4thICAAAE 2013 SEPTEMBER 22-25, Hammamet Tunisia
4th International Conference of the African Association of Agricultural Economists
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Invited paper presented at the 4th International Conference of the African Association of Agricultural Economists, September 22-25, 2013, Hammamet, Tunisia

Smallholder Demand for Maize Hybrids and Selective Seed Subsidies in Zambia

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Submission for HarvestPlus Invited Panel Session

under the theme

"From Research to Implementaiton:

Informing Development and Delivery of Biofortified Crops"

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Abstract

Zambian farmers have long experience with maize hybrids and input subsidies. The successful development and diffusion of improved maize seed in Zambia during the 1970s–80s was supported by government commitment to parastatal grain and seed marketing and subsidized provision of services to maize growers. When this system was dismantled under fiscal duress, production of the nation's staple food—maize—declined. In 2002, concerned that national food security might be jeopardized, the government reinstated subsidies for fertilizers and maize seed with the stated goal of building the resource base of smallholders. We test the hypothesis that the subsidy on hybrid seed use in Zambia is selectively biased both by the delivery mechanism and through self-selection of farmers who choose to exercise their claim. We find that the subsidy is a recursive determinant of seed demand but its recipients have more land, more income, and lower poverty rates. In 2010, we estimate that 14% of smallholders had a high predicted demand for hybrid seed but did not grow it—and were not reached by the program. This paper contributes to an emerging body of literature that documents the effects of the new generation of "smart" input subsidies in Africa, with a focus on seed (as compared to fertilizer), and a detailed exploration of demand segments.

1. Introduction

For major food staples such as maize, selling both improved seed and fertilizer at subsidized prices via state-owned companies was the modus operandi in many countries of sub-Saharan Africa during the 1970s and 1980s, including Zambia. Bending under the fiscal burden of these systems and the pressure exerted by international financial institutions such as the IMF, governments gradually dismantled them as part of structural adjustment programs launched in the 1980s and early 1990s. In recent years, policies seemed to have come full circle, and subsidies are again commonplace—though they remain controversial (Kelly, Crawford, and Ricker-Gilbert 2011). Opponents point to the costly experiences of the 1970s and 1980s, arguing that subsidies undercut the private sector distribution network and divert scarce public funds from other important investments. Proponents believe that subsidies are needed to guide African's smallholders toward commercialization, and that the public use of funds is justified to reverse the secular trend of declining soil fertility (Minot and Benson 2009).

Zambia's smallholder farmers, who are widely dispersed across this relatively land-abundant but land-locked nation, have long depended on seed and fertilizer subsidies for maize production. Despite this dependence, Zambia's maize seed industry is one of the more dynamic in Eastern and Southern Africa with respect to diversity in types and numbers of seed companies (Kassie et al. forthcoming). Before independence in 1964, Zambian commercial farmers benefited from several highly successful hybrids produced by the maize breeding program in Southern Rhodesia; following independence, donor investments in maize research led to the release of a plethora of improved open-pollinated varieties and hybrids that were well-adapted to the needs of smallholder farmers (Howard and Mungoma 1997).

Combined with suitable germplasm, fertilizer subsidies, pan-seasonal and pan-territorial pricing, and geographically dispersed market depots bolstered rates of return to maize production even in remote areas of the country during the 1980s. After structural adjustment began in the 1990s, however, the national area share of maize and use of hybrid seed and fertilizer plummeted—which led to a disturbing decline in the production of Zambia's leading food staple.

Perceiving a threat to national food security, the Government of Zambia re-established subsidized inputs for maize production. The justification for the establishment of the Farmer Input Support Program in 2002 was that a public role was needed to manage the transition toward full market liberalization, 'rebuild the resource base' of smallholders and help instill a 'sense of self-reliance' (FISP/GoZ 2008). Since 2002, fertilizer and maize seed have been distributed through the program, now called the Farmer Input Support Program (FISP).

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. Initially, the FISP package was designed for one hectare, including 200 kg each of basal and top dressing, and 20 kg of hybrid seed. During 2009/10, the size of the package was halved in order to facilitate diffusion to a larger number of smallholders under the Farmer Input Support Program (FISP).

In a number of countries scattered across Sub-Saharan Africa, empirical evidence is emerging that subsidies are often received by farmers who might otherwise purchase inputs commercially, undermining efforts to privatize seed and fertilizer industries (Xu et al. 2009 Ricker-Gilbert et al. 2011; Mason and Ricker-Gilbert 2012). In effect, the government remains the major client of the inputs industries, and input-using farmers can utilize the package to expand the scale of their use or trade their claims in secondary markets (Minot and Benson, 2009; Holden and Lunduka 2010a,b). Meanwhile, the goals of reaching poorer farmers are overshadowed by evidence that programs have promoted political patronage and the interests of rural elites (Banful 2010; Pan and Christiansen 2012; Mason and Ricker-Gilbert 2012). Targeting programs could be made more efficient (Hossou and Zeller 2012). Based on farm panel data over a 6-year period, Ricker-Gilbert and Jayne (2011) found that the receipt of the subsidy had little enduring effect on the household incomes or asset wealth of recipients in Malawi.

