Disrupting Demand for Commercial Seed: Input Subsidies in Malawi and Zambia

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Working Paper No. 63

April 2012

Indaba Agricultural Policy Research Institute (IAPRI)

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ACKNOWLEDGMENTS

The Indaba Agricultural Policy Research Institute is a non-profit company limited by guarantee and collaboratively works with public and private stakeholders. IAPRI exists to carry out agricultural policy research and outreach, serving the agricultural sector in Zambia so as to contribute to sustainable pro-poor agricultural development.

The authors gratefully acknowledge funding support for the work in Malawi from the Department for International Development (DFID)/Malawi, the United States Agency for International Development Malawi Mission (USAID/Malawi), and from USAID's Bureau of Economic Growth, Agriculture and Trade to the Food Security III Cooperative Agreement at Michigan State University. The Zambia portion of this study was funded by the USAID Zambia Mission (USAID/Zambia). The authors also wish to thank Drs. Kim Yi Dionne and Melinda Smale for helpful comments on earlier versions of the paper. We further would like to acknowledge Patricia Johannes for her valuable formatting and editorial assistance.

Any views expressed or remaining errors are solely the responsibility of the authors.

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EXECUTIVE SUMMARY

Input subsidy programs that provide inorganic fertilizer and improved maize seed to small farmers below market rates are currently receiving a great deal of support as a sustainable strategy to foster an African Green Revolution. In recent years numerous countries in Sub-Saharan Africa (SSA) including Ghana, Kenya, Malawi, Mali, Senegal, Tanzania, and Zambia have implemented such programs at substantial cost to government and donor budgets. For example, in 2008 Malawi spent roughly 70% of the Ministry of Agriculture's budget or just over 16% of the government's total budget subsidizing fertilizer and seed. In Zambia between 2004 and 2011, an average of 40% of the government's agricultural sector budget was devoted to fertilizer and maize seed subsidies each year.

Unlike the universal input subsidies that were common prior to the agricultural market reforms of the 1980s and 1990s, many of the current input subsidy programs in SSA target the subsidies towards households that meet certain criteria. By selecting people who would not otherwise participate in input markets, in principle these targeted input subsidies should not disrupt purchases of inputs at commercial prices in the way that universal input subsidies did in the past. The extent to which input subsidies disrupt commercial purchases of inputs is an important determinant of the impact of the subsidy program on total input use. If an input subsidy has a positive effect on purchases of inputs at commercial prices, then the subsidy can be said to *crowd in* commercial purchases. On the other hand, if an input subsidy has a negative effect on commercial purchases, then the subsidy can be said to *crowd out* or *displace* commercial purchases.

In this study, we use nationally representative household panel survey data from Malawi and Zambia to estimate the extent to which subsidized improved maize seed and subsidized fertilizer crowd out smallholders' commercial purchases of improved maize seed. (Improved maize seeds are defined in the study as hybrid varieties and open pollinated varieties (OPV).) Past efforts have quantified the effects of *fertilizer* subsidies on commercial purchases of *fertilizer* but this paper is the first to quantify the effects of subsidies for both *improved maize seed and fertilizer* on commercial *maize seed* purchases. Recent evidence from Malawi suggests that nearly half the maize yield gains from the input subsidy program come from uptake of improved maize seed. This makes it essential to understand the extent to which seed subsidies contributed to increasing improved seed use. In addition to estimating the crowding out effects of input subsidies, the study also examines the factors affecting the quantities of subsidized inputs received by smallholder households in Malawi and Zambia.

The study highlights four key findings. First, the distribution of subsidized inputs across smallholder households appears to be politically motivated in both Malawi and Zambia. In Malawi, other factors constant, households in districts won by the ruling party in the last presidential election receive 1.7 kilograms (kg) more subsidized maize seed and 11.4 kg more subsidized fertilizer than households in districts lost by the ruling party. In Zambia, households in constituencies won by the ruling party receive 10.8 kg more subsidized fertilizer, and that quantity increases by 0.5 kg for each percentage point increase in the ruling party's margin of victory. Both the Malawian and Zambian governments appear to be using subsidized inputs to reward patronage.

Second, the results point to other subsidy targeting problems as well. Households with larger landholdings receive significantly more subsidized fertilizer in both Malawi and Zambia, and more subsidized seed in Zambia. On average an additional hectare of land gets the household nearly 12 more kg of subsidized fertilizer in Malawi, and 1.58 more kg of subsidized fertilizer in Zambia. In addition, an extra hectare of land in Zambia gets the average household nearly 0.18 kg more subsidized maize seed. To the extent that landholding size is correlated with the household's ability to purchase inputs at market prices, these results suggest that targeting larger farmers may cause significant crowding out by the input subsidy programs. Targeting female-headed households might reduce the potential for crowding out of commercial purchases, but we find no evidence that female-headed households received significantly more subsidized inputs than male-headed households in either Malawi or Zambia.

