tables E11 and E12 in Appendix E. We find that LC households produce on average 1562 kg less maize as compared to UC households, and thus are 22 percentage points less likely to be net sellers of maize (p<0.01). LC households that are net sellers are 6 percentage points less likely to sell to FRA (p<0.01). These estimates are consistent with those obtained from the main specification.

Table 6. Test of Hypotheses

Hypothesis	Effect of interest	APE
1	Liquidity constraint on the probability of being a net buyer	0.15**
	Equality constraint on the probability of being a net buyer	(0.077)
1	Liquidity constraint on the probability of being a net seller	-0.18**
	Equality constraint on the probability of being a net sener	(0.088)
	Expected FRA price on probability of being a net seller for LC	0.017
	HH	(0.051)
2	Expected FRA price on probability of being a net seller for UC	-0.003
	HH	(0.013)
	Market price on probability of being a pet seller for I C HH	0.074
	Market price on probability of being a net sener for Le TIT	(0.169)
	Market price on probability of being a pet seller for UC HH	-0.005
	Market price on probability of being a liet selier for the fifth	(0.031)
	Liquidity constraint on the probability of selling to a small scale	-0.004
	trader	(0.007)
	Liquidity constraint on the probability of selling to EPA	-0.049**
3	Equility constraint on the probability of senting to FKA	(0.024)
	Liquidity constraint on the probability of selling to a large scale	-0.015**
	trader	(0.007)
	Liquidity constraint on the probability of selling to other	0.068**
	households	(0.031)

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors in parentheses are based on 500 bootstrap replications APE= Average partial Effect; LC= Liquidity Constrained; UC= Unconstrained; HH=Household; FRA= Food Reserve Agency

Robustness checks

We discuss some of the limitations of this study and the additional analyses conducted (wherever possible) to address them.

Validity of the instrument variable

The lagged moisture shock variable we use as an instrument may not be valid if there are channels apart from its effect on liquidity constraint that can influence maize output. For example, a moisture shock in period t-1 could affect maize output through a change in soil quality that persists into period t. We do not have a way to test this but do not expect this be a serious concern. A persistent change in soil quality is only likely if the dry spell is very severe. In such a case, soil nitrogen becomes unavailable to the plant in t-1 and leads to a carry-over of this nitrogen into the next season, which would increase the maize yield in period t (S. Snapp, personal communication, April 2, 2020). Thus, in the rare case that the instrument affects the maize output through a change in soil quality, our estimates of the impact of liquidity would be

biased upwards (less negative effect of LC) and can still be considered as a conservative lower limit to the true effect.

A second concern is related to potential serial correlation in the moisture shock variables. If some geographical locations are more prone to experiencing dry spells over several years, a moisture shock in period t-1 would also be linked to weather conditions in period t, and thus to maize output. We alleviate some of this concern by including information on long term average growing season moisture shock and rainfall in our models. Our use of CRE to control for time-constant unobserved heterogeneity should also alleviate some of these concerns. In addition, we run a falsification test by including a lead of the moisture shock variable (i.e., the moisture shock in period t+1) in the first stage CRE-POLS for liquidity status and the CRE-switching POLS for maize output. We test the null hypotheses that maize output and liquidity status are not correlated with moisture shocks in the next time period through any serial correlation in the moisture shock variable. We fail to reject this null for both liquidity status and maize output which further supports the validity of the instrument (Full results in table E13 in Appendix E). *Two-stage least squares as an alternative to switching regression*

The maize output equation is re-analyzed with a using CRE-two stage least squares (2SLS) approach as an alternative to the endogenous switching CRE-POLS of maize output to ensure robustness of our results. Unfortunately, we are unable to generate the effect of expected maize prices for LC and UC households separately due to lack of sufficiently strong IVs of the interaction terms of liquidity status and expected prices. The results (recorded in table E13 in Appendix E) show that LC households produce 2698 kg less maize, on average, than UC households (p<0.1). The test of endogeneity of liquidity status in the 2SLS estimation fails to reject the null of exogeneity. Both these results are consistent with our main results. *Sensitivity analysis using different measures of prices*

We use two alternative measures of market prices to check if our results are sensitive to the measure of maize market price used in the main analysis. The first measure is a moving average of monthly maize retail prices over the entire peak maize marketing season (May-October). The second is a similar measure computed for the months of July, August, and September only. Using these alternative measures of prices, however, does not change the analysis in any significant manner (Full results in tables E14 and E15, Appendix E). Both maize output and maize market position remain unresponsive to expected prices and realized prices, respectively.

Conclusions and policy implications

In this article we study the effect of liquidity constraints during the production period on Zambian maize growing smallholders' maize market participation. We show empirically that liquidity constrained households are not able to invest adequately in productivity-enhancing inputs (e.g., inorganic fertilizer and improved maize seed), limiting their capacity to produce a marketable surplus, thereby decreasing their probability of being a net seller. These results complement those of Alene et al. (2007), Boughton et al. (2007), and Mather et al. (2013), which found that insufficient access to public and private assets can limit a smallholder household from producing a marketable surplus and thus reduce their participation in output markets. They are also in line with Fink, Jack, and Masiye (2020), who show that a small credit intervention in the lean season in rural Zambia leads to significant improvements in agricultural production by releasing family labor from non-farm piecework and enabling them to devote more time to on-farm work.

We hypothesized but did not find strong evidence that liquidity constrained households are less responsive to an increase in expected maize prices. We suspect measurement error in the price variables and issues of multicollinearity could be partially responsible for this. Finally, we find evidence that liquidity constraints are associated with the marketing channel chosen by the household for its largest maize sale. Since liquidity constrained households produce lower marketable surplus, they are less likely to overcome the high fixed costs associated with accessing some channels. Specifically, in the case of maize markets in Zambia, liquidity constrained net seller households were found to be less likely to sell to the parastatal marketing board, FRA, as compared to small scale traders and other households. Overall, our results show that production bottlenecks, such as liquidity constraints during the production period, can limit a household's capacity to benefit from remunerative market and price policies. These results support the view that price policies may have limited effects on smallholders' food production and marketing responses if they lack access to the productive assets and inputs needed to expand production (Barrett 2008). This can exacerbate the disproportionate capturing of the benefits of agricultural market policies by wealthier farmers, as has indeed been reported for Zambia (Jayne et al. 2011; Fung et al. 2020). The results also have implications for a land abundant country like

Zambia where much of the increase in maize production has been a result of increases in crop acreage and not through an increase in productivity (Burke et al. 2010). In recent years, due largely to budget constraints, the FRA has reduced its maize purchases and shifted attention towards provision of food relief to vulnerable populations. There has also been evidence of better participation by private sector players in Zambian maize output markets (Mulenga et al. 2019). This is a welcome shift in light of the results of this article and the recent threat to the food security of Zambia due to droughts in the 2017/18 and 2018/19 agricultural season. The resources of the government spent on large scale interventions by the FRA in maize markets would likely be better spent on improving the productivity and resilience of smallholder farmers.

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Supplementary Material

Appendix A: Additional steps of conceptual model

Let a (potentially risk-averse) agricultural household maximize its expected utility of consumption of maize (c_{mz}) , leisure (c_l) , and market-purchased goods (c_{mk}) , given household level characteristics (z^h) that affect consumption tastes and preferences (equation 1a), subject to several constraints (equations 1b to 1e, described below). For simplicity, we assume maize to be the only agricultural product produced by the household. We explicitly model liquidity constraints during the production period and assume that the liquidity constraints apply only to the variable production inputs (here: labor (l) and non-labor variable inputs (x)).

