No. 8

HarvestPlus Working Paper | May 2012

Demand for Maize Hybrids, Seed Subsidies, and Seed Decisionmakers in Zambia

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ABSTRACT

The successful development and diffusion of improved maize seed in Zambia during the 1970s–80s was a major achievement of African agriculture but was predicated on a government commitment to parastatal grain and seed marketing, the provision of services to maize growers, and a pan-territorial pricing scheme that was fiscally unsustainable. Declining maize output when this system was dismantled contributed to the reinstatement in 2002 of subsidies for maize seed and fertilizer through the Fertilizer and Farmer Input Support Programs (FISP). In the meantime, seed liberalization has led to an array of new, improved maize varieties, most of which are hybrids. This analysis explores the determinants of demand for first-generation (F1) hybrid maize seed in Zambia based on a survey of maize growers during the 2010/11 cropping season. We estimate the determinants of demand with a control function approach to handle the potential endogeneity of the binary variable measuring subsidy receipt and compare determinants of demand between female and male seed decisionmakers. We find that hybrid seed use in Zambia is still very much an "affair of state" in that farmers' use of F1 hybrids is explained largely by inclusion in FISP. The quality (literacy) of the labor supply, the ratio of active labor to dependents in the household, sources of information, and length of residence in the village are predictors of maize seed subsidy receipt. Overall, we find that male and female seed decisionmakers may represent distinct demand segments. The fact that the percentage of seed decisionmakers who are women is much higher than the percentage of women who are de jure or de facto household heads has implications for the design of extension strategies and variety promotion.

Both authors are with the Department of Agricultural, Food, and Resource Economics, Michigan State University. This work was funded by HarvestPlus and the Food Security Research Program (Michigan State University) in Zambia. The authors thank Dorene Asare-Marfo for the preparation of the data, co-investigators Hugo De Groote, Ernest Kasuta, and especially Ekin Birol, as well as the enumerators, supervisors, and farmers who participated in the 2011 survey on which this analysis is based. They also thank Thom Jayne for his insights concerning maize in Eastern and Southern Africa.

CONTENTS

I. INTRODUCTION

The development and adoption of improved maize in Zambia is a major achievement of African agriculture. Historically, this achievement was predicated on the commitment of the government to ensure food security through large fiscal outlays on parastatal grain and seed marketing, provision of services to maize growers, and a pan-territorial pricing scheme. The story of this achievement, which was most evident from 1970–89, has been summarized by Smale and Jayne (2010). Howard (1994) and Howard and Mungoma (1997) documented the period in detail. Contemporaneous, in-depth research in the Eastern Province of the country examined fertilizer use and gender aspects of hybrid seed use (Jha and Hojjati 1993; Kumar 1994).

With the structural adjustment programs advanced by the International Monetary Fund and World Bank during the 1990s, the underpinnings of the integrated maize production and marketing system were gradually removed. Use of fertilizer and improved seed plummeted, and maize productivity declined. Despite evident progress in liberalizing seed markets, input subsidies for fertilizer and seed have again assumed major importance over the past decade. To our knowledge, no nationally representative analysis of hybrid seed adoption has been conducted during this more recent policy period. However, in-depth econometric analyses have demonstrated how fertilizer subsidies have "crowded out" commercial purchases while "crowding in" poorer growers (Xu et al. 2009).

This paper represents a first step in similar analysis of hybrid seed. We identify the determinants of hybrid seed adoption among maize-growing households during the major rainy season of 2010/11, while controlling for the effects of seed subsidy receipt in that year. Because many farmers in Zambia have grown or been exposed to maize hybrids for years, this paper defines adopters as growers of first-generation (F1) hybrids whose names they know. That is, we focus on farmers who constitute a potentially commercial demand for seed. We base our analysis on data collected in face-to-face interviews with a sample of over 1,128 maize growers representing the major maize-producing provinces in Zambia, of which only a handful cultivated over 20 hectares (ha). The survey was implemented by HarvestPlus, the International Maize and Wheat Improvement Center (CIMMYT), and the University of Zambia. The objective of the survey was to provide information that can be used by practitioners in designing strategies to promote vitamin A-enriched maize seed.

We begin by describing the maize seed Zambian farmers grow, the incidence of the subsidy, and the nature of information sources. We then identify the factors that influence whether farmers grow maize hybrids and how much hybrid seed they grow, employing a control function approach to test and account for the endogeneity of the maize seed subsidy. We also test differences between male and female decisionmakers. To measure and test the importance of variety attributes and of various information sources in decisionmaking, we apply principal components analysis and compute factor scores that are then used as explanatory variables.

II. HISTORICAL SYNOPSIS

Maize became the dominant food crop in Zambia during the first half of the 20th century, yielding higher returns than the previous staple cereals, sorghum and millet. Easier to process and market, particularly as an export to the British starch market, maize was also an easy way to pay workers on the large-scale farms and mines of the Federation of Rhodesia and Nyasaland (Smale and Jayne 2010).

Following independence in 1964, the government invested in expanding state-directed marketing systems to support smallholder farmers and ensure a supply of inexpensive food for urban populations, tying grain marketing to the delivery of seeds, fertilizer, and credit on beneficial terms. As in other countries of Eastern and Southern Africa, maize became a cornerstone of the modern state (Jayne and Jones 1997).

Initially, hybrids introduced from Zimbabwe before independence had more than doubled yields on commercial farms; following independence, Zambia's maize breeders introduced an impressive array of double and three-way cross hybrids with yield advantages, even without fertilizer, in all but the most difficult growing environments (Howard 1994). With lots of land, favorable weather, and the establishment of a seed industry (including Zamseed), the period from 1970 to 1989 was characterized by adoption rates that climbed to 65 percent and a 4.9 percent annual rate of growth in maize yields (Smale and Jayne 2010).