Third, our results indicate that subsidies for improved maize seed do in fact crowd out commercial seed purchases by smallholders in Malawi and Zambia. Each one kg increase in subsidized seed acquired by the household reduces commercial improved maize seed purchases by 0.56 kg in Malawi and by 0.49 kg in Zambia. Put differently, for each metric ton of subsidized seed distributed by the government, total improved maize seed usage increases by only 0.44 MT in Malawi and 0.51 MT in Zambia.

Fourth, receipt of subsidized fertilizer has no economically significant effect on commercial improved maize seed demand in Malawi or Zambia. In Malawi, a one kg increase in the quantity of subsidized fertilizer acquired by the household has no statistically significant effect on demand for commercial improved maize seed. In Zambia, the effect is statistically significant at the 1% level but a one kg increase in subsidized fertilizer raises commercial seed demand by just 0.007 kg. This increase is very small in magnitude. To put it in perspective, this result implies that if a Zambian smallholder household received 200 kg more subsidized fertilizer (the standard subsidized input pack size under the Farmer Input Support Program), its demand for commercial seed would increase by just 1.4 kg, or enough seed to plant approximately 0.07 hectare (ha) based on government-recommended seeding rates.

Evidence from our study shows that part of why crowding out of commercial improved maize seed occurs is because some of the subsidized seed is targeted to households that would otherwise buy the inputs at market prices. Therefore the subsidy programs are not having as large an impact on increasing improved maize seed use as they otherwise might. Depoliticizing the distribution of subsidized seed and fertilizer may be one potential way to reduce displacement and increase the effectiveness and equity of these programs. Given that the subsidy programs are funded by taxpayer and donor money, the allocation of subsidized inputs should not be allowed to be politically motivated. This is difficult to achieve in practice as one likely reason for the resurgent popularity of input subsidies in SSA is the political dividends that they pay to the ruling party. Targeting female-headed households and households with smaller landholdings may be another way to reduce crowding out. And in Zambia, conversion to a voucher-based input subsidy system might better incentivize private investment in fertilizer and seed retailing than the current parallel government subsidized input distribution system.

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ACRONYMS

AISP	Malawi Agricultural Input Subsidy Program
AISS1	Agricultural Inputs Support Survey 1
AISS2	Agricultural Inputs Support Survey 2
APE	average partial effect
CF	control function
CRE	correlated random effects
CSO	Central Statistical Office
CV	coefficient of variation
DFID	United Kingdom Department for International Development
DH	double hurdle
FE	fixed effects
FISP	Malawi Fertilizer Input Subsidy Program
FSP	Zambia Fertilizer Support Program
FSRP	Food Security Research Project
GRZ	Government of the Republic of Zambia
ha	hectare
HH	household
IHS2	Second Integrated Household Survey
IV	instrumental variable
kg	kilogram
MACO	Ministry of Agriculture and Cooperatives
MT	metric ton
MWK	Malawian Kwacha
NSO	National Statistical Office
OPV	Open-pollinated variety
SEA	standard enumeration area
SEEV	suspected endogenous explanatory variable
SS	Supplemental Survey
SSA	Sub-Saharan Africa
TIP	Malawi Extended Targeted Input Program
ZMK	Zambian Kwacha

1. INTRODUCTION

Input subsidy programs that provide inorganic fertilizer and improved maize seed to small farmers below market rates are currently receiving a great deal of support as a sustainable strategy to foster an African Green Revolution (Denning et al. 2009). In recent years numerous countries in Sub-Saharan Africa (SSA) including Ghana, Kenya, Malawi, Mali, Senegal, Tanzania, and Zambia have implemented such programs at substantial cost to government and donor budgets. For example, in 2008 Malawi spent roughly 70% of the Ministry of Agriculture's budget or just over 16% of the government's total budget subsidizing fertilizer and seed (Dorward and Chirwa 2011). In Zambia between 2004 and 2011, an average of 40% of the government's agricultural sector budget was devoted to fertilizer and maize seed subsidies each year (Government of the Republic of Zambia various years). The high direct and opportunity costs of input subsidy programs justify thorough evaluation of their benefits relative to their costs.

Unlike the universal input subsidies that were common prior to the agricultural market reforms of the 1980s and 1990s, many of the current input subsidy programs in SSA target the subsidies towards households that meet certain criteria. A general criterion for targeted input subsidies to boost total seed and fertilizer use is that the subsidies should go to people who would not be able to purchase fertilizer and seed at commercial prices. By selecting people who would not otherwise participate in input markets, in principle these subsidies should not disrupt purchases of commercial inputs in the way that universal input subsidies did in the past.