In Zambia, as case study implemented by the Civil Society for Poverty Reduction (CSPR, 2005) found very little impact of the FSP on poverty or household food security. Based on panel data collected by the Food Security Research Project and the Zambian Central Statistical Office in 2004 and 2008, Burke et al. (2012) found that the FISP tends to have reached the least poor of smallholder of farm households in Zambia. The third (32%) of smallholder farm households with below 1 ha of land received less than 10 percent of FISP fertilizer, while the third (37%) with over 2 ha received two-thirds of FISP fertilizers. Informal interviews suggested that smallholders who are unable to afford the co-payment sell their claim to larger farmers.

Given these findings, we hypothesize that there is potential for two types of "selection bias" in Zambia's subsidy implementation. First, the FISP packet is delivered via farmers who are members of registered cooperatives. Thus, those who qualify match the characteristics required by the formal and informal norms of their local cooperatives. Second, farmers who choose to exercise their claim to the package have more resources to do so, since using the package requires a co-payment. In 2012, for example, a package of 100 kg each of basal and top dressing combined with a 10-kg "pocket" of seed cost a subsidy recipient ZMK 280,000 (about USD 54 in April)

Our objective in this paper is to test this hypothesis by exploring the demand for hybrid seed in the presence of the seed subsidy program. First, we test the maintained hypothesis that the subsidy on hybrid seed use in Zambia is selectively biased, both by the delivery mechanism and through self-selection of farmers among those who exercise their claim. We apply an instrumented control function approach applied to single-period, cross-sectional data collected from a sample of over 1,128 households in the major maize-producing provinces of the country in 2011. Second, we compare demand segments of smallholder maize growers according to whether or not they received a maize seed subsidy and whether or not our model predicts they have a high demand for hybrid seed (over 90th percentile).

This paper contributes to an emerging body of literature that documents the effects of the new generation of "smart" input subsidies in Africa, with a rare focus on seed (as compared to fertilizer), and a detailed characterization of seed demand segments. Next, we summarize the data design. We then report descriptive statistics to motivate our econometric model, which is presented in the fourth section. Econometric results are presented in the fifth section, followed by findings based on predictions. Conclusions are drawn in the final, sixth section.

2. Data

The data were collected through face-to-face farmer interviews in a survey that was implemented by HarvestPlus, the International Maize and Wheat Improvement Center (CIMMYT), and the University of Zambia. The population domain includes five provinces (Central, Copperbelt, Eastern, Lusaka, Northern, and Southern), located in three agroecological zones (I, IIA, and III) of Zambia. 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. These were eliminated in our analysis. In Zambia farmers cultivating less than 20 ha are defined as "smallholders."

3. Descriptive Analysis

Because many farmers in Zambia have grown or been exposed to maize hybrids for years, we define hybrid users as growers of first-generation (F1) hybrids whose names they know. Farmers who grew only local maize and/or recycled hybrids, seed of hybrids they could not identify, or improved open-pollinated varieties have not been classified as hybrid users. During the 2010/11 rainy season, over two-thirds of farmers surveyed grew F1 hybrids that they could name (68 percent). Over a third of farmers grew local maize, but many of these were farmers who also grew F1 hybrids, recycled hybrids, improved open-pollinated varieties or a modern variety they could not name.

Nearly two-thirds (65.4 percent) of farmers interviewed received a maize seed subsidy, and virtually all of these (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. Table 1 shows that the highest incidence of the subsidy was in AEZIII (75 percent of farmers), followed by AEZIIA (61 percent), and AEZ1 (56 percent). Thus, the chances of receiving a subsidy rise from the southern areas of the country to the north.

TABLE 1

Across all zones, on average, subsidy beneficiaries planted 18 kgs received through the subsidy, and a total of 23 kgs, implying that they purchased another 5 kgs on their own—and also that they planted more than a standard package. Farmers who did not benefit from the subsidy planted an average of only 10 kgs, less than half the amount planted by beneficiaries. This pattern holds when AEZs are taken individually (Table 2).

TABLE 2

Supporting the maintained hypothesis of Burke et al. (2012), across all three agroecologies, farm households receiving the subsidy had significantly more income (proxied here by expenditures), cultivated land and total land, although the significance with respect to total land area was only 5% with a one-tailed test (Table 3). Land differences hold whether considered per household or per household member, but the same is not true for income. Given the wide variation in total assets, mean differences between beneficiaries and non-beneficiaries were not statistically significant, either in terms of total value or assets per capita.