The household's problem is summarized below:

$\max_{c_{mz}, c_l, c_{mk}, q_{mz}, x, l} EU(c_{mz}, c_l, c_{mk}; z^h)$	(1a)
$q_{mz} = g(l, \boldsymbol{x}; \boldsymbol{z}^{\boldsymbol{q}}) + \varepsilon$	(1b) [Production function]
$q_{mz} - c_{mz} = m$	(1c) [Equilibrium condition]
$\eta(\boldsymbol{p}_{\boldsymbol{x}}\boldsymbol{x} + wl - K) = 0$ If LC: $(\boldsymbol{p}_{\boldsymbol{x}}\boldsymbol{x} + wl - K) = 0$ and $\eta > 0$ If UC: $(\boldsymbol{p}_{\boldsymbol{x}}\boldsymbol{x} + wl - K) < 0$ and $\eta = 0$	(1d) [Liquidity constraint]

 $p_{mk}c_{mk} + wl + p_x x \le p_e m + w(T - c_l)$ (1e) [Income constraint]

The production function (1b) represents the production technology that transforms farm labor (l)(consisting of hired and/or family labor) and non-labor inputs (x) into maize (q_{mz}), given the levels of fixed and quasi-fixed factors affecting production (z^q) and random shocks (ε) such as weather that can shift output supply. The equilibrium constraint (1c) indicates that the quantity of maize sold (m) is the quantity of maize produced minus the quantity of maize consumed. If m is negative, it implies that the household purchased additional maize beyond its production to meet consumption needs. Let w and p_x denote the prices of labor (1) and non-labor inputs (x), respectively, assumed to be known at planting time. Following de Janvry et al. (1992), the input purchase liquidity constraint (1d) states that if a household is liquidity constrained (LC), liquidity is binding (with shadow price of liquidity $\eta > 0$) and the amount of agricultural inputs used will be limited by some upper limit K that represents the household's available cash. On the other hand, if the household is not liquidity constrained (UC), $\eta = 0$ and use of inputs are not limited by K. Finally, the income constraint (1e) balances the income and expenditures of the household. Here p_e is the household's expectation, as of planting time, of the maize price that will prevail at harvest time; T is the household's total time endowment; and p_{mk} is the vector of prices for other market purchased consumption goods. Combining the income and liquidity constraints (1e and 1d, respectively) gives us the full income constraint as follows:

 $p_{mk}c_{mk} + wl + p_x x + \eta(p_x x + wl - K) \le p_e m + w(T - c_l) \quad (1f) \quad [Full-income \text{ constraint}]$ If LC, $\eta > 0$ and $p_{mk}c_{mk} + wl \quad (1 + \eta) + p_x x(1 + \eta) \le p_e m + w(T - c_l) + \eta K \quad (2a)$
where $1 + \eta$ represents an implicit input price markup for households that are liquidity constrained.

If UC,
$$\eta = 0$$
 and $p_{mk}c_{mk} + wl + p_x x \le p_e m + w(T - c_l)$ (2b)

Liquidity-constrained and unconstrained households will then maximize their expected utility under different sets of constraints, and thus have different input demand and output supply functions:

If LC:
$$q^{LC} = q^{LC}(p_e, p_{mk}, w(1+\eta), p_x(1+\eta), K, z^h, z^q)$$
 (3a)

If UC:
$$\boldsymbol{q}^{UC} = \boldsymbol{q}^{UC}(p_e, \boldsymbol{p}_{mk}, w, p_x, \boldsymbol{z}^h, \boldsymbol{z}^q)$$
(3b)

Appendix B: Test for Attrition bias

We follow recommendations made by Woodridge (2010) to check for attrition bias. First, compute a dummy variable (s_{it+1}) that takes value 1 if a household was part of the balanced sample used for analysis and 0 otherwise. This means that s_{it+1} takes value 0 if it was a maize growing household interviewed in RALS 2012 dropped out of the analytical sample either due to (i) not being successfully re-interviewed in RALS 2015, or (ii) not growing maize in RALS 2015. Then, include s_{it+1} as an additional regressor in each regression analysis and conduct the analysis for sub-sample of the first wave of the survey only. The test of attrition bias consists of testing the null hypothesis that the parameter on s_{it+1} equals zero against a two-sided alternative, conditional on all observed covariates. If we were using more than 2 waves of data, this test would be conducted on data from all but the last wave, and estimated via households fixed effects to control for time-invariant unobserved heterogeneity. However, we are unable to control for time-invariant unobserved heterogeneity in our test of attrition bias because we have only two waves of panel data.

Our approach is slightly different than that suggested by Wooldridge (2010) because we compute s_{it+1} based on attrition due to re-interview *and* maize growing status, whereas Wooldridge (2010) suggested the test only for attrition based on re-interview. A more thorough test for attrition bias among those households that stopped growing maize between the 2012 and 2015 RALS waves would require an exclusion restriction that is statistically significantly related to growing maize but not to unobservables affecting any of the dependent variables of interest in our analysis. Unfortunately, we are unable to find such an exclusion restriction. However, we believe that this should not be a cause of concern since a large majority (89%) of the full balanced panel of all households interviewed in RALS 2012 and 2015 grew at least some amount of maize. Further, among the households that attrited out of the first wave of maize growing households (1,711), only 22% (389) left the sample because they stopped growing maize. Thus, the chief reason for attrition was the lack of a successful re-interview.

We fail to reject the null of no attrition bias at the 10% level of significance for all variables except the maize market position (table B1). However, since in the main regressions we control for household level unobserved heterogeneity in addition to the controls used here, thus, we believe that there is no major cause of concern due to attrition bias in our main results.

Outcome variable		p-value
HH is liquidity con	strained at planting time=1	0.388
Maize output (kg)	For liquidity constrained households	0.607
	For unconstrained households	0.532
Quantity based mai	ize market position	0.000***
Value based maize	market position	0.000***
Net maize sales (kg	<u>y</u>)	0.860
Total maize sales (kg)	0.285
Maize marketing cl	hannel	0.367

Table B1: Test results for attrition bias

Notes: The reported p-values have been obtained from OLS of given outcome variables against all observed covariates used in main regression and for all maize growing households of 2012 wave. N= 7,774 for all regressions except for maize marketing channel. N= 4,632 for maize marketing channel. ***p < 0.01, **p < 0.05, *p < 0.10

Appendix C: Computation of expected and realized farmgate FRA and market price of maize

We refrain from using household level prices in the analysis for the following reasons: 1) Prices in the RALS are only collected for households that sell maize (which comprise of 42% of the sample), thus generating concerns about incidental truncation if we use these prices. 2) One of our main outcome variables (maize market position) has been computed using household level prices. Using the same prices as an explanatory variable would lead to simultaneous bias.

The following constructs of price are used instead:

1) Realized farmgate market price of maize:

We have access to monthly district level retail maize prices for Zambia. These prices were observed in the nearest district administrative town. We use these prices as estimates of the maize purchase price offered by private traders to smallholder farmers within a given village. Prices observed in the month of August of the relevant marketing period are used for the main analysis because that is when most maize sales have been observed in Zambia across different years and provinces. Alternatively, average of prices covering different months were also used to conduct sensitivity analysis (Section 6.4 in main text).

A major limitation with using district-level mean maize price data is that it does not account for the cost of transporting maize from the village to the town. Thus it does not represent farmgate prices which are more representative of the prices actually faced by the household. Fortunately, for farmers whose largest maize sale was made somewhere away from their homestead, RALS records their transport costs (per kilogram per kilometer) to that point of sale. Additionally, RALS also records an approximate measure of the cost of transporting maize to the nearest FRA depot for all households irrespective of whether or not they sell any maize to FRA. Using this information, we are able to construct a piecewise transport cost of maize for each cluster in each year. It is expected (and observed in the data) that the cost of transport per unit per kilometer falls as the distance of sale increases. This is expected because: i) The most expensive part of transport is that to the nearest feeder road; ii) subsequently, transport on a feeder road is more expensive than transport on a tarmac road; and iii) there may be fixed costs of transporting maize, such as a fixed payment made in contracting the transport to a middleman. This fixed cost then translates into lower per kilometer costs when the distance travelled is larger. We thus compute a piecewise maize transport cost per kilogram per kilometer for the categories of 0-5 km, 5-10 km, and more than 10 km. We follow Mason et al. (2015) for choosing these categories. These categories are reasonable because: (i) most households have feeder roads within a distance of 0-5 km, (ii) the district town is often located 10 km or further away from households; and (iii) the categories allowed enough observations in each category to be able to compute villages level medians. The rule of thumb used while computing the median was that there are at least five observations per cluster to obtain a median. When this was not

possible, we used the district or the provincial median, whichever permitted at least five observations. The piecewise cost was used to compute estimated costs of transport (per kilogram) from the homestead to the nearest district town. We then compute the farmgate market price of maize by subtracting this cost from the district mean retail maize price.

2) Expected farmgate price of maize:

We use a simple naïve expectation of the maize price to construct the expected market price of maize. For this we use the district mean retail price of the marketing season immediately before the marketing season of interest to us. Farmgate prices are computed in the same manner as for marketing period prices, assuming that transport costs do not change significantly between two consequent marketing seasons.