The main objective of this article is to determine the extent to which receipt of subsidized improved maize seed affects Malawian and Zambian smallholder households' demand for such seed on the commercial market.[1] If receipt of subsidized improved maize seed has a positive effect on farmers' demand for commercial seed, *ceteris paribus*, then the seed subsidy can be said to *crowd in* commercial seed purchases. Conversely, if farmers who acquire subsidized seed use it in place of what would have been commercial seed purchases, then it can be said that the seed subsidy program *crowds out* or *displaces* commercial seed purchases. Determining the extent of seed crowding in/out from the subsidy is essential for understanding how much additional improved maize seed ends up on farmers' fields. This ultimately determines how effective subsidy programs are at boosting maize production and improving smallholder food security.

A second objective is to determine the extent to which receipt of subsidized *fertilizer* crowds in or crowds out commercial improved maize seed purchases. To achieve the article's objectives, we use nationally representative panel household survey data from Malawi and Zambia to estimate household-level models of demand for commercial improved maize seed, where the two key explanatory variables of interest are the quantities of subsidized improved maize seed and subsidized fertilizer received by the household.

There is a small but growing literature that quantifies the impacts of input subsidy programs in SSA (see, for example, Banful 2011; Chibwana, Fisher, and Shively 2011; Chibwana et al.

[1] In this study improved maize seeds are defined as hybrid varieties and open pollinated varieties (OPV). Although smallholder farm households in Malawi and Zambia report that more than 95% of the improved maize seed they acquire is hybrid (95.5% and 98.6% for Malawi and Zambia, respectively), anecdotal evidence from Malawi indicates that most farmers refer to *any* improved seed purchased commercially as hybrid. Given this evidence and the fact that the Malawi input subsidy pack included OPV maize seed during the period of analysis, we examine the effects of the inputs subsidies on improved maize seed purchases in general, rather than on hybrid and OPV purchases separately.

2012; Holden and Lunduka 2010; Mason 2011; Ricker-Gilbert, Jayne, and Chirwa 2011; Xu et al. 2009). However the vast majority of past efforts have focused on the effectiveness of the *fertilizer* component of the input subsidy programs, while relatively little attention has been paid to evaluating the *seed* component of the programs. To our knowledge, the only study to consider the seed component finds that nearly half of the yield gains from Malawi's input subsidy program come from increases in improved seed use (Chibwana et al. 2012). By focusing on the seed component of input subsidy programs, the present article broadens the knowledge base on the impacts of input subsidies.

Furthermore, this article is the first to empirically estimate the extent to which subsidies for improved maize seed and fertilizer crowd out commercial *improved maize seed* purchases. It builds on previous studies that estimate the displacement effects of fertilizer subsidies on commercial *fertilizer* purchases in Zambia (Xu et al. 2009; Mason 2011) and in Malawi (Ricker-Gilbert, Jayne, and Chirwa 2011). The general finding of these previous studies is that subsidized fertilizer displaces commercial fertilizer, and that the displacement rate is higher among wealthier households who are more likely to purchase fertilizer at commercial prices.

Beyond these contributions, this article makes two additional contributions to the existing literature. First, the study is the first to take a cross-country approach when measuring the impacts of an input subsidy program. We conduct very similar analyses in Malawi and Zambia using nationally representative farm household panel data from both countries. These data were collected during years when the seed and fertilizer subsidy programs were in place in both countries. We analyze data from each country separately, but compare and contrast the results in order to draw robust and externally valid conclusions that can be generalized to other countries in SSA.

Second, this article provides a useful application for dealing with two potentially endogenous explanatory variables in non-linear panel data models. Non-linearities arise in this application because the dependent variable, kilograms of improved maize seed purchased on the commercial market, takes on properties of a corner solution variable. Corner solution variables, sometimes called censored variables, have a relatively continuous distribution over a range of values, but take on one or two focal points with positive probability (Wooldridge 2010). In our study household commercial seed purchases have a pile up at zero, because many households do not buy seed commercially, but for those who do the quantity purchased is relatively continuous.

In addition, the two key explanatory variables of interest, quantity of subsidized maize seed acquired by the household and quantity of subsidized fertilizer acquired by the household, also take on properties of corner solution variables. Many households acquire no subsidized seed or fertilizer, but those who acquire subsidized inputs often obtain various quantities of them in practice. Furthermore, since subsidized seed and fertilizer are not distributed randomly in either Malawi or Zambia, it is likely that unobservable factors that affect commercial seed demand also affect how much subsidized seed and fertilizer households acquire. In other words, the quantity of subsidized improved maize seed acquired by the household and the quantity of subsidized fertilizer acquired by the household are likely to be endogenous to the household's demand for commercial improved maize seed.