Preferential government policies were a major contributing factor. Fertilizer subsidies, pan-seasonal and pan-territorial pricing, and geographically dispersed market depots bolstered rates of return to maize production even in remote areas. Considering the full cost of seed development, extension, and marketing, however, the rate of return to maize research investment was actually negative (Howard and Mungoma 1997). Despite Zambia's comparative advantage in crops other than maize, policies were skewed in favor of maize production. Fiscally unsustainable, this system was partially dismantled after 1993 during structural adjustment programs.

Expenditure on agriculture as a share of public resources was erratic through 1990 but fell to a negligible level from 1990, only rising again in the early 2000s. Combined with a decade of droughts and food crises in 1991–1992 and 2002–2003, policy changes induced a retraction of maize production areas, a drop in hybrid adoption from an estimated 72 percent in 1990 to under 22 percent in 1996 and a decline in fertilizer use on maize. Diversification of smallholder crops and income in remote areas, and of national exports, was one potentially beneficial consequence of these changes (Howard and Mungoma 1997).

Nonetheless, maize remains a cornerstone of the Zambian agricultural economy and government agricultural policy. Today, maize is Zambia's number one commodity in terms of value, second after sugarcane in production and fourth in exports after sugar, cotton, and tobacco (FAO). Maize represents an estimated 41 percent of gross farm household income and 33 percent of total household crop sales (Jayne et al. 2010). The crop provides about half of per capita daily calories (FAO). Although per capita wheat consumption has risen dramatically, particularly in urban settings, maize remains the primary staple and occupies an important share of the total food expenditures of poor households (Jayne et al. 2010). In Zambia's relatively land-abundant rural landscape, maize covers 1.1 million of 5.5 million ha of arable land, dominating cropped areas and especially cereals (FAO).

Seed and fertilizer subsidies have been re-established, albeit in a different form. The stated goal of the Farmer Input Support Program (FISP), formally established in 2009/10 but preceded by the Fertilizer Support Program started in 2002, has been to improve access of small-scale farmers to inputs while enhancing the participation and competitiveness of the private sector. In each cropping season since then, fertilizer and maize seed have been distributed through the program, including a subsidy rate that has risen over the years to 80 percent in 2008/9, falling to 75 percent in the seasons since that year. During 2009/10, the size of the package was halved in order to facilitate diffusion to a larger number of smallholders.

FISP operates by selecting private suppliers through a tender process. Local transporters distribute inputs to designated collection points, and selected cooperatives and other farmer organizations issue inputs to approved farmers and pay a portion of the costs at participating banks or financial institutions. To engage smallholders, official policy is to select from a wide range of growers than previously targeted and to promote the involvement of the extension service.

Over the past decade, the maize seed sector has been liberalized. From 2000 to 2011, 126 new varieties were released by 14 different companies, and almost all varieties are now held by private companies. The baseline survey report that precedes this paper (De Groote et al. 2011) documents that by 2010, 203 maize varieties had been released to farmers, and 106 modern maize varieties were grown in the 2010/11 season. Most of these were hybrids, but no single hybrid occupied more than 10 percent of area in that season. It appears that a combination of FISP and seed sector liberalization has contributed to the equitable diffusion of hybrids over space.

III. DATA

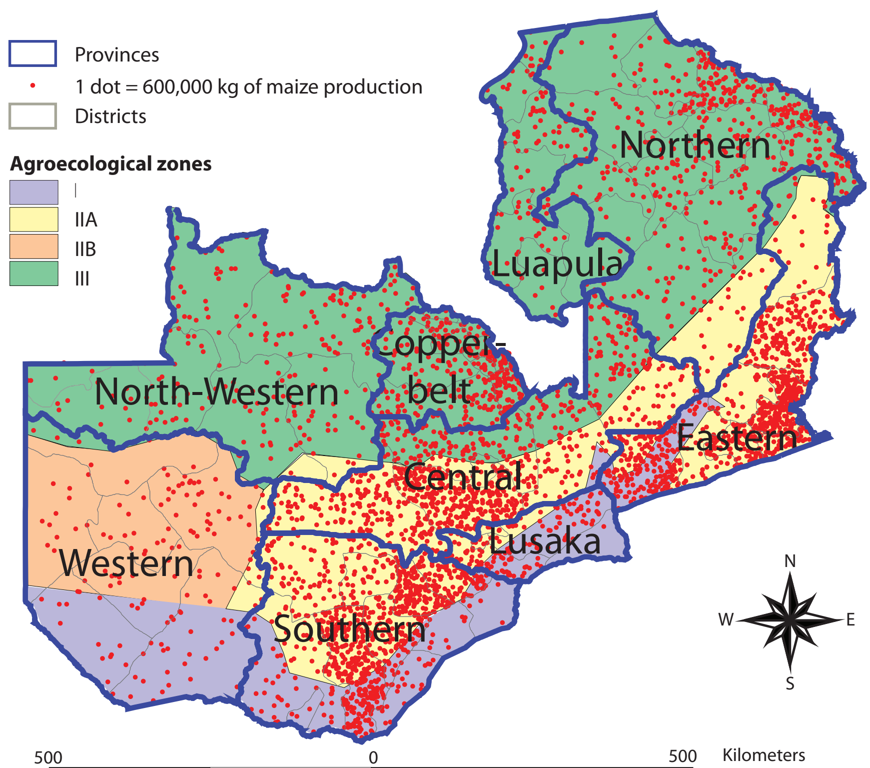
A detailed description of the sample design is found in De Groote et al. (2011). The population domain incudes five provinces (Central, Copperbelt, Eastern, Lusaka, Northern, and Southern), located in three agroecological zones (I, IIA, and III) of Zambia. A stratified, two-stage sample was designed. The three agroecological zones (AEZs) served as strata. The total number of households in the sample was allocated proportionate to population and maize production (20 percent for zone I, 40 percent each for the other two zones). First-stage sampling units were standard enumeration areas (SEA). Numbering 113, these were selected with probability proportionate to size, by AEZ, from lists maintained by the Central Statistical Office. The second-stage units were all households living in each SEA. Ten households were selected in each SEA by simple random sample drawn from a list. By design, data are self-weighted. Data were collected by three survey teams, each including a supervisor and five enumerators, in June and August 2011. The full sample consists of 1,128 households, of which only 19 cultivated more than 20 ha. In Zambia farmers cultivating less than 20 ha are defined as "smallholders." Figure 1 shows the spatial distribution of maize production in Zambia, highlighting both its widespread nature and its concentration in Central, Eastern, and Southern provinces.