3) Expected and realized farmgate FRA price:

The FRA prices are pan-territorial and announced by the government around June-July of every marketing year. To approximate the expected FRA prices, we simply use FRA's publicly announced pan territorial price as of the marketing season prior to the marketing season of interest to us (in other words the FRA price as of the planting time). The FRA price as of marketing season was the price announced at the time the smallholders actually sold maize. In practice, the farmgate prices received by the farmer will be heterogenous given differences in transport costs from each household. RALS records the cost of transport to the nearest FRA depot for both the planting and marketing periods. Thus, we are able to obtain good estimates of the farmgate FRA prices during both the planting and marketing periods.

All prices are adjusted by the consumer price index with a base of 2017.

Table D1. Summary statistics for explanatory and dependent variables used in t	he analysis
(by RALS wave)	

	201	12	2015	
	Mean	SD	Mean	SD
Panel A: Explanatory varia	bles			
Expected farmgate FRA price (ZMW/kg, 2017=100)	2.21	0.11	1.79	0.10
Expected farmgate market maize price (ZMW/kg,				
2017=100)	1.26	0.35	1.60	0.48
Farmgate FRA maize price (ZMW/kg, 2017=100)	2.04	0.07	1.88	0.07
Farmgate maize price (ZMW/kg, 2017=100)	1.41	0.58	1.71	0.41
Commercial basal fertilizer price	C 12	110	FCC	0.71
(district median, ZMW/kg , $2017=100$)	0.13	1.10	5.00	0.71
Wage to weed 0.25 ha (district median, ZMW, $2017=100$)	99.7	40.2	92.7	37.5
Maize seed price (district median, ZMW/kg, 2017=100)	9.24	6.11	10.42	5.09
Age of the HH head (years)	46.4	14.6	49.1	14.5
Education of household head (years)	6.15	3.66	6.06	3.67
Male-headed household=1	0.82	0.38	0.80	0.40
Full-time adult equivalents	5.01	2.26	5.19	2.28
Landholding size (ha)	3.15	3.21	3.29	3.40
Tropical livestock units	2.83	8.10	2.80	7.66
Number of plows	0.42	0.86	0.50	0.94
Number of harrows	0.07	0.29	0.08	0.31
Number of ox-carts	0.15	0.40	0.18	0.43
Distance to unpaved road (cluster median, km)	0.94	2.95	1.01	2.40
Distance to paved road (cluster median, km)	28.3	35.0	24.9	30.5
Distance to agricultural market (cluster median, km) Number of maize traders visiting village between May-	23.4	24.6	23.1	23.8
October	3.71	3.14	3.58	2.59
HH owned a radio at the beginning of marketing period HH owned a cellphone at the beginning of marketing	0.66	0.47	0.64	0.48
period	0.58	0.49	0.65	0.48
HH owned a bicycle at the beginning of marketing period HH experienced moisture shock in current growing	0.70	0.46	0.70	0.46
season(t)=1	0.18	0.38	0.48	0.50
Growing season rainfall (mm)	788.4	81.5	833.9	74.9
HH has experienced long term moisture shock (16-yr MA)=1	0.57	0.49	0.41	0.49

Long run mean growing season rainfall (mm) (16-yr MA)	797.1	63.7	806.9	68.0			
HH experienced moisture shock in last growing season (t-							
1) (Instrument)=1	1.00	0.05	0.42	0.49			
Panel B: Selected dependent variables							
Quantity of maize produced by HH (kg)	3777	6667	3835	6710			
Quantity of inorganic fertilizer used on maize crop by HH							
(kg/ha)	192	214	217	185			
HH used improved maize seed =1	0.62	0.49	0.69	0.46			
Net maize sales made by the HH (kg)	2282	5793	2390	6229			
Number of observations	6063 6063		63				

Notes: HH=household; MA=moving average; ZMW=Zambian Kwacha

	2012		2015		Total	
	Number	%	Number	%	Number	%
Did not have enough cash	3,141	78.5	2,520	82.3	5,661	80.2
It was not profitable to buy fertilizer	390	9.8	118	3.9	508	7.2
Transport costs were too high	38	1.0	29	1.0	67	0.9
Fertilizer was not available in stores	77	1.9	29	1.0	106	1.5
Soil is fertile, don't need fertilizer	267	6.7	149	4.9	416	5.9
Had enough fertilizer	71	1.8	211	6.9	282	4.0
Others	15	0.4	8	0.3	23	0.3
Total	3,999	100.0	3,064	100.0	7,063	100.0

Table D2. Response to the question: What is the most important reason a household did not purchase commercial fertilizer?

Table D3. Response to the question: Why did the household not receive FISP fertilizer?

	2012		2015		To	otal
	Num		Num		Num	
	ber	%	ber	%	ber	%
Could not afford FISP down payment	980	29.8	760	24.3	1740	27.1
Could not afford cooperative membership	553	16.8	420	13.4	973	15.1
Not eligible for FISP	371	11.3	723	23.1	1094	17.0
FISP fertilizer not available	407	12.4	233	7.4	640	10.0
Did not want to get FISP because of late						
delivery/other reasons	276	8.4	388	12.4	664	10.3
Denied cooperative membership/Did not want						
membership	306	9.3	273	8.7	579	9.0
Soil is fertile (do not need fertilizer)	232	7.1	132	4.2	364	5.7
Don't know	101	3.1	50	1.6	151	2.4
Others	63	1.9	155	4.9	218	3.4
Total	3289	100.0	3134	100.0	6423	100.0

Variables	Criteria 1 or 2	Criterion 1	Criterion 2
Landholding size (ha)	-1.05***	-0.89***	-0.94***
Full-time adult equivalents	-0.60***	-0.47***	-0.73***
Tropical livestock units	-1.49***	-1.25***	-1.30***
Number of plows	-0.24***	-0.20***	-0.19***
Number of harrows	-0.07***	-0.06***	-0.05***
Number of ox-carts	-0.11***	-0.09***	-0.08***
HH owned a bicycle at the beginning of the marketing period $= 1$	-0.19***	-0.17***	-0.19***
HH owned a radio at the beginning of the marketing period $= 1$	-0.19***	-0.18***	-0.20***
HH owned a cell phone at the beginning of the marketing period $= 1$	-0.24***	-0.21***	-0.26***
HH owned a television at the beginning of the marketing period $= 1$	-0.19***	-0.17***	-0.17***
Gross per capita income, ZMW	-1,823***	-1,593***	-1,587***
Non-farm income earned during peak maize marketing season, ZMW [#]	-4,065***	-3,547***	-3,240***
Distance to feeder road (cluster median, km)	-0.06	-0.1	-0.05
Distance to paved road (cluster median, km)	5.46***	6.24***	4.39***
Distance to district town (cluster median, km)	2.75***	3.01***	2.64***
Distance to agricultural market (cluster median, km)	3.08***	3.60***	1.45**
No. of maize traders visiting village during peak maize marketing season [#]	-0.29***	-0.30***	-0.14*
Quantity of fertilizer applied to maize field, kg/ha	-151***	-137***	-225***
HH used improved maize seed=1	-0.32***	-0.28***	-0.52***
Maize productivity (kg/ha)	-783***	-694***	-977***

Table D4. Difference in means of key variable between the LC and UC households (LC-UC)

Amount of maize produced per capita

-394***

-344***

Notes: [#]Peak maize marketing season runs from May-October. The sample consists of all observations in the analytical sample (N=12126)

*** p<0.01, ** p<0.05, * p<0.1; HH=household; ZMW=Zambian Kwacha

Table D5: Variation in liquidity status between 2012 and 2015 RALS waves

		RAL	S 2015
		UC	LC
RALS 2012	UC	32%	13%
	LC	23%	33%

Notes: N=6063

 Table D6: Maize market position by RALS wave and liquidity status using quantity based definition

	Marke	ting season 2	2011/12	Marketing season 2014/15			
	UC	LC	Total	UC	LC	Total	
Net buyer	17%	26%	23%	17%	31%	24%	
Autarkic	16%	31%	26%	16%	31%	24%	
Net seller	67%	42%	52%	67%	38%	52%	
Sample size	2,698	3,365	6,063	3,290	2,773	6,063	

 Table D7. Maize market position by RALS wave and liquidity status using value based definition

	Mark	eting year 2011/12		Marketing year 2014/15		
	UC	LC	Total	UC	LC	Total
Net buyer	16%	26%	22%	29%	39%	34%
Autarkic	15%	30%	25%	16%	31%	24%
Net seller	68%	44%	52%	56%	31%	42%
Sample size	2,698	3,365	6,063	3,290	2,773	6,063

Table D8: Choice of marketing channel for the largest maize transaction made by net sellers, by RALS wave and liquidity status

	Marke	Marketing year 2011/12			eting year 2	014/15
	UC	LC	Total	UC	LC	Total
Small scale trader	12%	21%	17%	24%	28%	26%
Large scale trader	10%	9%	10%	17%	14%	16%
FRA	70%	58%	64%	50%	44%	48%
Other households	7%	11%	9%	9%	15%	11%

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Sample size	2,002	1,616	3,618	2,343	1,148	3,491
Let α be the number of the second						

Notes: Other households included sale other households for consumption (96%), schools and hospitals (2%), and NGOs and church (1%).