TABLE 3

Kolmogorov-Smirnov tests confirm smaller land values among non-recipients and a difference between underlying distributions at less than 1% statistical significance. Thus, the most salient finding is consistent with findings reported by Burke et al. (2012) and Mason and Ricker-Gilbert (2012). FISP tends to favor those with more land. Based on these bivariate statistics, we conclude that the subsidy delivery during the survey year was biased away from relatively land-poor smallholders.

In Table 4, we explore the poverty incidence of subsidy recipients. Among the many possible indicators of poverty, we use the simplest form of the Foster-Greer-Thorbecke index—the headcount ratio. We multiplied the World Bank poverty lines ($1.25 or $2.00 per capita per day) by the ratio of the Gross Domestic Product (GDP) measured in current ZMK to its equivalent expressed in terms of international dollars (converted by Purchasing Power Parity). In 2010, for example, the ratio provides the number of ZMK required to purchase one international dollar in 2010. Per capita daily amounts were multiplied by 365 days and household size. We then compared observed annual income for each household during the year preceding the survey to the poverty line, coding those below the poverty line as 1 and those above as 0. (A more exhaustive analysis would consider multiple indicators, or a multidimensional indicator (OPHI 2010), but the focus of our study is maize hybrid use rather than poverty per se.)

We find that farm households who received the subsidy in 2010/11 have significantly lower headcount ratios as a group than those who did not, whether measured at the ZMK international equivalent of $1.25 per capita per day or $2.00. Thus, bivariate statistics also indicate that that the subsidy delivery in the survey year was selectively biased towards less poor farm households.

TABLE 4

We examine these questions more systematically in the following sections, based on a multivariate econometric model and predicted values.

4. Econometric Strategy

4.1 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 decision-making 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 trait preferences, and related to agronomic performance, agroecological conditions. Seed supply and demand are influenced by seed market characteristics, including the seed subsidy and the distance or time to seed sources.

4.2 Estimation Procedure

The cross-tabulations presented above suggest that maize seed subsidy (s) may be endogenous in the decision to grow hybrid seed. A body of literature has been devoted to using instrumental variables to reduce bias from omitted variables in the estimate of causal relationships; this method allows us to estimate the coefficients of interest consistently and without asymptotic bias.

The instrumental variables approach has also been extensively applied in order to handle selection bias in studies of targeted and voluntary participation in programs and their impacts (Ravallion 2004). Angrist and Krueger (2001) note that with a dummy endogenous regressor, instrumental variables techniques estimate causal effects for those who would “take the treatment” (grow hybrid seed) if assigned to the treatment group (a subsidy program), but otherwise would not. The instrumental variables model is estimated via two-stage least squares, with a binary variable measuring maize seed subsidy receipt as a dependent variable in the first stage.

Our equation system has an additional constraint: the demand for hybrid seed *H* includes a corner solution response for farmers whose optimal choice is zero. Tobit regression can be used to estimate demand including zero values, but not with instrumental variables estimated with two-stage least squares. 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.

The control function approach also 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 through 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 included as explanatory variables. The test of endogeneity is the statistical significance of the coefficient of the residual.

In the first-stage regression, we regress the binary maize seed subsidy variable against all exogenous variables in reduced form. Membership of a household member in a registered association served as the instrument in this regression. In this regression, given the systematic relationship hypothesized between the seed price (unit value of expenditures on maize seed) and the maize seed subsidy, we used distance to the source of seed for the major maize variety, an indicator of household transactions costs, as an indicator of transactions costs.

In the second-stage, we estimate a Tobit regression and test the endogeneity of the maize seed subsidy by including the residual estimated from the first-stage regression. Self-selection bias could be expressed through the decision of some farmers, and not others, to exercise their claim and/or purchase additional seed from those who receive the subsidy. All regressions were estimated fully robust standard errors, accounting for possible clustering by village in the sample design.

To analyze characteristics of demand segments, we used the predicted values of the second-stage, Tobit regression to group households according to their rank below and within the 90^{th} percentile.

4.3 Variable Definition

Definitions of variables we use to measure the parameters in equation (1) and their summary statistics are shown in Table 5. For household characteristics, we included the quality and quantity of human capital in terms of the number of literate persons in the household, the number of dependents, and the number of adults[1]. Total land owned was used as measure of physical capital. The amount of credit received was non-zero in only 21 cases and was not included as a separate indicator of 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 keyed to georeferenced coordinates recorded for each household. 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 preferences regarding variety traits. 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 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 analysis 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 5. The third factor, which explains less, is dominated by grain color and demand. The likelihood-ratio test supports the statistical significance of the models. Eigenvalues were 8.37 and 1.25 for Factors 1 and 2.