IV. DESCRIPTIVE ANALYSIS

Table 1 shows the percent of farm households surveyed by maize type planted in the 2010/11 main rainy season. Farmers grew as many as 5 varieties simultaneously and 1 to 2 (1.79) varieties, on average. Thus, the percentages listed Table 1 total over 100 percent. One-third of farmers (33 percent) grew local maize (typically one variety). Over two-thirds grew F1 hybrids that they could name (68 percent). About one in five (19 percent) grew a modern variety that was recycled or they could not name. Less than 1 percent grew improved open-pollinated varieties (IOPVs). Of all varieties grown, about 5 percent of names were listed as "don't know." For many of these, farmers could report the seed company—suggesting that they were improved maize types.

Virtually all farmers who received a seed subsidy (over 96 percent) cited FISP as the source. The remaining 4 percent of farmers cited the Programme Against Malnutrition (PAM), nongovernmental organizations (NGOs), or community development programs as sources. The difference in adoption rates for named F1 hybrids differs dramatically between households excluded from the subsidy program (45 percent) and included (81 percent). There is no statistical relationship between growing an unnamed modern variety, recycled seed, or IOPV and the seed subsidy (Table 2).

Figure 1: Distribution of Maize Production in Zambia



Source: Created by Hugo De Groote, 2011.

Table 1: Percent of Farmers by Maize Type

	Percent
Local	33.0
F1, named hybrid	68.4
Improved open-pollinated variety (IOPV)	0.45
Recycled or unnamed modern	18.7

Source for all tables: Authors, based on data from HarvestPlus Maize Seed Adoption Survey, Zambia, 2011

Table 2: Number and Percent of Farmers Growing Modern Maize by Receipt of Seed Subsidy

		Grow named F1 hybrid				Grow unnamed modern or IOPV		
Receive subsidy		No	Yes	Total		No	Yes	Total
No	N	211	175	386		319	67	386
	%	54.7	45.3	100		82.6	17.4	100
Yes	N	142	590	732	*	583	149	732
	%	19.4	80.6	100		79.6	20.4	100
Total	N	353	765	1,118		902	216	1,118
	%	31.6	68.4	100		80.7	19.3	100

* Pearson chi-squared test shows significant difference at <1% between households that did and did not receive the hybrid maize seed subsidy.

Incidence of the maize seed subsidy is statistically equal for households headed by men and women. This is true regardless of whether the head is defined as the recognized (*de jure*) or the actual (*de facto*) decisionmaker. *De facto* decisionmakers are those present more than 6 months of the year and who are reported to be responsible for day-to-day decisions. About one in five households (19 percent) are headed *de facto* by women, and 16 percent are recognized as headed by women. This difference is neither meaningful nor significant (Table 3).

Use of maize hybrids differs significantly, but not by large magnitudes, between male- and female-headed households. However, when we consider those who decided which maize variety to plant, 71 percent of male decisionmakers, compared to only 62 percent of female decisionmakers, grew hybrids. This differential (nearly 10 percent) is statistically significant and meaningful in magnitude. It is also important to know that nearly one in four seed decisionmakers is female (24 percent). Women are more represented in maize production than in headship (Table 4), which confirms that programs designed to reach women with extension information need to address women in male-headed households as well as in female-headed households. In terms of crop productivity, recent work by Peterman et al. (2011) confirms the significance of the plot manager's gender as compared to the household head.

Differences in terms of mean kilograms (kg) of hybrid seed planted are also meaningful in size (Table 5). On average, male decisionmakers grow 20 kg of hybrid seed (near a hectare, by standard seed rates), compared to 13 kg planted by women. The discrepancy probably reflects that while receipt of hybrid seed via the subsidy may be equivalent for male- and female-headed households, more male-headed households grow hybrid seed outside of the subsidy program.

Where do farmers learn about hybrid seed? Two types of data regarding information sources were collected in the baseline survey. The first pertained to any information about agriculture, health, or nutrition received by the respondent or anyone in the household. Enumerators asked respondents to report the information source, its importance, how frequently it is used, and how much trust is placed in the information. The second category of questions was specific to maize varieties. These questions included whether or not the farmer saw a demonstration of this variety and from whom and where the farmer obtained information about the variety for the first time.