Table D9: Descriptive statistics for maize net sellers by maize marketing channel, 2011/12 maize marketing year

	% of net- sellers that	% sold at	Dista those	nce cover e who trav (km)	ed by velled	Fa (ZM)	armgate prio W/kg, 2017=	ce :100)
	sold to channel	laringate	Min	Median	Max	Min	Median	Max
Small scale trader	17	74	.5	7	202	0.58	1.45	11.5
Large scale trader	10	33	.1	10	420	0.58	1.45	11.7
FRA	64	9	.1	5	180	1.49	2.06	2.38
Other households	9	87	0.5	5.5	130	0.64	1.47	4.16
Sample size	3,618	3,618		2,654			3,618	

Notes: Farmgate price is the price received by the household at the point of sale and adjusted for the cost incurred in transporting the maize from the homestead to the point of sale. It has been computed using prices and costs reported by the household.

Table D10: Descriptive statistics for maize net sellers by maize marketing channel, 2014/15 maize marketing year

	% of net- sellers	% sold at	Dista thos	ance cover e who trav (km)	ed by velled	Fa (ZM	armgate prio W/kg, 2017=	ce 100)
	that sold to channel	farmgate	Min	Median	Max	Min	Median	Max
Small scale trader	26	66	.15	8	237	0.06	1.40	4.46
Large scale trader	16	30	.1	20	570	0.56	1.40	4.89
FRA	48	11	.15	5	200	0.54	1.74	3.80
Other households	11	85	1	3	60	0.69	1.51	10.7
Sample size	3.618	3.618		2,654			3,618	

Notes: Farmgate price is the price received by the household at the point of sale and adjusted for the cost incurred in transporting the maize from the homestead to the point of sale. It has been computed using prices and costs reported by the household.



Figure D1. Trends in FRA maize purchase, smallholder maize sales, and FRA purchase as % of smallholder sales, 2007/08 to 2017/18 marketing years

Source: Mason and Myers (2013) and Fung et al. (2020), compiled data obtained from the FRA, Crop Forecast Surveys, Post-Harvest Surveys, and Supplemental Surveys for relevant years. Note: Estimates of smallholder maize sales were not available for 2016/17.



Figure D2: Percent of largest maize transactions, by month and marketing channel

Source: Author's calculations from RALS 2012 and 2015 survey data.

Note: 2012/12 maize marketing channel in Panel A and 2014/15 maize marketing channel in Panel B

Appendix E

Table E1. First stage regression of liquidity status on full set of exogenous variables:	
CRE-Linear probability model	

Variables	Coefficient
Dependent variable: Liquidity status $(=1 \text{ if } HH \text{ is } LC; = 0 \text{ if } HH$	is UC)
Expected farmgate FRA price (ZMW/kg, 2017=100)	0.027
	(0.0813)
Expected farmgate market maize price (ZMW/kg, 2017=100)	-0.021
	(0.0171)
Commercial basal fertilizer price (district median, ZMW/kg, 2017=100)	-0.021*
	(0.00920)
Wage to weed 0.25 ha (district median, ZMW, 2017=100)	0.00069**
	(0.000226)
Maize seed price (district median, ZMW/kg, 2017=100)	0.00083
	(0.00328)
Age of the HH head (years)	0.0015***
	(0.000398)
Education of household head (years)	-0.017***
	(0.00170)
Male-headed household=1	-0.054***
	(0.0146)
Full-time adult equivalents	-0.00088
	(0.00683)
Landholding size (ha)	-0.0067*
	(0.00289)
Tropical livestock units	-0.0044**
	(0.00150)
Number of plows	-0.028
	(0.0153)
Number of harrows	-0.035
	(0.0414)
Number of ox-carts	-0.044
	(0.0286)
HH experienced moisture shock in current growing season(t)=1	0.0051
	(0.0222)
Growing season rainfall (mm)	0.000087
	(0.000168)
HH has experienced long term moisture shock (16-yr MA)=1	0.0068
	(0.0203)

Long run mean growing season rainfall (mm) (16-yr MA)	-0.00037
	(0.000368)
HH experienced moisture shock in last growing season (t-1) (Instrument)=1	0.092***
	(0.0228)
Time fixed effects	Yes
District fixed effects	Yes
CRE time averages	Yes
Observations	12,126

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses; F-stat for instrument (Moisture shock at t-1) = 16.27 (p=0.0001); LC= Liquidity Constrained; UC= Unconstrained; HH=household. ZMW=Zambian Kwacha; MA=moving average

Variables	Average Par	tial Effects	
	ŪČ	LC	
TTTT 1. 11/2 2 1 1 1 1 1 2 2 1 1		-	
HH was liquidity constrained during planting time=1		12/2.0***	
	504.0	(70.98)	
Expected farmgate FRA price (ZMW/kg, 2017=100)	524.2	123.6	
	(793.0)	(243.8)	
Expected farmgate market maize price (ZMW/kg, 2017=100)	-38.6	-19.5	
Commencial basel fortilizer price (district medice, 7MW/kg	(211.6)	(63.83)	
2017–100)	191 8*	-30.3	
2017-100)	(86.26)	(23.56)	
Wage to weed 0.25 ha (district median ZMW, 2017=100)	-3.41	0.017	
	(3.762)	(0.912)	
Maize seed price (district median ZMW/kg 2017=100)	52.9	-23.1	
male seed price (district median, 211 mag, 2017–100)	(40.69)	(14.20)	
	-	(11.20)	
Age of the HH head (years)	26.1***	-1.87	
	(5.815)	(1.411)	
Education of household head (years)	131.4***	55.0***	
	(21.85)	(7.500)	
Male-headed household=1	-254.8	-106.6*	
	(179.7)	(49.61)	
Full-time adult equivalents	193.7	42.4	
-	(109.2)	(36.17)	
Landholding size (ha)	566.4***	137.3***	
	(103.2)	(32.04)	
Tropical livestock units	69.1	37.9**	
-	(36.72)	(11.65)	
Number of plows	180.6	111.9	
	(274.6)	(101.4)	
Number of harrows	206.2	783.6	
	(796.4)	(524.1)	
Number of ox-carts	360.7	-0.41	
	(500.5)	(247.9)	
HH experienced moisture shock in current growing season(t)=1	-2.31	-168.6	
	(246.7)	(86.97)	
Growing season rainfall (mm)	0.36	-1.11	

Table E2. Full results: CRE-exogenous switching POLS for maize output

	(1.751)	(0.641)	
HH has experienced long term moisture shock (16-yr MA)=1	192.9	-84.4	
	(281.4)	(87.65)	
Long run mean growing season rainfall (mm) (16-yr MA)	6.36	2.23	
	(6.512)	(1.242)	
Time fixed effects	Yes		
District fixed effects	Yes		
CRE time averages	Yes		
Observations	12,126		

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses LC= Liquidity Constrained; UC= Unconstrained; HH=household. ZMW=Zambian Kwacha; MA=moving average