To deal with these complexities, the household-level models of commercial improved maize seed demand are estimated via correlated random effects (CRE) Tobit combined with the control function (CF) method. Use of the Tobit estimator deals with the corner solution nature of the dependent variable, while the CRE framework provides a way to control for time-constant unobservable factors that may affect commercial seed demand. The CRE approach (Mundlak 1978; Chamberlain 1984) entails including household time averages of all explanatory variables as additional covariates in the commercial seed demand Tobits. The CF method with instrumental variables is used to deal with correlation between subsidized seed, subsidized fertilizer, and time-varying unobservable factors that affect commercial seed demand (Rivers and Vuong 1988; Vella 1993). Dealing with potential endogeneity caused by the way subsidized seed and fertilizer were distributed in Malawi and Zambia is an important part of this paper's modeling effort.

Estimation results indicate that an additional kilogram of subsidized improved maize seed crowds out 0.56 kg of commercial improved maize seed in Malawi and 0.49 kg of commercial improved maize seed in Zambia. Another way to interpret these results is that 100 tons of subsidized improved maize seed distributed to farmers only adds an additional 44 new tons of improved maize seed to farmers' fields in Malawi, and 51 new tons of improved maize seed to farmers' fields in Zambia. We also find that acquiring subsidized fertilizer has an economically insignificant effect on commercial seed purchases in both countries. The fact that our estimates of seed crowding out are similar in Malawi and Zambia provides external validity to our results and allows us to draw conclusions that can be useful for other governments in SSA.

The remainder of this article is organized as follows. The next section describes the key features of the maize seed and fertilizer subsidies in Malawi and Zambia. The third section outlines the methods used in the study, and the fourth section describes the data. Descriptive and econometric results are presented in the fifth section, and the paper concludes with a discussion of the policy implications of the results.

2. BACKGROUND ON INPUT SUBSIDY PROGRAMS IN MALAWI AND ZAMBIA

2.1. Malawi

Fertilizer subsidy programs have existed in almost every year for decades in Malawi.[2] This sub-section briefly discusses the logistics and administration of seed and fertilizer subsidies in Malawi during the 2002/3 through 2008/9 growing seasons.[3] This period includes the years covered by the household panel survey data used in this study (2006/07 and 2008/09). During the 2002 growing season, the government of Malawi officially reached 2.8 million households with the Extended Targeted Input Program (TIP), and in 2003/04 the program reached 1.7 million households. The TIP program offered 2 kg of hybrid maize seed, 1 kg of legume seed, and 10 kg of inorganic fertilizer to recipient households during 2002/03 and 2003/04. In 2002/03 a total of 4,000 metric tons (MT) of improved maize seed was distributed through TIP, and in 2003/04 a total of 3,400 MT was distributed through the program (Table 1). The intention of the program was to enable beneficiary households to plant an additional 0.1 hectares of maize. The program used paper vouchers that were given to recipient households. These households could redeem their vouchers at government depots and acquire free seed and fertilizer.

During 2004/05 10,000 MT of seed were delivered to farmers in Malawi, and recipient farmers were able to acquire 5 kg of OPV maize seed for free. Malawi also distributed 54,000 metric tons of fertilizer to farmers during that year. Unfortunately during that season much of the subsidized inputs were delivered late. Late delivery coupled with a drought caused Malawi to have a very poor harvest that year.

Table 1. Malawi and Zambia Input Subsidy Programs: Subsidy Level and Quantity of Improved Maize Seed and Fertilizer Distributed, 2002/03-2010/11

	Malawi				Zambia		
	% subsidy level for seed	Improved Maize seed (MT)	% subsidy level for fertilizer	Subsidized fertilizer (MT)	% subsidy level for seed & fertilizer	Improved Maize seed (MT)	Subsidized fertilizer (MT)
2002/2003	100	4,000	100	35,000	50	2,400	48,000
2003/2004	100	3,400	100	22,000	50	3,000	60,000
2004/2005	100	10,000	100	54,000	50	2,500	50,000
2005/2006	NA	NA	64	131,388	50	2,500	50,000
2006/2007	100	4,524	72	174,688	60	4,200	84,000
2007/2008	100	5,541	79	216,553	60	2,550	50,000
2008/2009	100	5,365	91	202,278	75	4,000	80,000
2009/2010	100	8,652	88	161,495	75	5,340	106,000
2010/2011	100	10,650	93	160,531	75	8,790	178,000

Source: Malawi data sources: Dorward et al. (2008), Dorward and Chirwa (2011), Malawi Logistics Unit (various years); Zambia data source: MACO (various years). Note: NA = Data not available. Zambia figures are for the Fertilizer Support Program (2002/03-2008/09) and the Farmer Input Support Program (2009/10-2010/11).

[2] For a review of input subsidy programs in Malawi since independence see Harrigan (2008).
[3] The agricultural year in both Malawi and Zambia is from October through September.