With respect to generalized information sources, the radio is the most widely utilized by households surveyed,

Table 3: Household Headship by Subsidy Receipt

		De jure head			*De facto* head		
Receive subsidy		Male	Female	Total	Male	Female	Total
No	N	319	68	387	304	78	382
	%	82.4	17.6	100	79.6	20.4	100
Yes	N	613	119	732	591	136	727
	%	83.7	16.2	100	81.3	18.7	100
Total	N	932	187	1,119	895	214	1,109
	%	83.3	16.7	100	80.7	19.3	100

* Pearson chi-squared tests show no significant differences (5%) in subsidy receipt between male and female heads according to either *de jure* or *de facto* headship.

Table 4: Hybrid Use by Headship and Seed Decisionmaker

		De jure head				*De facto* head				Choose maize seed			
		No F1	Yes F1	Total		No F1	Yes F1	Total		No F1	Yes F1	Total	
Male	N	282	651	933		272	624	896		248	595	843	
	%	30.2	69.8	100		30.4	69.6	100		29.4	70.6	100	
Female	N	72	114	186	*	79	134	213	*	104	167	271	*
	%	38.71	61.3	100		37.1	62.9	100		38.4	61.6	100	
Total	N	354	765	1,119		351	758	1,109		352	762	1,114	
	%	31.7	68.4	100		31.7	68.4	100		31.7	68.4	100	

* Pearson chi-squared tests show significant differences at 5% in hybrid use between men and women in and of the three decisionmaking groups.

Table 5: Mean Hybrid Seed Planted (kg) by Headship and Decisionmaker

	De jure		*De facto*		Choose maize seed	
Male	20.4		21.1		21.8	
Female	13.9	*	12.2	*	12.3	*

*T-tests show significant differences of means at 5% between men and women.

followed by health clinics. Radio is significantly less utilized by *de jure* female heads—either because they do not own a radio or because their schedule does not permit listening to it (Table 6). Although female-headed households use extension information significantly less than male-headed households, there is no statistical difference in their use of registered farmers' groups, health clinics, and other social groups for information. Newspapers are used by about a quarter of the population, but the percentage of female-headed households using them is half that of male-headed households. Unregistered farmers' groups were not frequently cited as sources of agricultural, health, or nutritional information. Social groups are used by under a fifth of the farmers surveyed. Thus, we concluded that a) information sources appear to be primarily official, formally structured, and publicly funded in rural Zambia, and b) extension, radio, and newspapers are gendered sources of information, but registered farmers' groups, social groups, and health clinics are not.

Of respondents who cited using one of these sources, most described it as "very important." The percentage distributions in rank were roughly similar across sources, except for registered farmers' groups, which were less frequently ranked as "very important." Thus, respondents appear to be unwilling or unable to discriminate strongly among sources. One interpretation is that they desire information, regardless of the source. Another interpretation is that they are unwilling to show disrespect for public sources of information, which is a common courtesy in rural areas of Zambia (Table 7).

Trust in information mirrors perceptions of relative importance fairly closely (Table 8). The majority of respondents using any of the information categories stated that they trusted the source "completely." Again, there was less confidence in registered farmers' groups than in other sources. This finding is of interest given that registered groups establish the eligibility for receiving subsidies and are thus a primary channel for maize seed and fertilizer. Only 1 farmer in 616 stated that he/she did not trust the extension officer "at all."

With respect to variety-specific information, extension remains the central vehicle in Zambia. Primary sources of information about the major maize variety grown are widely distributed, with only the extension officer (36 percent) and a farmer in the same group (11 percent) reported by more than 10 percent of farmers. About 2 percent were provided with seed information by NGOs, and other sources were distributed in small percentages across a range of providers, including other farmers (neighbors and friends), as well as agricultural shows, agrodealers, and posters. Differences were not significant in the overall frequency distribution of sources by sex of household head.

Table 6: Percentage of Households Receiving Information about Agriculture, Health, or Nutrition by Source and *de jure* Headship

	Percentage of households		
Source	Male-headed	Female-headed	Total
Newspaper*	27.0	13.6	24.9
Radio*	82.6	60.7	79.2
Health clinic	65.9	68.2	66.3
Extension officer*	61.6	52.6	56.1
Registered farmers' group	54.4	54.9	54.5
Unregistered farmers' group	3.5	4.7	3.7
Other social group	16.7	18.4	17.0

*Differences significant with Pearson chi-squared test at 5% significance.

Table 7: Rank of Information (Agriculture, Health, Nutrition) Source According to Importance

Source		Importance				Total
		Of little importance	Moderately important	Important	Very important	
Newspaper	N	5	16	85	147	253
	%	1.98	6.32	33.6	58.10	100
Radio	N	3	18	307	526	854
	%	0.35	2.11	35.95	61.59	100
Health clinic	N	1	7	262	470	740
	%	0.14	0.95	35.41	63.51	100
Extension officer	N	0	14	196	410	620
	%	0.00	2.26	31.61	66.13	100
Registered farmers' group	N	0	6	19	13	38
	%	0.00	15.79	50.00	34.21	100
Unregistered farmers' group	N	1	7	262	470	740
	%	0.14	0.95	35.41	63.51	100
Other social group	N	0	8	61	97	166
	%	0.00	4.82	36.75	58.43	100

Table 8: Rank of Information (Agriculture, Health, Nutrition) Source According to Trust

Source		Trust				Total
		A little	Somewhat	A lot	Completely	
Newspaper	N	5	50	83	112	250
	%	2.00	20	33.2	44.8	100
Radio	N	10	66	293	478	847
	%	1.18	7.79	34.59	56.43	100
Health clinic	N	2	53	225	457	737
	%	0.27	7.19	30.53	62.01	100
Extension officer	N	1	25	206	383	616
	%	0.16	4.06	33.44	62.18	100
Registered farmers' group	N	1	10	10	15	36
	%	2.78	27.78	27.78	41.67	100
Unregistered farmers' group	N	3	25	226	283	537
	%	0.56	4.66	42.09	52.7	100
Other social group	N	4	23	32	107	166
	%	2.41	13.86	19.28	64.46	100

Note: One farmer said "not at all" for extension officer.