Enumerators recorded seed costs and kg purchased by farmers, from which we have calculated a farm-gate seed price (or unit value). Output prices were reported in only 421 cases (only 579 farmers sold any maize), and we did not include this variable. We also use the distance to the source of the major maize variety grown by the household as an indicator of transactions costs.

5. Results

5.1. Regression analysis

Regression of the amount of hybrid seed planted (kgs) on all exogenous variables with the exception of the instrumental variable entered in the first-stage regression results in failure to

[1] We do not use sex of household head because it is not significant in maize seed subsidy receipt, and is correlated with other observed and unobserved explanatory variables in the hybrid seed equations

reject the null hypothesis that maize seed subsidy receipt is exogenous. The p-value of coefficient on the residual from the reduced form regression is 0.238. Thus, the criteria for subsidy receipt are not choice variables, at least as these are measured in a single season of data collection. We interpret this result as implying that qualification for the subsidy pre-determines the amount of hybrid seed planted, or that the relationship between subsidy receipt and hybrid seed quantities used is recursive.

Results of the structural (Tobit) regression predicting use of hybrid maize seed with the maize seed subsidy treated as an exogenous variable and the seed unit value entered in place of the transactions costs variable are shown in Table 5. Although we expect the price variable and seed subsidy variable to be systematically related, their partial correlation coefficient is only weakly significant, with a p-value of 0.11. Thus, for coherence with our conceptual model and economic theory, we control for the subsidy effect as well as for seed expenditures per unit in the equation explaining hybrid seed demand.

Receiving the subsidy increases the average kgs grown by a 10 kgs on average, which is the amount included in the package (equivalent to a half-hectare assuming the average seeding rate of 20 kgs per ha). On average, seed subsidy recipients planted 2.97 ha of maize, as compared to 1.39 ha planted by non-recipients in the survey season. Even considering the subsidy effect, an additional hectare per farm is associated with 12 more kgs of hybrid seed. Not all land is devoted to maize. Average temperature has no statistical relationship with hybrid use in the Tobit regression, and the relationship with the range in temperature is weak once other factors, and the seed subsidy, have been taken into account. The role of the seed price and maize seed subsidy are both strong and positive. The seed price is positively related, because controlling for the effect of the subsidy, prices of F1 hybrids are higher than the prices for other types of seed. Other seed types purchased include recycled hybrids, IOPVs, unnamed modern maize types, and occasionally, and for much lower prices and typically under duress (when farmers have no stocks of their own), local maize. As we have shown above, those who receive subsidies also often purchase non-subsidized F1 hybrid seed on the market.

5.2. Post-estimation analysis

The Tobit results (Table 6) are employed in this section to examine the structure of the demand for maize hybrids along two axes: 1) maize growers in the 90th percentile for hybrid seed use, and 2) maize growers who received and did not receive subsidized seed. We selected 90th percentile, although it is a large value, because use rates, and predicted use rates, are quite high in Zambia. Around this point, cumulative adoption rates are also relatively flat.

Of the larger set of farmers who received subsidized seed (719 total) about 38% were below the 90th percentile for predicted use of hybrid maize. Of those who did not receive subsidized seed (380 total), 61% were predicted to be in the 90th percentile. This percentage was evidently higher than the percentage of farmers who were predicted to be in the high use group and also received subsidized seed. Further, of the smallholders who did not receive the subsidy but who are predicted to be in the 90th percentile for hybrid seed use, 64% did not plant hybrid maize. This segment of farmers represented about 14% of the sample population. On the basis of our estimates, we conclude that there is a potentially significant (in terms of share of the population), 'unsubsidized' demand for hybrid seed in Zambia that remains to be met by other means.

Table 6 reports headcount poverty ratios for those households predicted to be in the 90th percentile of hybrid seed use. Consistent with Table 3, even when considering other factors included in the econometric analysis, the data confirm that the FISP program draws in a set of households with a lower poverty headcount ratio. Again, the data suggest a selective bias away from poorer households in the de facto design of the program. For the sample population as a whole, it is also helpful to note that headcount ratios estimated here are comparable with those reported in the World Bank Development indicators (86% rural poverty headcount ratio in 2006).

Tables 7 through 10 compare a range of household characteristics among three groups of households: 1) households with low predicted hybrid demand who did not receive a subsidy; 2) households with a high predicted hybrid demand who received a subsidy; and 3) households with a high predicted hybrid demand who did not receive a subsidy. Differences of means and percentages have been tested only for the two groups in the 90th percentile for predicted hybrid demand.

Table 7 shows that in terms of human capital characteristics, smallholders with high predicted use who received the subsidy are no different from those who did not in terms of the share of female household heads, the age of the head, the number of children from 1-3 years of age ore members over 46 years of age. However, they have more children and adults in other age groups (4-8, 9-13, 14-18, 19-45 years), and their household size is larger on average by one person. These households have also lived longer in the village, and have more literate adults. The proportion of seed decision-makers who are men is higher, and the share of these who are literate, is greater in the subsidized group.