During the following season (2005/06), the government of Malawi decided to greatly expand the scale of its targeted fertilizer subsidy program, and continued to subsidize improved maize seed for farmers. The new program, originally called the Agricultural Input Subsidy Program (AISP) and later changed to the Fertilizer Input Subsidy Program (FISP), continued the use of vouchers that were given to beneficiary households, just as in the earlier TIP program.[4]

During the 2005/06 season coupons for approximately 131,000 metric tons of fertilizer (2.63 million 50 kg bags) were distributed to farmers. The subsidy program cost US $48 million during the 2005/06 growing season. Unfortunately no data are available on subsidized seed distributed to farmers during 2005/06. The rains were good in 2005/06 and yields were high, making the subsidy program very popular. Consequently it was extended and further scaled up for the 2006/07 growing season. During that year the government procured and distributed 175,000 metric tons of fertilizer to farmers for maize and tobacco production. Coupons for 4,524 tons of subsidized hybrid and OPV maize seed were available as well. Coupon recipients paid the equivalent of US $6.75 for a 50 kg bag of fertilizer and received their maize seed for free. The same 50 kg bag of fertilizer cost the government US $24.50 delivered at market, amounting to a subsidy rate of about 72%. Officially each household was eligible to receive two coupons good for two 50 kg bags of fertilizer at a discounted price, and one coupon for a two kilogram bag of hybrid maize seed or a four kilogram bag of OPV seed. In reality, the actual amount of subsidized fertilizer and seed acquired by households varied greatly. For example, based on the survey data used in this study, in 2008/09 subsidy participants in Malawi received a median of 50 kg of fertilizer and 2 kg of hybrid maize seed. Five percent of participants received less than 50 kg while 49% of participants received more than 50 kg of fertilizer. For households receiving maize seed through the subsidy, the 25th and 90th percentiles were 2 kg and 6 kg of maize seed, respectively. The subsidy program in Malawi cost nearly US $85 million with most of the bill being paid by the Malawian government and a minority by the United Kingdom's Department for International Development (DFID).

The subsidy program was scaled-up even further in 2007/08 when 216,500 metric tons of fertilizer and 5,541 tons of hybrid and OPV seed were procured by the Malawian government at an estimated cost of nearly US $117 million. The government made 202,000 metric tons of subsidized fertilizer and 5,365 tons of subsidized seed available in the 2008/09 season and spent an estimated US $265 million on the program. The higher cost was due to an increase in fertilizer prices and an expansion of the subsidy to smallholder tea and coffee crops (Dorward and Chirwa 2011). The proportion of the fertilizer cost that was paid by the government increased to greater than 90% in 2008/09. Farmers were officially required to pay the equivalent of US $5.33 for a 50 kg bag of fertilizer that cost between US $40 and $70 at commercial prices, while vouchers for improved maize seed could again be redeemed at no charge.

From 2002/03 to 2005/06 all subsidized seed and fertilizer coupons distributed in Malawi had to be redeemed at government depots. In 2006/07 and 2007/08 major private input suppliers were allowed to participate in the fertilizer subsidy program, so recipient households could redeem their vouchers at the private suppliers' stores. However, due to reports of corruption and the government's desire to increase control of fertilizer distribution, all subsidized fertilizer vouchers had to once again be redeemed at government depots starting in 2008/09.

[4] For a logistical review of the AISP and FISP in Malawi from 2005/06 to 2008/09, see Dorward and Chirwa (2011) and Malawi Logistics Unit Reports for primary logistical data.

Conversely, the seed component of Malawi's input subsidy program involved the private sector from 2006/07 onward. Recipient households could redeem their maize seed vouchers at a wide range of large and small input suppliers' stores.

Throughout the years of the subsidy's implementation, the process of determining who received coupons for fertilizer and seed was subject to a great deal of local idiosyncrasies. At the regional level, coupons were supposed to have been allocated based on the number of hectares under cultivation. At the village level, subsidy program committees and the village heads were supposed to determine who was eligible for the program. In more recent years open community forums were held in some villages where community members could decide for themselves who should receive the subsidy. The general program eligibility criteria was that beneficiaries should be "full time smallholder farmers who cannot afford to purchase one or two bags of fertilizer at prevailing commercial prices as determined by local leaders in their areas"[5] (Dorward et al. 2008). However, numerous unofficial criteria may have been used in voucher allocation, such as households' relationship to village leaders, length of residence, and social and/or financial standing of the household in the village.

2.2. Zambia

As in Malawi, fertilizer subsidy programs have a long and varied history in Zambia. Such programs were partially scaled back during structural adjustment in the 1990s. Then, in the 2002/03 agricultural season (which is covered in the first wave of the panel survey data used in the analysis), the Government of the Republic of Zambia (GRZ) established the Fertilizer Support Program (FSP). FSP was initially envisioned as a three-year program under which the subsidy level would be reduced from 50% in the first year, to 25% in the second, to 0% in the third (Ministry of Agriculture and Cooperatives, Zambia 2002). However, FSP ended up running through the 2008/09 agricultural year. In 2009/10, FSP was slightly redesigned and renamed the Farmer Input Support Program. This program has been implemented each year from 2009/10 to present.