Variables	Average Par	rtial Effects
	UC	LC
HH was liquidity constrained during planting time=1		-1389.8
		(1508.1)
Residuals from first stage regression	-27.6	313.1
	(2593.1)	(732.5)
Expected farmgate FRA price (ZMW/kg, 2017=100)	523.5	131.4
	(794.0)	(243.6)
Expected farmgate market maize price (ZMW/kg, 2017=100)	-37.8	-27.6
	(219.4)	(67.62)
Commercial basal fertilizer price (district median, ZMW/kg, 2017=100)	192.5	-37.3
	(106.2)	(30.02)
Wage to weed 0.25 ha (district median, ZMW, 2017=100)	-3.43	0.26
	(4.351)	(1.129)
Maize seed price (district median, ZMW/kg, 2017=100)	52.8	-22.9
	(41.23)	(14.22)
Age of the HH head (years)	-26.1***	-1.41
	(6.494)	(1.686)
Education of household head (years)	131.8**	49.7***
	(47.64)	(14.64)
Male-headed household=1	-253.3	-122.8
	(244.1)	(64.66)
Full-time adult equivalents	193.7	42.5
-	(109.1)	(36.15)
Landholding size (ha)	566.6***	135.1***
	(102.1)	(31.84)
Tropical livestock units	69.2	36.7**
	(37.72)	(11.98)
Number of plows	181.4	102.8
	(282.5)	(100.4)
Number of harrows	207.2	770.3
	(804.5)	(524.4)
Number of ox-carts	361.9	-13.5
	(523.1)	(253.7)
HH experienced moisture shock in current growing season(t)=1	-1.82	-175.0*
	(249.5)	(85.42)
Growing season rainfall (mm)	0.36	-1.07
	(1.845)	(0.654)

Table E3. Full results: CRE-endogenous switching POLS for maize output

HH has experienced long term moisture shock (16-yr MA)=1	yr MA)=1 192.8 -81.0		
	(281.3)	(88.51)	
Long run mean growing season rainfall (mm) (16-yr MA)	6.36	2.27	
	(6.513)	(1.248)	
Time fixed effects	Yes		
District fixed effects	Yes		
CRE time averages	Yes		
Observations	12,126		

 Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses</td>

 LC= Liquidity Constrained; UC= Unconstrained; HH=household. ZMW=Zambian Kwacha; MA=moving average;

 FRA=Food Reserve Agency

Variables	Difference in APE (LC-UC)
Full-time adult equivalents	-151.3
	(116.4)
Landholding size (ha)	-429.1***
	(115.3)
Tropical livestock units	-31.2
	(38.60)

Table E4. Difference in APEs of key variables on maize output between LC and UChouseholds, based on CRE-Exogeneous switching POLS

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses LC= Liquidity Constrained; UC= Unconstrained; APE=Average Partial Effects

Table E5. Full results: CRE-exogenous switching POLS for morganic fertilizer and improved seed use in maize							
	Dependent variable:		Dependent v	ariable: HH			
	Inorganic fertilizer used in maize (kg/ha)		used improved maize seed=1				
	Average Par	tial Effects	Average Par	rtial Effects			
	UC	LC	UC	LC			
HH was liquidity constrained during planting time=1		-112.9***		-0.19***			
		(4.534)		(0.0110)			
Expected farmgate FRA price (ZMW/kg, 2017=100)	22.5	11.4	0.18	0.091			
	(75.59)	(33.09)	(0.109)	(0.0960)			
Expected farmgate market maize price (ZMW/kg, 2017=100)	-12.3	2.69	-0.0053	0.0048			
	(10.53)	(7.660)	(0.0229)	(0.0206)			
Commercial basal fertilizer price (district median, ZMW/kg, 2017=100)	9.52	-0.50	-0.0064	0.00083			
	(5.093)	(3.890)	(0.0141)	(0.00887)			
Wage to weed 0.25 ha (district median, ZMW, 2017=100)	-0.13	-0.12	0.00036	-0.00043			
	(0.116)	(0.0915)	(0.000218)	(0.000289)			
Maize seed price (district median, ZMW/kg, 2017=100)	0.13	-1.06	0.016***	0.014**			
	(2.267)	(1.481)	(0.00464)	(0.00449)			
Age of the HH head (years)	-0.081	0.34	-0.000070	-0.000069			
	(0.232)	(0.193)	(0.000547)	(0.000497)			
Education of household head (years)	6.08***	6.63***	0.014***	0.022***			
	(1.043)	(0.844)	(0.00195)	(0.00234)			
Male-headed household=1	-12.1	-20.2**	0.060**	-0.042*			
	(9.026)	(7.025)	(0.0220)	(0.0184)			
Full-time adult equivalents	-4.24	-2.17	-0.0014	0.0076			
	(3.463)	(3.606)	(0.00815)	(0.00895)			
Landholding size (ha)	-7.45***	-6.01***	0.0039	0.0074			

Table E5. Full results: CRE-exogenous switching POLS for inorganic fertilizer and improved seed use in maize

	(1.424)	(1.813)	(0.00281)	(0.00412)
Tropical livestock units	0.33	-0.13	0.0018	0.0047
	(0.796)	(0.866)	(0.00117)	(0.00455)
Number of plows	9.38	11.9	0.021	-0.015
	(6.140)	(8.384)	(0.0139)	(0.0266)
Number of harrows	21.7	-7.62	-0.026	-0.037
	(20.86)	(24.99)	(0.0293)	(0.0805)
Number of ox-carts	-10.6	-6.02	0.021	0.089
	(11.94)	(14.24)	(0.0296)	(0.0489)
HH experienced moisture shock in current growing season(t)=1	-19.0	3.89	-0.040	0.033
	(11.07)	(9.955)	(0.0278)	(0.0288)
Growing season rainfall (mm)	-0.10	0.16	0.000065	0.00057**
	(0.0997)	(0.0913)	(0.000198)	(0.000214)
HH has experienced long term moisture shock (16-yr MA)=1	3.37	-8.88	0.087***	-0.037
	(8.906)	(8.930)	(0.0233)	(0.0260)
Long run mean growing season rainfall (mm) (16-yr MA)	0.043	0.42*	0.00064	0.00095*
	(0.205)	(0.194)	(0.000502)	(0.000464)
Time fixed effects	Yes			
District fixed effects	Yes			
CRE time averages	Yes			
Observations	12,126			

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses LC= Liquidity Constrained; UC= Unconstrained; HH=household. ZMW=Zambian Kwacha; MA=moving average; FRA=Food Reserve Agency

Variables	Average Partial Effects		
	Net-buyer	Autarkic	Net-seller
Quantity of maize produced, kg	-0.00012***	-0.000020***	0.00014***
	(0.0000157)	(0.00000147)	(0.0000161)
Farmgate maize price (ZMW/kg, 2017=100)	-0.0021	-0.00036	0.0025
	(0.0116)	(0.00195)	(0.0135)
Farmgate FRA maize price (ZMW/kg, 2017=100)	-0.061	-0.010	0.071
	(0.106)	(0.0180)	(0.124)
Age of the HH head (years)	0.00021	0.000035	-0.00024
	(0.000229)	(0.0000385)	(0.000267)
Education of household head (years)	0.0017	0.00029	-0.0020
	(0.00114)	(0.000189)	(0.00133)
Full-time adult equivalents	0.021*	0.0038*	-0.025*
	(0.00881)	(0.00180)	(0.0106)
Male-headed household=1	0.013**	0.0021**	-0.015**
	(0.00460)	(0.000826)	(0.00538)
Distance to unpaved road (cluster median, km) #	0.0014	0.00024	-0.0017
	(0.00154)	(0.000263)	(0.00180)
Distance to paved road (cluster median, km) #	-0.00030	-0.000051	0.00035
	(0.000269)	(0.0000467)	(0.000315)
Distance to agricultural market (cluster median, km) #	0.00021	0.000035	-0.00024
	(0.000338)	(0.0000567)	(0.000395)
Number of maize traders visiting village between May-October #	-0.0018	-0.00030	0.0021
	(0.00207)	(0.000351)	(0.00242)
HH owned a radio at the beginning of marketing period=1	-0.0073	-0.0012	0.0085
	(0.0120)	(0.00205)	(0.0141)
HH owned a cellphone at the beginning of marketing period=1	0.0065	0.0011	-0.0076

Table E6. Full results: CRE-ordered Probit for quantity-based definition of maize market position

	(0.0134)	(0.00221)	(0.0156)
HH owned a bicycle at the beginning of marketing period=1	0.0066	0.0011	-0.0077
	(0.0131)	(0.00222)	(0.0153)
Time fixed effects		Yes	
District fixed effects		Yes	
CRE time averages		Yes	
Observations		12126	

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses. HH=household. ZMW=Zambian Kwacha; FRA=Food Reserve Agency. #The cluster level medians were used for these variables even if they were collected at the household level in order to remove outliers. Cluster here refers to the standard enumeration area consisting of approximately 20 villages.