Financial capital, measured in terms of total land areas and income are higher for the subsidized as compared to unsubsidized growers in the 90th percentile for predicted hybrid seed use. While the total value of assets did not differ between the groups, the share of households owning cell phones, radios and televisions was greater among subsidy beneficiaries (Table 7).

As expected, almost all of these belong to a registered farmer association, compared to only 23 percent of high predicted users who did not, received a subsidy. This statistic also suggests that some members of farmer associations did not choose to exercise their right to purchasing subsidized seed. A much higher proportion of recipients of subsidies with high predicted use had attended a variety demonstration. These figures reflect a combination of the financial and political capital that becomes available to farmers when they satisfy the norms of the registered association in their village (Table 7).

Compared to the groups with high probability of growing maize hybrids, the group of farmers with low predicted hybrid use who did not receive a subsidy have a much lower proportion of female household heads; in general, as shown elsewhere, female headship in itself is not an impediment to subsidy receipt in Zambia. Low predicted use, non-recipients are of a slightly younger age than the other two groups of farmers. Notably, they have resided in the village surveyed for the least number of years among all groups. Their land sizes are only a fraction of those of the other groups, but their income and assets are comparable at the mean. This finding suggests that they may earn income through nonfarm sources, or grow crops with relatively higher value per hectare. Unfortunately, however, information on other income sources and crops was not collected in the survey. The membership of this group in registered farm associations and attendance of variety demonstrations is similar to that of the unsubsidized smallholders with high predicted use (Table 7).

Of particular interest are the statistics related to maize sales and surplus maize production. Consistent with our other findings, maize growers with a high predicted demand for hybrid seed, but who did not receive a subsidy, were significantly less likely to sell maize. We estimate that the maize surplus (production over consumption) that these farmers produced was on average less than a third that of farmers who had high predicted demand but who received the subsidy. With respect to either statistic, these farmers are on average similar to those who had a low probability of growing maize hybrids and received no subsidy (Table 7). This finding is sobering, because it suggests a foregone production potential.

To explore means by which these groups might be reached, we also analyzed their information sources. In general, male or female respondents in the group receiving the subsidy, with a predicted high demand for hybrids, are more likely to use any type of information source than those of either of the other two groups. The difference is most pronounced with respect to using information provided by extension (Tables 8 and 9).

Primary sources of seed are presented, by group, in Table 10. By far the largest source of seed for the group not receiving the subsidy, with low predicted hybrid demand, is the local agrodealer, followed by family, neighbor, or own stocks[2]. Farmers in this group clearly purchased improved seed at the agrodealer and obtained recycled improved seed or local maize from close contacts or the previous harvest. A small percentage reported that they obtained seed via the subsidy or a farmer association—this would be through a secondary market, where farmers decide to sell some or all of the hybrid seed they obtain to other farmers. Among farmers who received the subsidy and have high predicted demand for hybrid seed, over half obtained their seed through the program. However, 24 percent also purchased seed at an agrodealer and 3 percent from a seed company. The group of farmers with a high predicted demand who did not receive a subsidy relied much more heavily on family, neighbors and their own stocks than either of the other two groups, although 30 percent also purchased at agrodealers and another minor percentage obtained seed indirectly from the subsidy program.

[2] The order of importance for all sample farmers is: 43% (subsidy); 26% (agrodealer); 22% (family, neighbors, stocks), followed by other sources.

6. Conclusions

In this paper, we have tested the hypothesis that the maize seed subsidy in Zambia is selectively biased, via the delivery mechanism or through self-selection of farmers among those who exercise their claim. We estimated the demand for maize hybrids based on a representative sample of smallholders in the major maize-growing areas of the country. We find that receipt of the maize seed subsidy determines hybrid seed use recursively, but that the de facto design of the program is biased away from poorer farmers with less land.

We then classified farmers along two dimensions: receipt of seed subsidy and predicted hybrid demand. On the basis of our estimates, we conclude that there is a potentially significant (in terms of share of the population), ‘unsubsidized’ demand for hybrid seed in Zambia that remains to be met by other means. As expected, households with a high predicted demand for hybrid seed who do not receive the subsidy have fewer members, lower literacy rates, smaller land areas, less income, less access to and use of information than those who did. Perhaps the most disturbing finding is that their estimated production of maize over consumption needs was less than one-third that of high demand farmers who received the subsidy. Although our calculation is simplistic, the difference points to foregone production potential.

Our understanding of the Zambia program is that at its genesis, it was not designed to reduce poverty per se but to “re-boot” maize productivity among smallholders after the decline of the 1990s. Thus, there was no explicit focus on the nation’s poorest maize farmers, but on smallholder farmers who had the capacity and resources to utilize inputs effectively, whether or not they were relatively poor. In the current design, farmers must be members of registered farmer groups to receive inputs at the subsidized price, but a cash co-payment is required. Naturally, some choose to sell their rights to the farmers who are willing to pay for them.