Under FSP, beneficiary farmers were to receive an input pack consisting of 400 kg of fertilizer (200 kg each of basal and top dressing), and 20 kg of hybrid maize seed. The pack was to be used to plant one hectare of maize. The input pack size was halved in 2009/10 with the inception of the Farmer Input Support Program. In theory, each beneficiary farmer was to receive only one pack of inputs; however, in practice, the quantities of subsidized inputs received varied greatly across participants. For example, based on the survey data used in this study, in 2002/03 FSP participants received a median of 200 kg of fertilizer and 11.6 kg of hybrid maize seed. Twenty-five percent of participants received 100 kg of fertilizer or less while 10% of participants received more than 600 kg of fertilizer. For households receiving hybrid maize seed through FSP, the 25th and 90th percentiles were 9.4 kg and 57 kg of hybrid maize seed, respectively.

The subsidy level increased over time from 50% in 2002/03-2005/06, to 60% in 2006/07 and 2007/08, and then to 75% from 2008/09 to the present (Table 1). A total of 2,400 MT of hybrid maize seed and 48,000 MT of fertilizer were distributed through FSP in 2002/03. The program was significantly scaled up to 4,200 MT of seed and 84,000 MT of fertilizer in 2006/07 (which is covered in the second wave of the panel survey data used in the study).

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[5] In Zambia, smallholder households are defined as those cultivating less than 20 hectares of land. We were unable to find a formal definition of smallholder in Malawi, but no respondent in our smallholder survey owns more than 12 hectares.

And in 2010/11, more than double those amounts of inputs were distributed through the Farmer Input Support Program (Table 1).

To be eligible to receive fertilizer and hybrid maize seed through FSP, farmers were required to be members of cooperatives or other farmer organizations. Beneficiary cooperatives were pre-selected by District Agriculture Committees in collaboration with other local leaders. Individual farmer beneficiaries were then identified within pre-selected cooperatives by the cooperative boards in conjunction with local extension officers and other local leaders. Beneficiaries were required to:

i. be small-scale farmers actively involved in farming in the cooperative coverage area;
ii. have the capacity to grow one to five hectares of maize;
iii. be able to pay the farmer share of the cost of inputs (e.g., 50% in 2002/03);
iv. not be benefiting from the Food Security Pack Program, a smaller, grant-based GRZ input subsidy program targeted at 'vulnerable but viable' farming households that cultivate less than one hectare of land; and
v. not be a defaulter under the agricultural input credit schemes in place prior to 2002/03 (Ministry of Agriculture and Cooperatives, Zambia, various years; Tembo 2007).

Subsidized fertilizer and seed in Zambia mainly moved through a government distribution system that operated in parallel to, rather than through, private agro-dealers. GRZ used a tender process to select a small number of trading firms to procure fertilizer and hybrid maize seed on its behalf and move the inputs to the main FSP depots in participating districts. GRZ then contracted local distributors to transport the inputs from the main depots to FSP satellite depots. Upon selection, individual farmer beneficiaries paid their share of the input costs to their cooperative, which in turn deposited the funds at a participating bank. Once the government deposited the balance due and inputs were positioned at the FSP satellite depots, selected farmers reported to their local FSP satellite depot to collect their subsidized inputs (Ministry of Agriculture and Cooperatives, Zambia various years).

3. METHODS

3.1. Conceptual Framework

Our starting point for the analysis of seed crowding out is an input demand function derived from a non-separable agricultural household model. Farm household production and consumption decisions in Malawi and Zambia are unlikely to be separable given imperfections in labor, credit, and other markets. As a consequence of non-separability, both production- and consumption-side variables may affect household demand for farm inputs. Demand for commercial improved maize seed (y) is defined as:

(1) $y=y(\boldsymbol{p}, \boldsymbol{x}, \boldsymbol{c}; s, f, \boldsymbol{z})$

where $\boldsymbol{p}$ is a vector of expected crop prices at the next harvest; $\boldsymbol{x}$ is a vector of variable input prices; $\boldsymbol{c}$ is a vector of consumer prices; and s and f are respectively the quantity of subsidized improved maize seed and the quantity of subsidized fertilizer acquired by the household. We treat s and f as quasi-fixed factors of production rather than as variable inputs because households cannot freely choose the quantities of subsidized inputs that they receive. The vector of other shifters such as household landholding, farm assets, labor supply, market access constraints, and variables that affect the households' tastes and preferences as consumers is represented by $\boldsymbol{z}$.