V. ECONOMETRIC STRATEGY

A. Conceptual Basis

Although the history of maize research in Zambia indicates that many Zambian farmers have experience growing hybrid maize, we know that not all farmers are commercially oriented and that despite the progress made in liberalizing seed and grain markets, markets do not function perfectly. The theory of the agricultural household (Singh, Squire, and Strauss 1986) applies to decisionmaking in this context and includes profit-maximization as a special case when markets are perfect and production and consumption decisions are separable. When they are not, seed decisions result from the choices of consumption amounts and product combinations that maximize the utility of the farm household, subject to a full income constraint that embodies non-farm and farm income net of expenditures, credit and repayment, and family labor availability. Formal derivations of crop variety choice decisions based on the theory of the household farm are found in Meng (1997), Van Dusen (2000), and Edmeades (2003), among others, but are not presented here.

In this decisionmaking framework, prices faced by the household are endogenous functions of the observed prices and the household characteristics that affect access to transaction information, credit, transport, and other market services. Seed demand is conditioned on agroecological conditions. Seed supply and demand are influenced by seed market characteristics, including the seed subsidy, the distance or time to seed sources (as an indicator of "hard" infrastructure), how information is obtained (as an indicator of "soft" infrastructure), and seed preferences. The general form of the estimated equation can be represented by

(1) $$H = h\,(s, P_h, P_m, \Omega_h, \Omega_m, \gamma, \lambda).$$

is quantity of hybrid seed planted by the household, s records whether or not the household receives a hybrid seed via a subsidy, P_h is the seed price paid at the farm-gate, and P_m is the market price for maize grain. The vector Ω_h includes household characteristics, Ω_m captures market characteristics, and γ is an indicator of the agroecological conditions in which the household farms. The variable λ refers to seed preferences, which are parameters of the underlying utility function of the household theoretic framework.

B. Estimation Procedure

The potential endogeneity of the maize seed subsidy variable, and its significant relationship to hybrid seed use, means that a single-equation, ordinary least squares regression could produce biased coefficient estimates. In addition, the demand for hybrid seed includes a corner solution response for farmers whose optimal choice is zero. Tobit regression can be used to estimate demand including zero values. However, instrumental variables Tobit with a discrete endogenous variable is called a "forbidden regression" because it implies that in the second stage, a nonlinear function of an endogenous variable is replaced with the same nonlinear function of fitted values from a first-stage estimation (Wooldridge 2002: 236). The control function approach enables us to account and test the endogeneity or self-selection bias in a nonlinear model such as the Tobit when the suspected endogenous variable is binary.

As in a two-stage instrumental variables model, the control function approach requires an instrumental variable to be used in the first stage, reduced form estimation of seed subsidy receipt. The instrumental variable, which is not included in the second-stage estimation of the structural equation, should be correlated with receipt of the seed subsidy but not with the amount of hybrid seed planted when other covariates are considered, except via the seed subsidy. In the second stage, however, the structural model is estimated with the observed endogenous variable and the residual from the first stage as explanatory variables. The test of endogeneity is the statistical significance of the coefficient of the residual, with bootstrapped standard errors. The control function approach is described in early work by Smith and Blundell (1986) and Vella (1993).

Our approach follows that used by Ricker-Gilbert et al. (2011) to model the effects of the fertilizer subsidy in Zambia, although the model estimated here is much simpler given its estimation with cross-sectional as compared to panel data. In the first-stage regression, the binary maize seed subsidy variable was regressed against all exogenous variables in reduced form, including the information factors and the residence of the household in the village. The length of time that the household has resided in the village served as the instrument, as in the analysis by Ricker-Gilbert et al. (2011). While this variable is hypothesized to affect a household's capacity to obtain a subsidy through village status, there is no particular reason why it should affect the household's ability to obtain hybrid seed independent of the subsidy. The first-stage probit regression was estimated with robust standard errors (Huber-White).

Table 9: Variable Definition and Summary Statistics

Variable	Construction	Mean	St. Dev.
Dependent			
Hybrid seed planted	Total kg planted, named F1 hybrid	19.3	41.0
Explanatory variables			
Received seed subsidy (endogenous)	1=received maize seed subsidy; 0=otherwise	0.654	0.476
Literacy	Number of literate household members	3.66	2.35
Dependents	Number of household members <15 and >64 years of age	3.58	1.89
Active adults	Number of households >15 and <64 years of age	3.28	2.09
De facto headship	1=female head makes day-to-day decisions; 0=otherwise	0.192	0.394
Assets	Total value of farm and household assets (million Zambian kwacha [ZMK])	64.3	315.8
Importance of agronomic traits	Factor score (see text)	-0.00304	0.989
Importance of consumption traits	Factor score (see text)	-0.0229	1.006
Time to seed source	Minutes to seed source, major maize variety	52.2	114
Average temperature	Average mean monthly climate data "1 km^2" resolution from 1950–2000	20.9	1.36
Temperature range	Average maximum less average minimum temperature at 1 km^2 resolution from 1950–2000	13.4	1.20
Extension/registered group	Factor score (see text)	-1.8E-09	1.00
Health clinic/social group	Factor score (see text)	-6E-09	1.00
Residence	Years household has resided in village	20.7	17.4

In the second stage, the censored variable for kg of hybrid seed planted was regressed against the same set of explanatory variables, excluding residence of the household, as well as the observed binary variable for seed subsidy receipt and the residual from the first stage. The second-stage regression was estimated by Tobit, and standard errors were obtained by bootstrapping (50 iterations).