Still, we conclude that it will be important for the Government of Zambia to continue to promote other means of meeting the demand for hybrid maize seed in rural areas, and to explore different mechanisms for subsidy delivery. In the coming season, a pilot voucher program which confers more responsibility on local agro-dealers will be tested. In addition, various means of incentivizing existing social networks, such as community development and other local organizations, may support outreach to maize growers with a demand for hybrid seed but less cash and land.

References

Angrist, J. D. and A.B. Krueger. 2001. Instrumental Variables and the Search for Identification: From Supply and Demand to Natural Experiments. *Journal of Economic Perspectives* 15 (4): 69-85.

Banful, A.B. 2010. Old Problems in the New Solutions? Politically-Motivated Allocation of Progrma Benefits and the "New" Fertilizer Subsidies. IFPRI Discussion Paper 01002. International Food Policy Research Institute (IFPRI): Washington, D.C.

Burke, W.J., T.S. Jayne, and N.J. Sitko. 2012. Can the FISP More Effectively Achieve Food Production and Poverty Reduction Goals? Policy Synthesis. Food Security Research Project—Zambia. No. 51. Ministry of Agriculture & Cooperatives, Agricultural Consultative Forum, Michigan State University – Lusaka, Zambia No. 51 (Downloadable at http://wwwaec.msu.edu/agecon/fs2/zambia/index.htm)

Civil Society for Poverty Reduction (CSPR). 2005. Targeting small-scale farmers in the implementation of Zambia's Poverty Reduction Strategy Paper: An Assessment of the Implementation and Effectiveness of the Fertilizer Support Programme. CSPR, Lusaka, Zambia.

Edmeades, S. 2003. Variety Choice and Attribute Trade-Offs Within the Framework of Agricultural Household Models: The Case of Bananas in Uganda. Ph.D. dissertation , North Carolina State University.

Fertilizer Support Program Internal Evaluation. 2008. Report on the proceedings of a GRZ and stakeholder group working meeting held at Kafue Gorge. ACR sponsored workshop, 20-22 August 2008. Summary report compiled by Michigan State University.

Hijmans, R. J., S. E. Cameron, J. L. Parra, P. G. Jones and A. Jarvis. 2005. "Very High Resolution Interpolated Climate Surfaces for Global Land Areas." *International Journal of Climatology* 25: 1965–1978.

Holden, S. and R. Lunduka. 2010a. "Too Poor to be Efficient? Impacts of the Targeted Fertilizer Subsidy Program in Malawi on Farm Plot Level Input Use, Crop Choice and Land Productivity." Mimeo. April 2010.

Holden, S. and R. Lunduka. 2010b. "NORAD-Project: Impacts of the Fertilizer Subsidy Program in Malawi: Targeting, Household Perceptions and Preferences." Mimeo. Agricultural University of Norway, April 2010.

Hossou, N. and M. Zeller. 2011. To target or not to target? The costs, benefits, and impacts of indicator-based targeting. *Food Policy* 36(5): 627-637.

Howard, J. and C. Mungoma. 1997. Zambia's stop-and-go maize revolution. In D. Byerlee and C. K. Eicher, *Africa's Emerging Maize Revolution*. Lynne Rienner, Boulder, Co.

Kassie, G. T., O. Erenstein, W. Mwangi, P. Setimela, and J. MacRobert. Forthcoming. Analysis of the maize seed industry in Southern Africa: Trends and Implications. SEP Working Paper. International Maize and Wheat Improvement Center (CIMMYT), Mexico, D.F.

Kelly, V., E. Crawford, and J. Ricker-Gilbert. 2011. The new generation of African fertilizer subsidies: Panacea or Pandora's box. USAID and Michigan State University Policy, Synthesis 87.

Mason, N. and J. Ricker-Gilbert 2012. Disrupting Demand for Commercial Seed: Input Subsidies in Malawi and Zambia. *World Development* (in press). Lusaka, Zambia.

Meng, E.C.H. 1997. Land allocation decisions and in situ conservation of crop genetic resources: the case of wheat landraces in Turkey. PhD dissertation, University of California at Davis, California.

Minot, N. and T. Benson 2009. *Fertilizer Subsidies in Africa: Are Vouchers the Answer?* International Food Policy Institute (IFPRI) Issue Brief 60. IFPRI, Washington, D.C.

Pan, L. and L. Christiaensen. 2012. "Who is Vouching for the Input Voucher? Decentralized Targeting and Elite Capture in Tanzania." World Development: in press. http://dx.doi.org/10.1016/j.worlddev.2012.04.2012.