3.2. Empirical Model

In the empirical application, the commercial improved maize seed equation is specified as:

(2) $y_{i,t} = \beta_0 + \boldsymbol{p_{i,t}}\boldsymbol{\beta_1} + \boldsymbol{x_{i,t}}\boldsymbol{\beta_2} + \beta_3 s_{i,t} + \beta_4 f_{i,t} + \boldsymbol{z_{i,t}}\boldsymbol{\beta_5} + c_i + u_{i,t}$

where i indexes the household and t indexes the year; $y_{i,t}$ is the kilograms of commercial improved maize seed purchased by the household; $\boldsymbol{p_{i,t}}$ is a vector of real crop prices (improved maize, local maize, and tobacco for Malawi, and maize, groundnuts, mixed beans, and sweet potatoes for Zambia);[6] $\boldsymbol{x_{i,t}}$ is a vector of real prices of variable inputs (agricultural labor wage rate and commercial fertilizer prices); $s_{i,t}$ and $f_{i,t}$ are, respectively, the kilograms of subsidized improved maize seed and fertilizer acquired by the household; $\boldsymbol{z_{i,t}}$ includes landholding size in hectares, the real value of household assets, variables related to the household's access to markets (kilometers to the nearest road and market or district town), number of adult equivalents, age of the household head, highest grade completed by the household head, a dummy variable to capture recent deaths in the household, expected rainfall and rainfall variability proxied by average rainfall and the coefficient of variation of rainfall over the previous five years, respectively, and year dummies; c_i is time-invariant household level unobserved heterogeneity; and $u_{i,t}$ is the time-varying error term.

Data on maize prices for local versus improved varieties are not available for Zambia; the available price data are for maize in general and not for specific varieties. In the Malawi model, farmers' expected crop prices are proxied by realized producer-level prices at harvest time, that are calculated from the household survey. In the Zambia model, these expected prices are proxied by producer-level crop prices at the previous harvest. (Producer-level crop

[6] These prices are included in the Zambia model because among Zambian smallholders the most commonly grown crops after maize are groundnuts, cassava, sweet potatoes, and mixed beans. Reliable data on producer-level prices for cassava are not available.

prices at the last harvest are not available for Malawi.) Note that consumer prices are implicitly included in the model because we deflate prices and the value of household assets by the consumer price index. Data on hybrid maize seed prices are not available but much of the variation in those prices should be captured by variables included in the model that are related to households' market access. See Table 2 and Table 3 for summary statistics for the dependent and explanatory variables used in the models for Malawi and Zambia, respectively.

Table 2. Summary Statistics - Malawi

Variable	Mean	Median	Std. dev.
Dependent variable:			
Kg of improved seed purchased commercially	3.701	0	27.273
Explanatory variables:			
Kg of subsidized improved maize seed acquired	2.196	0	14.336
Kg of subsidized fertilizer acquired	58.960	50	70.911
Km to paved road	19.437	10	25.033
Km to main market	40.456	35	33.394
Real HH assets (units, 2009=100)	58.651	13.072	28.404
Landholding (ha)	1.080	0.81	0.896
Age of household head	44.947	42	17.294
Highest grade completed by HH head:			
=1 if no formal education	0.268		
=1 if lower primary (grades 1 to 4)	0.253		
=1 if upper primary (grades 5 to 8)	0.352		
=1 if secondary (grades 9 to 12)	0.117		
=1 if post-secondary	0.010		
=1 if female headed HH	0.282		
Adult equivalents	4.318	4.12	1.963
=1 if death in family over past 2 years	0.033		
Real price of hybrid maize (MWK/kg, 2009=100)	21.473	22.612	7.331
Real price of local maize (MWK /kg, 2009=100)	21.021	18.914	8.661
Real price of tobacco (MWK /kg, 2009=100)	156.700	151.253	27.794
Real commercial fertilizer price (MWK/kg, 2009=100)	111.272	90	42.714
Real agricultural labor wage rate (units, 2009=100)	316.969	235.885	290.82
5 year avg rainfall (mm)	8.910	8.494	1.424
CV of 5 year rainfall (%)	25.8	27.0	7.8
Candidate instrumental variables:			
=1 if ruling party won HH's district in last presidential election	0.42		
Gov't-subsidized fertilizer allocated to HH's district (kg/rural HH)	71.72	66.46	38.04

Source: 2006/07 AISS1 and 2008/09 AISS2 Surveys.
Note: N= 2,750, MWK = Malawian Kwacha, HH = Household.