Average partial effects (marginal effects) were computed in all regressions. Finally, a Swait-Louviere test was applied to determine whether separate regressions should be estimated for female and male headship and for male and female seed decisionmakers.

C. Variable Definition

Definitions of variables we use to measure the parameters in equation (1) and their summary statistics are shown in Table 9. Following the asset pentagon of the livelihoods framework (see, for example, http://www.poverty-wellbeing.net/media/sla/docs/2-1.htm, accessed April 25, 2012), household characteristics Ω_h can be grouped in terms of human capital, natural, physical, social, and financial capital. Indicators of the quality and quantity of human capital included the number of literate persons in the household, the number of dependents, and the number of adults. *De facto* headship, a dummy variable, refers to the sex of the household member who makes day-to-day decisions and is present more than 6 months of the year.

With respect to physical capital, data on total land owned were sparse, and land cultivated during the rainy season is endogenous to hybrid seed planted. Previous research in Zambia has also indicated that in much of rural Zambia, labor rather than land remains the primary production constraint, as expressed in the labor variables we included. As a consequence, we measured farm physical assets with the value of total assets. The amount of credit received was non-zero in only 21 cases and was not included as a separate variable. Thus, the value of total assets expresses both farm physical and financial capital.

Broadly speaking, the natural capital of the household is strongly influenced by the agroclimatic and farming conditions of the area. We improve on dummy variables for agroecological zones by using average temperatures and the range of temperature by georeferenced site (γ). Temperatures are based on high-resolution monthly climate data from 1950–2000 (Hijmans et al. 2005), provided by Kai Sonder at CIMMYT (pers.comm., March 1, 2012).

Factor scores computed with principal components were used to express seed preferences (λ). Principal components analysis has been widely applied to collapse the dimensions of multiple covariates that are highly correlated to a single variate by positing a hypothetical, underlying variable that is a linear function of the others. Since this removes the collinearity among the variates, it improves the efficiency of estimation in a regression context.

When applying principal components analysis to a data matrix, some "components" (factors) are assumed to be common to two or more variables and some are assumed to be unique to each variable. The unique factors are then assumed to be orthogonal to each other and thus do not contribute to covariation among variables. The factor score, which computes a weighted linear combination of the variables that contribute most to the orthogonal factors, enables households to be ordered in terms of the underlying factor.

A major assumption of the approach is that the observed variables are linear combinations of the underlying variables and that the observed variables are in fact a reflection of, and generated by, the same unobserved phenomena. Many algorithms have been used to compute these relationships. The approach has been widely used in psychometric analysis, in the field of rural sociology to confirm latent variables in structural equation modeling, in combination with experimental methods in economics, and in applications of the sustainable livelihoods approach (see, for example, Geweke 1977; Neelamegham and Jain 1999; Jansen et al. 2006). A recent example for analysis of maize seed adoption is Langyintuo and Mungoma (2008).

In the baseline survey that serves as the basis of this study, farmers were asked to rank the importance of agronomic traits (emergence, plant vigor, resistance to

Table 10: Rotated Factor Loadings, Principal Components Analysis of Importance of Maize Seed Attributes

Attribute	Factor 1	Factor 2
Germination	0.6458	0.1586
Vigor	0.6360	0.3765
Drought tolerance	0.6014	0.3497
Pest resistance	0.7278	0.3704
Striga resistance	0.6076	0.3281
Disease resistance	0.6328	0.4607
Early maturity	0.1593	0.0099
Yield	0.6291	0.2531
Cob size	0.5132	0.4101
Tip cover	0.6529	0.1745
Grain color	0.1379	0.2302
Grain weight	0.3829	0.3868
Water absorption capacity	0.2650	0.7587
Pounds well	0.3006	0.8001
Taste in nshima	0.2634	0.7982
Taste roasted	0.1688	0.8382
Market demand	0.1708	0.3078
Proportion of variation explained	0.24	0.23

LR test: independent vs. saturated: chi-squared (136) = 9,520.39; Prob>chi-squared = 0.0000

Table 11: Rotated Factor Loadings, Principal Components Analysis of Sources of Information

Source	Factor 1	Factor 2
Newspaper	0.2217	0.0937
Radio	0.1209	0.114
Health clinic	0.0541	0.7738
Extension office	0.8487	0.1217
Unregistered farmers' group	-0.0635	-0.1244
Registered farmers' group	0.8818	-0.053
Social group	0.0115	0.7417
Proportion of variation explained	22.4	17.2

LR test: independent vs. saturated: chi-squared (21) = 517.20; Prob>chi-squared = 0.0000

drought, resistance to field pests, resistance to storage pests, resistance to plant diseases, early maturity, yield), cob and grain qualities (cob size, good tip cover, grain color, grain weight), processing and cooking attributes (water absorption capacity, pounding ability, taste as nshima, taste roasted), and market demand. Principal components with varimax rotation was applied to the 17 variables for the purpose of reducing the number of covariates measuring preferences.

Among the 17 variables, two factors explained roughly half of the variation, in roughly equal proportions. These were selected for factor score computation. The attributes that load most heavily (whose coefficients are largest) in the first factor are related to agronomic performance of maize seed. Those that load most heavily in the second are associated with grain processing and consumption. The two factors are called "importance of agronomic traits" and "importance of consumption traits" in Table 9. The third factor, which explains less, is dominated by grain color and demand. The likelihood-ratio test supports the statistical significance of the model (Table 10). Eigenvalues were 0.83 and 1.25 for Factors 1 and 2.