Variables	Average partial effects			
	Net-buyer	Autarkic	Net-seller	
Quantity of maize produced, kg	-0.000080***	-0.0000084***	0.000088***	
	(0.0000797)	(0.00000886)	(0.0000839)	
Farmgate maize price (ZMW/kg, 2017=100)	-0.024	-0.0025	0.027	
	(0.0136)	(0.00145)	(0.0150)	
Farmgate FRA maize price (ZMW/kg, 2017=100)	-0.040	-0.0042	0.044	
	(0.127)	(0.0134)	(0.141)	
Age of the HH head (years)	-0.00045	-0.000047	0.00050	
	(0.000257)	(0.0000271)	(0.000284)	
Education of household head (years)	0.0024	0.00025	-0.0026	
	(0.00126)	(0.000133)	(0.00139)	
Full-time adult equivalents	0.018	0.0020	-0.020	
	(0.0103)	(0.00130)	(0.0115)	
Male-headed household=1	0.012*	0.0013*	-0.013*	
	(0.00559)	(0.000596)	(0.00617)	
Distance to unpaved road (cluster median, km) #	0.00048	0.000051	-0.00053	
	(0.00188)	(0.000198)	(0.00208)	
Distance to paved road (cluster median, km) #	-0.00042	-0.000044	0.00046	
	(0.000353)	(0.0000374)	(0.000390)	
Distance to agricultural market (cluster median, km) #	0.00012	0.000013	-0.00014	
	(0.000388)	(0.0000409)	(0.000429)	
Number of maize traders visiting village between May-October #	-0.0069**	-0.00073**	0.0076**	
	(0.00249)	(0.000267)	(0.00275)	
HH owned a radio at the beginning of marketing period=1	-0.014	-0.0015	0.016	
	(0.0138)	(0.00143)	(0.0153)	
HH owned a cellphone at the beginning of marketing period=1	-0.0015	-0.00016	0.0017	
	(0.0154)	(0.00162)	(0.0170)	

Table E7. Full results: CRE-ordered Probit for value-based definition of maize market position

HH owned a bicycle at the beginning of marketing period=1	-0.013	-0.0013	0.014
	(0.0151)	(0.00153)	(0.0166)
Time fixed effects		Yes	
District fixed effects		Yes	
CRE time averages		Yes	
Observations		12126	

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses. #The cluster level medians were used for these variables even if they were collected at the household level in order to remove outliers. Cluster here refers to the standard enumeration area consisting of approximately 20 villages. HH=household. ZMW=Zambian Kwacha; FRA=Food Reserve Agency

Variables	Average Partial Effects
Quantity of maize produced, kg	0.86***
	(0.0194)
Farmgate maize price (ZMW/kg, 2017=100)	19.3
	(27.26)
Farmgate FRA maize price (ZMW/kg, 2017=100)	34.6
	(256.2)
Age of the HH head (years)	-4.31***
	(0.691)
Education of household head (years)	-10.9***
	(3.316)
Full-time adult equivalents	-73.2**
	(23.69)
Male-headed household=1	-32.5*
	(13.76)
Distance to unpaved road (cluster median, km) #	-6.21
	(4.094)
Distance to paved road (cluster median, km) #	0.26
	(0.686)
Distance to agricultural market (cluster median, km) #	-2.63**
	(1.020)
Number of maize traders visiting village between May-October #	-1.33
	(5.199)
HH owned a radio at the beginning of marketing period=1	-41.8
	(31.11)
HH owned a cellphone at the beginning of marketing period=1	-9.17
	(30.48)
HH owned a bicycle at the beginning of marketing period=1	-41.4
	(35.42)
Time fixed effects	Yes
District fixed effects	Yes
CRE time averages	Yes
Observations	12126

Table E8. Full results: CRE-POLS for net maize sales (maize sold - maize and maize meal purchased)

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses. #The cluster level medians were used for these variables even if they were collected at the household level in order to remove outliers. Cluster here refers to the standard enumeration area consisting of approximately 20 villages. HH=household. ZMW=Zambian Kwacha; FRA=Food Reserve Agency

Variables	Coefficient
Quantity of maize produced, kg	0.74***
	(0.026)
Farmgate maize price (ZMW/kg, 2017=100)	172.0**
	(58.8)
Farmgate FRA maize price (ZMW/kg, 2017=100)	392.2
	(582.0)
Age of the HH head (years)	-4.98***
	(1.33)
Education of household head (years)	7.51
	(5.63)
Full-time adult equivalents	-16.0
	(27.6)
Male-headed household=1	-93.5*
	(45.7)
Distance to unpaved road (cluster median, km) #	-23.6
	(12.7)
Distance to paved road (cluster median, km) #	1.83
	(1.31)
Distance to agricultural market (cluster median, km) #	-1.53
	(1.64)
Number of maize traders visiting village between May-October #	-2.80
	(9.53)
HH owned a radio at the beginning of marketing period=1	46.6
	(57.9)
HH owned a cellphone at the beginning of marketing period=1	61.1
	(52.5)
HH owned a bicycle at the beginning of marketing period=1	-24.6
	(61.2)
Time fixed effects	Yes
District fixed effects	Yes
CRE time averages	Yes
Observations	12,126

Table E9. Full results: CRE-Tobit selection equation of quantity of maize sales made in largest transaction

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses; #The cluster level medians were used for these variables even if they were collected at the household level in order to remove outliers. Cluster here refers to the standard enumeration area consisting of approximately 20 villages. HH=household. ZMW=Zambian Kwacha; FRA=Food Reserve Agency.

Variables	Average Partial Effects			
	Small scale traders	FRA	Large scale traders	Other households
— —	0.0000030	0.000039***	0.000012***	-0.000054***
Quantity of maize produced, kg	(0.0000081)	(0.000089)	(0.000036)	(0.000013)
	0.0044	-0.036	0.044*	-0.013
Farmgate maize price (ZMW/kg, 2017=100)	(0.033)	(0.033)	(0.025)	(0.022)
	0.081	0.46	-0.29	-0.24
Farmgate FRA maize price (ZMW/kg, 2017=100)	(0.42)	(0.43)	(0.28)	(0.27)
	-0.0012*	0.0010	-0.00071	0.00093**
Age of the HH head (years)	(0.00066)	(0.00075)	(0.00050)	(0.00043)
	0.00080	0.0018	-0.0019	-0.00073
Education of nousenoid head (years)	(0.0029)	(0.0030)	(0.0022)	(0.0022)
Full time adult accirclants	-0.0068	0.0060	-0.0058	0.0065
Full-time adult equivalents	(0.012)	(0.012)	(0.010)	(0.009)
Mala handad haysahald-1	0.012	-0.034	0.019	0.0036
Male-headed household=1	(0.020)	(0.029)	(0.020)	(0.017)
Distance to uppered good (cluster modion km) #	0.0029	-0.0041	0.0026	-0.0014
Distance to unpaved road (cluster median, km)	(0.0072)	(0.0074)	(0.0048)	(0.0046)
Distance to payed read (aluster modion 1/m) #	0.00036	-0.0016	0.00096	0.00030
Distance to paved foad (cluster median, km)	(0.0011)	(0.0010)	(0.0012)	(0.0006)
Distance to agricultural market (cluster modion km) #	0.00038	0.00066	-0.0011	0.00010
Distance to agricultural market (cluster median, km)	(0.00086)	(0.00078)	(0.00074)	(0.00063)
Number of maize traders visiting village between	-0.0047	-0.0015	0.0049	0.0014
May-October #	(0.0050)	(0.0051)	(0.0046)	(0.0038)
HH owned a radio at the beginning of marketing	0.0018	-0.0010	-0.0053	0.0045
period=1	(0.029)	(0.034)	(0.025)	(0.021)

Table E10. Full results: CRE-multinomial logit of choice of marketing channel made for the largest transaction of maize by net seller households

HH owned a cellphone at the beginning of marketing	-0.013	-0.013	0.027	-0.0019
period=1	(0.034)	(0.033)	(0.025)	(0.022)
HH owned a bicycle at the beginning of marketing	-0.0080	-0.00082	0.022	-0.014
period=1	(0.032)	(0.035)	(0.030)	(0.025)
Deside all from CDE Table all stiens are time	0.000019	0.000051***	0.000024***	-0.000094***
Residuals from CRE-Tobit selection equation	(0.000012)	(0.000011)	(0.0000053)	(0.000012)
Time fixed effects		Yes		
Province fixed effects		Yes		
CRE time averages		Yes		
Observations		7108		

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses and bootstrapped with 500 replications to account for the generated regressor (CRE-Tobit residuals); #The cluster level medians were used for these variables even if they were collected at the household level in order to remove outliers. Cluster here refers to the standard enumeration area consisting of approximately 20 villages. HH=household. ZMW=Zambian Kwacha; FRA=Food Reserve Agency.