Ravallion, M. 1994. *Poverty Comparisons. Fundamentals in Pure and Applied Economics* Volume 56. Harwood Academic Publishers.

Ricker-Gilbert, J., T. S. Jayne, and E. Chirwa. 2011. "Subsidies and Crowding Out: A Double-Hurdle Model of Fertilizer Demand in Malawi." *American Journal of Agricultural Economics* 93(1): 26-42.

Singh, I., L. Squire, and J. Strauss, eds. 1986. *Agricultural Household Models: Extensions, Applications and Policy*. Baltimore, MD, US: John Hopkins University Press.

Van Dusen, E. 2000. In situ conservation of crop genetic resources in the Mexican Milpa System. PhD thesis, University of California at Davis, California.

Xu, Z., W. J. Burke, T. S. Jayne, J. Govereh. 2009. "Do Input Subsidy Programs 'Crowd In' or 'Crowd Out' Commercial Market Development? Modeling Fertilizer Demand in a Two-Channel Marketing System." *Agricultural Economics* 40: 79–94.

Table 1: Comparison of Mean (S.E.) Kgs of Maize Hybrid Seed Planted, by Receipt of Maize Seed Subsidy and Agroecological Zone

	Received subsidy		
	No	Yes	P value*
AEZ1			
Total hybrid seed (kgs) planted	11.95	27.17	0.0025
	(3.336)	(3.539)	
Hybrid seed received on subsidy	0.0	14.49	0.0000
	(0.000)	(0.923)	
AEZIIA			
Total hybrid seed (kgs) planted	8.98	20.85	0.0032
	1.919143	2.944871	
Hybrid seed received on subsidy	0.0	18.63	0.0000
	(0.000)	(1.447)	
AEZIII			
Total hybrid seed (kgs) planted	11.32	22.96	0.0023
	2.729413	1.99536	
Hybrid seed received on subsidy	0.0	17.94	0.0000
	(0.000)	(1.125)	
All zones			
Total hybrid seed (kgs) planted	10.42	22.89	0.0000
	(1.45)	(1.56)	
Hybrid seed received on subsidy	0.00	18.18	0.0000
	(0.000)	(0.754)	

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

*P-value from difference of means tests conducted with two tails.

Table 2: Comparison of Mean (S.E.) Income, Assets, and Land by Receipt of Seed Subsidy

	Received subsidy		
	No	Yes	P value*
Total annual expenditures (mill ZMK)	7.75	9.42	0.0569
	(0.900)	(0.604)	
Total annual expenditures (mill ZMK)/household size	1.34	1.45	0.4855
	(0.146)	(0.085)	
Total value of assets (mill ZMK)	53. 88	68.59	0.2329
	(13.23)	(12.86)	
Total value of assets (mill ZMK)/household size	8.85	15.20	0.4463
	(2.03)	(5.95)	
Total land + (ha)	8.95	14.38	0.0909
	(2.859)	(2.471)	
Total land+ (ha)/household size	1.29	2.39	0.0267
	(0.22)	(0.33)	
Cultivated land (ha) in rainy season	1.89	2.97	0.0000
	(0.11)	(0.09)	
Cultivated land (ha) in rainy season/household size	0.329	0.467	0.0000
	(0.17)	(0.17)	

*P-value from difference of means tests.
+ Response rates were not as high for total land owned as for cultivated land in the rainy season, and we interpreted this variable as total land area to which farm households had access. Very little land was titled (overall mean of only 1.85 ha).

Table 3: Headcount poverty ratio by receipt of maize seed subsidy

	Received subsidy			
poverty line	No	Yes	All	p-value
$1.25/day (PPP)	0.8263	0.7677	0.7880	0.0240
$2/day (PPP)	0.9079	0.8679	0.8817	0.0510

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

*P-values from difference of means tests, n=1105.

Table 4: 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	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
Land	Total land area owned by household	12.56	53.86
Agronomic preferences	Factor score, importance of agronomic traits	-0.00304	0.989
Consumption preferences	Factor score, importance of consumption traits	-0.0229	1.006
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
Registered association	Household member a member of a registered association	.71	.45
Distance to seed source	Kms to seed source of major maize variety	17.01	43.86
Seed price (ZMK/kg)	Total maize seed expenditures/kgs planted	8098.86	5790.39

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

Table 5: Tobit regression predicting amount of hybrid maize seed planted

	dy/dx	Delta-method Std. Err.	P>z
Literacy	3.0041	1.4721	0.0410
Dependents	-0.5336	0.7204	0.4590
Adults	-3.0677	1.7914	0.0870
Land area (ha)	11.6117	1.7369	0.0000
Agronomic preferences	2.8679	2.3079	0.2140
Consumption preferences	-6.7049	1.9926	0.0010
Average temperature	-1.2850	1.4121	0.3630
Range in temperature	2.6060	1.5933	0.1020
Receive subsidy	9.8327	3.6770	0.0070
Seed price	0.0011	0.0004	0.0010

F (20) = 8.48, Prob > F = 0.0000, n=727

Log pseudolikelihood = -2241.681 , Prob > chi2 = 0.0000

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

Note: District fixed effects and constant not listed in table.