With respect to prices and market characteristics, enumerators recorded seed costs and kg purchased by farmers, from which we have calculated a farm-gate seed price P_h. Output prices P_m were reported in only 421 cases, and we did not include this variable. Availability of "hard" market infrastructure was measured by the minutes to the seed source, and we used factor analysis to measure "soft" market infrastructure (together, Ω_m). All sources of information (radio, newspaper, clinic, registered and unregistered farmers' associations, and social sources) were significantly correlated. Farmers who benefit from access to formal sources of information also enjoy greater access to informal sources of information.

Unfortunately, it was not feasible to conduct a useful factor analysis for use, trust, and frequency of use for all sources of information, because of the diminishing number of observations. We conducted a principal components analysis of information source, retaining two factors that explained 40 percent of variation in the seven variables. The likelihood ratio test indicated significance of the model (LR test: independent versus saturated: chi-squared (21) = 517.20; Prob>chi-squared = 0.0000). Rotated factor loadings, shown below, led us to describe the first factor as most associated with use of information extension and registered farmers' groups. These can be considered part of the "formal" agricultural information system. The variables that load most heavily on Factor 2 are use of health clinics and social group (Table 11). Eigenvalues were both greater than unity. In Table 9, factor 1 is renamed "extension/registered group," and factor 2 is "health clinic/social group."

VI. FINDINGS

Results for first-stage, reduced form probit regression are shown in Table 12. Households who received maize seed subsidies had higher numbers of literate adults. With a one-tailed test at the 5 percent level of significance, the number of dependents is positively related to subsidy receipt, and the number of economically active adults is negatively related. We interpret this finding as consistent with the notion that households with higher dependency ratios, and those that may have had greater difficulty meeting their consumption needs with family labor, were more likely to receive subsidies. Wealth, as expressed in the total value of household assets, bore no relationship to subsidy receipt. As expected, seed subsidy receipt is independent of the distance in minutes from the household to the point of seed sales. This is because seed provided through the subsidy program is not supplied at a commercial point of sales but through the registered farmers' group. The importance respondents ascribe to consumption-related variety attributes was negatively associated with subsidy receipt. The meaning of this finding is unclear, since these attributes are thought to be important for subsistence growers. One interpretation is that farmers receiving subsidies tend to be less adamant about their stated preferences because they believe strong statements might affect whether or not they receive seed. The longer a household has lived in a village, and thus the more established, the more likely the household is to have received subsidized seed. This is consistent with the findings in Ricker-Gilbert et al. (2011).

Lower average temperatures with a narrower range are associated with subsidy receipt, reflecting higher incidence in the northern regions of the country. Given the importance of extension and registered farmers' groups in the implementation of the subsidy program, this information factor has by far the largest magnitude of effect on the likelihood that a farmer receives subsidized maize seed. Farmers who received subsidies also relied significantly less on information from the health clinic and informal social groups. The higher the seed price paid at the farm-gate, the less likely to receive a subsidy. This makes sense given than farmers who are able to pay a higher price for hybrid seed commercially are less likely to have received subsidized seed.

The variance inflation factor shows little evidence of significant multicollinearity in the regression. The average variance inflation factor across variables is 1.11, with 1.29 for range in temperature.

Second-stage findings are reported in Table 13. As expected, the predicted probability of receiving a maize seed subsidy has an enormous impact on the probability of growing a named, F1 hybrid and is significant with a one-tailed test at 5 percent. The residual from the first-stage regression is also associated positively, significantly, and by a large magnitude with the dependent variable, supporting the endogeneity or selection bias of the seed subsidy in the demand for hybrid seed. Other statistically significant factors include assets, which contribute positively. Neither human capital variables nor agronomic or consumption-related traits are important in the extent of hybrid seed planted. The higher the seed price, the more hybrid seed is planted. This is counterintuitive, except that farmers with more maize area may be willing to pay a higher price for the seed. In the second-stage regression, the greater the range in temperature, the more hybrid seed is planted.

The descriptive statistics reported in Section 3 suggest the need to test whether the regressions should be estimated for male and female seed decisionmakers separately. The Swait-Louviere (log likelihood ratio) test comparing pooled and separate Tobit regressions suggests the rejection of the null hypothesis at the 1 percent level of significance.[1] The null hypothesis is that pooling male and female seed decisionmakers imposes a statistically significant restriction. Thus, the result suggests that the slope and intercept coefficients explaining the demand for maize hybrids are jointly distinct for male and female decisionmakers. This is an important policy finding because it supports the generally held perception that male and female seed decisionmakers represent distinct demand segments. The result will be explored in greater detail in further work.

1 The values of the log-likelihood functions are -2,634.58 in the pooled regression and -1,902.9208 and 413.51 in separate regressions, with a chi-squared (15) critical value of 20.00. The value of the log-likelihood ratio comparing the restricted and unrestricted regressions is 98.