Variables	Averag Efi	e Partial fects
	UC	LC
HH was liquidity constrained during planting time=1		- 1561.5***
		(68.91)
Expected farmgate FRA price (ZMW/kg, 2017=100)	391.0	67.4
	(408.9)	(321.9)
Expected farmgate market maize price (ZMW/kg, 2017=100)	62.2	93.3
	(115.9)	(70.18)
Commercial basal fertilizer price (district median, ZMW/kg,		
2017=100)	36.8	16.5
	(36.41)	(27.56)
Wage to weed 0.25 ha (district median, ZMW, 2017=100)	-3.67	0.088
	(2.175)	(0.806)
Maize seed price (district median, ZMW/kg, 2017=100)	38.7	-28.3*
	(23.86)	(12.61)
Age of the HH head (years)	- 16.4***	-1.46
	(3.546)	(1.290)
Education of household head (years)	108.8***	14.5*
	(14.63)	(7.082)
Male-headed household=1	- 385.5***	53.2
	(102.0)	(49.79)
Full-time adult equivalents	138.1*	56.9
i un time aduit equivalento	(66.98)	(30.56)
Landholding size (ha)	435.4***	118.3*
	(66.87)	(47.61)
Tropical livestock units	68.0**	35.5*
	(25.56)	(17.42)
Number of plows	314.9	43.4
•	(185.5)	(133.5)
Number of harrows	526.0	4.57
	(634.3)	(617.9)
Number of ox-carts	463.7	-53.7
	(345.3)	(340.6)

Table E11. Full results: CRE-exogenous switching POLS for maize output using alternate definition of liquidity status

HH experienced moisture shock in current growing season(t)=1	-111.4	-61.4
	(141.9)	(89.89)
Growing season rainfall (mm)	-1.06	-0.94
	(0.920)	(0.602)
HH has experienced long term moisture shock (16-yr MA)=1	49.0	9.39
	(172.5)	(83.34)
Long run mean growing season rainfall (mm) (16-yr MA)	5.70**	2.40*
	(1.956)	(1.011)
Time fixed effects	Y	es
District fixed effects	Yes	
CRE time averages	Yes	
Observations	12,126	

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses LC= Liquidity Constrained; UC= Unconstrained; HH=household. ZMW=Zambian Kwacha; MA=moving average

Hypothesis	Effect of interest	APE
	Liquidity constraint on the probability of being a pat hyper	0.188***
1	Equidity constraint on the probability of being a net buyer	(0.027)
1	Liquidity constraint on the probability of being a pat huver	-0.221***
	Equility constraint on the probability of being a net ouyer	(0.028)
	Expected FRA price on probability of being a net seller for LC	0.009
	HH	(0.065)
	Expected FRA price on probability of being a net seller for UC	0.055
r	HH	(0.125)
	Market price on probability of being a net seller for I C HH	0.013
	Market price on probability of being a net sener for Le fiff	(0.013)
	Market price on probability of being a net seller for UC HH	0.009
	Market pree on probability of being a net sener for de fint	(0.025)
	Liquidity constraint on the probability of selling to a small scale	-0.005
	trader	(0.013)
	Liquidity constraint on the probability of selling to FRA	-0.061***
3	Equality constraint on the probability of senting to 1 K/Y	(0.014)
3	Liquidity constraint on the probability of selling to a large scale	-0.019***
	trader	(0.006)
	Liquidity constraint on the probability of selling to other	0.084***
	households	(0.020)

Table E12.	. Test of hypotheses	using alternate definition	of liquidity status

Notes: Standard errors in parentheses are based on 500 bootstrap replications APE= Average partial Effect; LC= Liquidity Constrained; UC= Unconstrained; HH=Household; FRA= Food Reserve Agency

	Regression estimates from CRE-POLS of HH's liquidity status	Average Partial Effects from CRE-switching POLS of maize output (kg)	
		UC	LC
HH experienced a moisture shock in t+1	0.013	18.0	-22.0
HH was liquidity constrained during	(0.0302)	(329.0)	-1268.3***
Expected farmgate FRA price (ZMW/kg, 2017=100)	0.028	(71.01) 528.4 (792.7)	(71.01) 121.5 (243.4)
Expected farmgate market maize price	-0.019	-35.1	-22.2
Commercial basal fertilizer price (district	-0.021*	(213.4) 191.0*	-29.4
Wage to weed 0.25 ha (district median,	(0.00929) 0.00069**	(87.15) -3.51	0.016
Maize seed price (district median,	(0.000226) 0.00097	(3.756) 53.9	(0.911) -23.4
ZMW/kg, 2017=100)	(0.00331) 0.0014***	(40.91) -25.9***	(14.47) -1.86
	(0.000399) -0.017***	(5.807) 131.8***	(1.408) 54.9***
Education of nousehold head (years)	(0.00170) -0.054***	(21.89) -254.6	(7.512) -106.4*
Male-headed household=1	(0.0146)	(179.8)	(49.53)
Full-time adult equivalents	(0.00685)	(109.6)	(36.21)
Landholding size (ha)	-0.0067* (0.00289)	567.2*** (103.3)	137.1*** (32.08)
Tropical livestock units	-0.0044** (0.00150)	68.9 (36.71)	38.0** (11.65)
Number of plows	-0.028 (0.0153)	180.5 (274.6)	112.0
Number of harrows	-0.035	210.6	782.9
Number of ox-carts	-0.044	357.6	-0.65
HH experienced moisture shock in	(0.0285) -0.0038	(500.0) -25.1	(248.1) -151.0
current growing season(t)=1	(0.0289)	(283.6)	(94.66)

Table E13: Falsification tests for validity of instruments

Growing season rainfall (mm)	0.000086	0.31	-1.11
	(0.000168)	(1.747)	(0.649)
HH has experienced long term moisture	0.0062	192.3	-84.8
shock (16-yr MA)=1	(0.0204)	(283.1)	(88.03)
Long run mean growing season rainfall	-0.00052	6.81	2.32
(mm) (16-yr MA)	(0.000377)	(6.555)	(1.287)
HH experienced moisture shock in last	0.096***		
growing season (t-1) (Instrument)=1	(0.0234)		
Time fixed effects	Yes	Yes	
District fixed effects	Yes	Yes	
CRE time averages	Yes	Yes	
Observations	12,126	12,126	

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level in parentheses LC= Liquidity Constrained; UC= Unconstrained; HH=household. ZMW=Zambian Kwacha; MA=moving average; FRA=Food Reserve Agency

Variable	Coefficient
HH was liquidity constrained during planting time=1	-2698.3*
	(1153.8)
Expected farmgate FRA price (ZMW/kg, 2017=100)	472.4
	(267.3)
Expected farmgate market maize price (ZMW/kg, 2017=100)	-48.8
	(97.81)
Commercial basal fertilizer price (district median, ZMW/kg, 2017=100)	-35.4
	(45.70)
Wage to weed 0.25 ha (district median, ZMW, 2017=100)	-1.57
	(2.057)
Maize seed price (district median, ZMW/kg, 2017=100)	27.4
	(18.53)
Age of the HH head (years)	-9.55**
	(3.006)
Education of household head (years)	59.3*
	(23.69)
Male-headed household=1	-482.4***
	(118.9)
Full-time adult equivalents	124.0*
	(55.97)
Landholding size (ha)	397.1***
	(55.91)
Tropical livestock units	57.0*
	(23.14)
Number of plows	197.0
	(169.1)
Number of harrows	504.8
	(589.1)
Number of ox-carts	389.5
	(303.3)
HH experienced moisture shock in current growing season(t)=1	-99.7
	(121.6)
Growing season rainfall (mm)	-0.64
	(0.755)
HH has experienced long term moisture shock (16-yr MA)=1	170.3
	(146.1)
Long run mean growing season rainfall (mm) (16-yr MA)	9.07***
	(1.443)

Time fixed effects	Yes
District fixed effects	Yes
CRE time averages	Yes
Observations	12126