Table 6: Headcount poverty ratio, households predicted to be in the 90th percentile for hybrid seed use, by receipt of maize seed subsidy

	Received subsidy			
poverty line	No	Yes	All	p-value
$1.25/day (PPP)	0.8707	0.7747	0.8104	0.0027
$2/day (PPP)	0.9181	0.8582	0.8817	0.0284

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

*P-values from difference of means tests, n=1105

Table 7: Comparison of characteristics of smallholders who receive no subsidy and have low predicted demand for hybrid seed with those that have a high predicted demand for hybrid seed, by receipt of seed subsidy

	Under 90th percentile,	90th percentile		
	No subsidy	No subsidy	Subsidy	p-value
Female head (%)	15.17	23.38	20.92	0.5147
Age of head (yrs)	47.76	49.00	49.02	0.9877
Household members 1 to-3 yrs	0.51	0.66	0.64	0.7212
4 to 8 yrs	1.01	1.02	1.25	0.0131
9 to 13 yrs	0.96	0.91	1.33	0.0000
14 to 18 yrs	0.93	0.91	1.21	0.0013
19 to 45 yrs	2.07	1.91	2.22	0.0034
46 + yrs	0.81	0.88	1.00	0.1262
Household size	6.29	6.29	7.66	0.0000
Residence in village (yrs)	18.21	20.21	22.93	0.0000
Number of literate adults in household	3.07	2.83	4.24	0.0000
Seed decision-maker male (%)	80.69	68.40	77.16	0.0160
Seed decision-maker literate (%)	75.86	66.67	82.74	0.0000
Seed decision-maker age (yrs)	47.21	47.32	47.91	0.6291
Cultivated land area (ha)	1.59	2.08	3.33	0.4135
Total land area (ha)	5.81	12.94	20.66	0.0000
Assets (mill ZMK)	67.71	44.98	80.09	0.2375
Income (mill ZMK per year)	9.23	6.79	10.08	0.0189
Member of registered farmer association	26.35	22.94	93.64	0.0000
Estimated maize surplus+	974.56	978.05	3297.35	0.0000
Sold maize (%)	24.14	27.03	69.33	0.0000
Attended a variety demonstration	5.41	6.03	36.96	0.0000
Owns a cell phone	58.11	48.26	78.17	0.0000
Owns a radio	68.92	64.78	83.50	0.0000
Owns a television	31.39	20.77	45.61	0.0000

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

*P-value from difference of means tests or Pearson chi-squared for percentages

Differences tests between high probability groups only

+ Estimated total production less total consumption

Table 8: Percentage of male respondents using information source, by predicted demand for hybrid seed and subsidy receipt

		Newspaper	Radio	Clinic	Extension	Social group
Under 90th percentile,	n	28	74	45	28	16
no subsidy	%	30.43	80.43	49.45	30.43	17.98
90th percentile,	n	23	130	95	53	9
no subsidy	%	14.56	82.28	60.13	33.54	6.04
90th percentile,	n	92	244	168	207	35
Subsidy	%	33.58	89.05	62.22	75.82	14.06
	p-value	0.0000	0.003	0.198	0.0000	0.0000

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

*P-value from Pearson chi-squared test

Table 9: Percentage of female respondents using information source, by predicted demand for hybrid seed and subsidy receipt

		Newspaper	Radio	Clinic	Extension	Social group
Under 90th percentile,	n	5	74	75	16	17
no subsidy	%	10.38	70.48	71.43	15.09	16.5
90th percentile,	n	9	100	139	20	15
no subsidy	%	5.36	59.17	82.25	11.98	9.32
90th percentile,	n	37	227	263	165	41
Subsidy	%	12.01	73.94	86.23	53.92	14.19
	p-value	0.003	0.198	0.008	0.000	0.000

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

*P-value from Pearson chi-squared test

Table 10: Primary source of seed for major maize variety, by predicted use of hybrid seed and and maize seed subsidy

	Pr < 90%, no subsidy		Pr > 90%, no subsidy		Pr>90%, subsidy	
	n	%	n	%	n	%
Seed company	1	0.69	7	3.17	9	2.52
Agrodealer	86	59.31	66	29.86	84	23.53
Subsidy or farmer association	19	8.28	7	3.16	188	52.66
Local or district market	7	4.83	7	3.17	14	3.63
Family, neighbor, stocks	30	20.69	126	57.01	51	14.29
Other	7	5.52	8	3.62	11	3.08
All	150	100	221	100	357	100

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

*P-value from Pearson chi-squared test