Table 12: First-Stage, Reduced Form Probit Regression (Average Partial Effects) Explaining Receipt of Maize Seed Subsidy

	Delta-method		
	dy/dx	Std. Err.	P>z
Literacy	0.0346	0.0098	0.000
Dependents	0.0145	0.0080	0.070
Labor supply	-0.0185	0.0110	0.093
Assets (mill ZMK)	-0.0000755	0.0000663	0.255
Agronomic traits	-0.0103	0.0202	0.609
Consumption traits	-0.0637	0.0188	0.001
Average temperature	-0.0380	0.0106	0.000
Temperature range	-0.0508	0.0142	0.000
Time to seed source	0.0000	0.0001	0.954
Extension/group	0.1489	0.0155	0.000
Clinic/social	-0.0575	0.0142	0.000
Residence	0.0024	0.0011	0.030
Seed price	-7.75E-06	0.0000	0.003
N	533		

LR test: independent vs. saturated: chi-squared (13) = 186.83; Prob>chi-squared = 0.0000
Note: Huber-White robust standard errors

Table 13: Second-Stage Tobit Regression Explaining the Quantity of F1 Hybrid Seed Planted, Including the Residual from the First-Stage, Reduced Form Probit Regression

	Delta-method		
	dy/dx	Std. Err.	P>z
Literacy	1.2625	2.0665	0.541
Dependents	2.0969	1.3293	0.115
Labor supply	2.3538	1.9875	0.236
Assets	0.0267	0.0100	0.008
Agronomic traits	2.5051	3.1040	0.420
Consumption traits	-2.5833	3.6784	0.483
Average temperature	-3.1755	2.4229	0.190
Temperature range	6.3768	2.8144	0.023
Time to seed source	0.0214	0.0190	0.262
Extension/group	-3.3009	6.1841	0.593
Clinic/social	4.3591	3.2670	0.182
Seed price	0.0029	0.0006	0.000
Subsidy receipt	11.7263	6.8665	0.088
Residual	60.0308	33.8353	0.076
N	533		

LR test: independent vs. saturated: chi-squared (15) = 110.75; Prob>chi-squared = 0.0000

VII. CONCLUSIONS

This paper has explored the relationships among seed decisionmakers, hybrid seed use, and the subsidized seed supplied to Zambian farmers during the major rainy season of 2010/11. Cross-sectional data was used to test the effects of the seed subsidy, seed decisionmaker characteristics, preferences over variety attributes, information sources, and other household characteristics on hybrid seed use. We defined demand for hybrid maize in terms of the quantity planted. Decisionmaking is defined in three ways: *de jure* household head, *de facto* household head, and the household member responsible for choosing the maize seed variety.

The descriptive statistics that motivated the econometric approach show that the difference in adoption rates for named F1 hybrids differs dramatically between households excluded from the FISP (45 percent) and included (81 percent). Incidence of the maize seed subsidy is statistically equal for households headed by men and women. This is true regardless of whether the head is defined as the recognized (*de jure*) or the actual (*de facto*) decisionmaker. The difference in adoption rates differs significantly by *de jure* and *de facto* headship and by nearly 10 percent between male and female seed decisionmakers. The percent of seed decisionmakers who are women is nearly one in four, which is considerably higher than the number of female heads (under one in five for either *de jure* or *de facto* definitions). Female-headed households also plant much less hybrid seed on average than male-headed.

General information sources appear to be primarily official, formally structured, and publicly funded in rural Zambia. Social groups and unregistered farmers' associations are less often used as sources of agricultural and health information. Women use farmers' groups as frequently as men but the radio, newspaper, and extension agents less frequently for general information. The preeminence of formal extension services is also evident with respect to variety-specific information received by farmers. Although a quarter of farmers had seen the major maize variety they grew in demonstrations, three-quarters of these demonstrations were conducted by extension agents.

We tested the endogeneity of maize subsidy receipt in the use of hybrid seed and whether separate regressions should be estimated to explain hybrid seed use among male and female decisionmakers. Subsidized maize seed is endogenous in the demand for hybrid seed (the quantity planted), and the magnitude of its effect is large. Statistical tests also support the hypothesis that male and female seed decisionmakers represent distinct demand segments. Other significant factors in the extent of hybrid seed planted include the total value of farm and household assets and the range in temperature.

Predicting that a household receives a maize seed subsidy is more robust in terms of statistically significant factors. These include both the quality (literacy) and the quantity of active labor (labor supply), number of dependents in the household, temperature, and "soft" infrastructure (sources of information). Length of residence in the village is another important predictor of maize seed subsidy receipt, as has been shown in other studies.

The seed price is a significant variable in both models. The price is negatively associated with the likelihood that a household receives subsidized seed, which is consistent with the interpretation that those who can afford to pay more qualify less often for a subsidy. The price is positively associated with the demand for hybrid seed. Although counterintuitive based on economic theory, this finding can be interpreted as consistent with the fact that larger growers are able to pay more for seed.

VIII. POLICY IMPLICATIONS

We find that hybrid seed use in Zambia is still very much an "affair of state" (a government matter) in that farmer use of F1 hybrids is explained largely by inclusion in FISP, extension contact, and membership in registered farmers' groups. A concern with this finding is that subsidized maize seed "crowds out" commercial demand, as has been shown in the case of fertilizer in Zambia (Xu et al. 2009) and Malawi (Ricker-Gilbert et al. 2011). In evaluating the pros and cons of the subsidy, the social costs of "crowding out" must be weighed against the social benefits of reaching poorer households. The data indicate, for example, that the subsidy incidence is equal among male- and female-headed households and that women have access to formal farmers' groups. However, women farmers still use hybrid seed less frequently and plant less of it on average. Overall, the finding that male and female seed decisionmakers may represent distinct demand segments merits further research.

The fact that the percentage of seed decisionmakers who are women is much higher than the percentage of women who are *de jure* or *de facto* household heads has implications for the design of extension strategies and variety promotion. Popular perceptions for this region of Sub-Saharan Africa suggest that maize is such an overwhelmingly important food staple that the division of labor is not gender-differentiated. This may warrant further investigation, especially because recent evidence suggests that while productivity may not differ by household headship, it does differ depending on whether the plot is managed by men or women (Peterman et al. 2011).

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