Notes: *** p<0.01, ** p<0.05, * p<0.1; Standard errors clustered at HH level are in parentheses. Instrument for liquidity status at time t is a dummy variable that takes value 1 if there was a moisture shock at t-1 and 0 otherwise, F-stat for instrument is 16.27 (p<0.001). The test for endogeneity shows that we cannot reject the null of the liquidity constraint being exogenous (F-stat=1.84, p-value=0.175). LC= Liquidity Constrained; UC= Unconstrained; HH=household. ZMW=Zambian Kwacha; MA=moving average; FRA=Food Reserve Agency
	Model 1		Mo	Model 2	
	UC	LC	UC	LC	
HH was liquidity constrained during planting time=1		-1273.0***		-1272.0***	
		(70.97)		(70.97)	
Expected farmgate FRA price (ZMW/kg, 2017=100)	525.4	122.3	523.9	119.7	
	(788.4)	(242.9)	(789.2)	(243.3)	
Expected farmgate market maize price (ZMW/kg, 2017=100)	-291.1	17.8	-182.0	-6.44	
	(238.6)	(64.48)	(235.4)	(66.23)	
Commercial basal fertilizer price (district median, ZMW/kg, 2017=100)	194.1*	-30.4	189.3*	-30.4	
	(85.04)	(23.51)	(85.58)	(23.96)	
Wage to weed 0.25 ha (district median, ZMW, 2017=100)	-4.30	0.016	-3.83	-0.019	
	(3.869)	(0.861)	(3.810)	(0.868)	
Maize seed price (district median, ZMW/kg, 2017=100)	54.2	-23.0	54.5	-22.6	
	(41.40)	(14.52)	(41.43)	(14.51)	
Age of the HH head (years)	-26.2***	-1.87	-26.1***	-1.87	
	(5.820)	(1.410)	(5.816)	(1.410)	
Education of household head (years)	131.3***	55.0***	131.5***	55.0***	
	(21.86)	(7.503)	(21.85)	(7.499)	
Male-headed household=1	-252.6	-106.2*	-254.6	-106.4*	
	(179.7)	(49.56)	(179.6)	(49.55)	
Full-time adult equivalents	191.5	41.7	192.7	42.1	
	(109.6)	(36.20)	(109.5)	(36.22)	
Landholding size (ha)	566.3***	137.4***	566.3***	137.3***	
	(103.2)	(32.01)	(103.3)	(32.05)	
Tropical livestock units	70.3	38.0**	69.7	37.9**	
	(36.75)	(11.61)	(36.75)	(11.64)	

Table E14: Average partial effects of sensitivity analysis using different measures of prices (CRE-exogenous switching POLS for maize output)

Number of plows	184.1	111.5	182.9	111.9
	(274.9)	(101.5)	(274.7)	(101.5)
Number of harrows	213.6	781.3	208.2	782.6
	(797.3)	(523.7)	(797.4)	(523.5)
Number of ox-carts	360.2	-0.45	361.2	-0.77
	(500.9)	(247.9)	(500.7)	(247.9)
HH experienced moisture shock in current growing season(t)=1	28.1	-174.0*	6.54	-171.1*
	(246.5)	(85.92)	(246.3)	(85.80)
Growing season rainfall (mm)	0.26	-1.10	0.35	-1.10
	(1.746)	(0.640)	(1.741)	(0.639)
HH has experienced long term moisture shock (16-yr MA)=1	198.2	-85.1	192.7	-84.4
	(281.4)	(88.30)	(281.5)	(87.67)
Long run mean growing season rainfall (mm) (16-yr MA)	6.58	2.18	6.53	2.22
	(6.520)	(1.249)	(6.536)	(1.255)
Time fixed effects	Yes		Yes	
District fixed effects	Yes		Yes	
CRE time averages	Yes		Yes	
Observations	12,126		12,126	

Notes: *** p<0.01, ** p<0.05, * p<0.1. The estimates are average partial effects. Standard errors in parenthesis are clustered at HH level. In Model 1 expected farmgate maize market price that was computed by taking MA of retail maize prices for the months of July, August, and September. In Model 2 it was computed by taking the MA of prices over the peak maize marketing season May-October. Both prices were adjusted for cost of transport from homestead to district administrative unit. LC= Liquidity Constrained; UC= Unconstrained; HH=household. ZMW=Zambian Kwacha; MA=moving average; FRA=Food Reserve Agency.

Variables		Model 1			Model 2	
	Net-buyer	Autarkic	Net-seller	Net-buyer	Autarkic	Net-seller
Quantity of maize produced, kg	-0.00012***	-0.000020***	0.00014***	-0.00012***	-0.000020***	0.00014***
	(0.000016)	(0.0000015)	(0.000016)	(0.000016)	(0.0000015)	(0.000016)
Farmgate maize price (ZMW/kg, 2017=100)	-0.0036	-0.00060	0.0042	0.0092	0.0016	-0.011
	(0.00934)	(0.00158)	(0.0109)	(0.0113)	(0.00191)	(0.0132)
Farmgate FRA maize price (ZMW/kg, 2017=100)	-0.057	-0.0097	0.067	-0.066	-0.011	0.077
	(0.107)	(0.0180)	(0.125)	(0.105)	(0.0177)	(0.123)
Age of the HH head (years)	0.00021	0.000035	-0.00024	0.00021	0.000035	-0.00024
	(0.000229)	(0.0000385)	(0.000267)	(0.000229)	(0.0000385)	(0.000267)
Education of household head	0.0017	0.00029	-0.0020	0.0017	0.00029	-0.0020
(years)	(0.00114)	(0.000189)	(0.00133)	(0.00114)	(0.000189)	(0.00133)
Full-time adult equivalents	0.021*	0.0038*	-0.025*	0.021*	0.0038*	-0.025*
	(0.00881)	(0.00180)	(0.0106)	(0.00881)	(0.00180)	(0.0106)
Male-headed household=1	0.013**	0.0021**	-0.015**	0.013**	0.0021**	-0.015**
	(0.00460)	(0.000827)	(0.00539)	(0.00460)	(0.000827)	(0.00538)
Distance to unpaved road (cluster median, km) #	0.0014	0.00023	-0.0016	0.0016	0.00027	-0.0018
	(0.00155)	(0.000265)	(0.00181)	(0.00153)	(0.000263)	(0.00179)
Distance to paved road (cluster median, km) [#]	-0.00031	-0.000052	0.00036	-0.00031	-0.000052	0.00036
	(0.000268)	(0.0000466)	(0.000314)	(0.000267)	(0.0000466)	(0.000314)
Distance to agricultural market (cluster median, km) #	0.00021	0.000036	-0.00025	0.00019	0.000032	-0.00022
	(0.000336)	(0.0000564)	(0.000393)	(0.000336)	(0.0000565)	(0.000392)
Number of maize traders visiting village between May-October [#] HH owned a radio at the beginning of marketing period	-0.0019	-0.00032	0.0022	-0.0020	-0.00033	0.0023
	(0.00209)	(0.000355)	(0.00245)	(0.00208)	(0.000353)	(0.00243)
	-0.0073	-0.0012	0.0086	-0.0074	-0.0013	0.0087
	(0.0120)	(0.00205)	(0.0141)	(0.0120)	(0.00206)	(0.0141)
	0.0065	0.0011	-0.0075	0.0061	0.0010	-0.0072

Table E15: Average partial effects of sensitivity analysis for different measures of prices (CRE-ordered Probit of quantity based maize market position)

HH owned a cellphone at the	(0.0134)	(0.00221)	(0.0156)	(0.0133)	(0.00221)	(0.0155)
beginning of marketing period	(010-10-1)	(0000)	(010-20-0)	(0.0000)	(*****===)	(000000)
HH owned a bicycle at the	0.0067	0.0011	-0.0078	0.0065	0.0011	-0.0077
beginning of marketing period	(0.0131)	(0.00222)	(0.0153)	(0.0131)	(0.00222)	(0.0153)
Time fixed effects		Yes			Yes	
District fixed effects		Yes			Yes	
CRE time averages	Yes			Yes		
Observations	12126			12126		

Notes: *** p<0.01, ** p<0.05, * p<0.1; #The cluster level medians were used for these variables even if they were collected at the household level in order to remove outliers. Cluster here refers to the standard enumeration area consisting of approximately 20 villages. All estimates in the table are average partial effects. Standard errors in parenthesis are clustered at HH level. In Model 1 farmgate maize market price refers to MA of retail maize prices for July, August, and September. In Model 2 it refers to MA of prices over the peak maize marketing season (May-October). Both prices were adjusted for cost of transport from homestead to district administrative unit. HH=household. ZMW=Zambian Kwacha. FRA=Food Reserve Agency.