Table 3. Summary Statistics - Zambia

Variable	Mean	Median	Std. dev.
Dependent variable:			
Kg of improved seed purchased commercially	7.276	0	25.447
Explanatory variables:			
Kg of subsidized improved maize seed acquired	1.941	0	11.653
Kg of subsidized fertilizer acquired	36.708	0	157.291
Km from center of SEA to nearest district town (as of 2000)	34.219	28.8	22.251
Km from center of SEA to nearest tarred/main road (as of 2000)	26.195	12.2	36.723
Km from center of SEA to nearest feeder road (as of 2000)	3.239	2.3	3.141
Km from homestead to nearest point to get vehicular transport	8.388	3.000	15.729
Real HH farm assets ('000,000 ZMK, 2006=100)	26.050	2.441	105.868
Landholding (ha)	2.067	1.500	2.361
Age of household head	50.510	49	14.987
Highest grade completed by HH head:			
=1 if no formal education	0.183		
=1 if lower primary (grades 1 to 4)	0.265		
=1 if upper primary (grades 5 to 7)	0.346		
=1 if secondary (grades 8 to 12)	0.188		
=1 if post-secondary	0.019		
=1 if female headed HH	0.229		
Adult equivalents	5.024	4.780	2.454
=1 if disease-related prime-age death in HH in past 3-4 yrs.	0.093		
Lagged real price of maize (ZMK/kg, 2006=100)	847.444	792.497	303.637
Lagged real price of groundnuts (ZMK/kg, 2006=100)	1,859.801	1,794.872	400.114
Lagged real price of mixed beans (ZMK/kg, 2006=100)	1,723.738	1,666.667	211.576
Lagged real price of sweet potato (ZMK/kg, 2006=100)	352.952	355.779	115.383
Real commercial fertilizer price (ZMK/kg, 2006=100)	2,655.603	2,688.085	522.823
Real wage to weed 0.25 ha field (ZMK, 2006=100)	32,613.740	32,403.880	11,082.050
5 year avg growing season rainfall (Nov-Mar, '00 mm)	9.403	9.346	2.029
CV of 5 year growing season rainfall (Nov-Mar, %)	22.288	21.023	8.620
Candidate instrumental variables:			
Gov't-subsidized maize seed allocated to HH's district (kg/rural HH)	1.955	1.698	1.356
=1 if ruling party won HH's constituency in last presidential election	0.506		
Percentage-point spread between ruling party & lead opposition	34.230	31.251	21.512

Source: 2004 and 2008 CSO/MACO/FSRP Supplemental Surveys.
Note: N=8,562. Prime-age refers to ages 15-59. CV=coefficient of variation. SEA = standard enumeration area. ZMK=Zambian Kwacha.

3.3. Estimation Strategy

The key parameters of interest in equation (2) are the coefficients on subsidized improved maize seed and subsidized fertilizer (β_3 and β_4). For robustness purposes, we estimate equation (2) using three different estimators. Equation (2) is estimated via i) fixed effects (FE), ii) CRE Tobit, and iii) CRE Tobit-CF using a balanced panel of households. (The data used in the analysis are discussed in detail in the next section.) All three estimators control for the potential correlation between the unobserved heterogeneity (c_i) and the observed covariates (call them $\boldsymbol{X}_{i,t}$). Under a rank assumption and strict exogeneity, i.e., $E(u_{i,t} \mid \boldsymbol{X}_i, c_i) = 0,\ t = 1,2,...,T$, FE is a consistent estimator of equation (2) (Wooldridge 2010).

The dependent variable in this application, quantity of improved maize seed purchased on the commercial market, takes on the properties of a corner solution variable because many people do not buy seed commercially, but for those who do the quantity that they purchase is relatively continuous. Therefore, a Tobit model may characterize the full distribution of commercial improved maize seed demand, $D(y_{i,t} \mid \boldsymbol{X}_{i,t}, c_i) = 0$, better than a linear model.[7] However, a fixed-effects-like approach to controlling for unobserved heterogeneity in Tobit and other non-linear panel data models typically results in inconsistent parameter estimates due to the so-called 'incidental parameters problem' (Wooldridge 2010). Fortunately, there is another estimation strategy that we can use to deal with correlation between the observed covariates and c_i when using a Tobit estimator. If in addition to strict exogeneity we assume that $c_i = \psi + \bar{\boldsymbol{X}}_i \xi + a_i$ and $c_i \mid \boldsymbol{X}_i \sim Normal(\psi + \bar{\boldsymbol{X}}_i \xi,\ \sigma_a^2)$ where $\bar{\boldsymbol{X}}_i$ is the average of $\boldsymbol{X}_{i,t}$, then we can control for the unobserved heterogeneity in a Tobit by including the $\bar{\boldsymbol{X}}_i$ as additional explanatory variables (Wooldridge 2010). This procedure generates the Correlated Random Effects Tobit (CRE Tobit) estimator, which produces consistent estimates, conditional on the assumptions mentioned above.

Although the CRE Tobit estimator deals with the corner solution nature of the dependent variable and controls for the unobserved heterogeneity, it does not control for the potential endogeneity of subsidized improved maize seed and subsidized fertilizer in equation (2). (All other covariates are assumed to be strictly exogenous.) Given that subsidized inputs are not allocated randomly across households, the quantities that households receive may be systematically related to time-varying unobservable factors that affect their demand for commercial improved maize seed ($u_{i,t}$). Furthermore, although subsidized seed and fertilizer are officially distributed in standardized packs, in reality, the quantities received vary substantially across households, and the majority of households receive no subsidized inputs.

[7] Another option would have been to use Cragg's double hurdle (DH) model (Cragg 1971) instead of a Tobit model. The advantage of the DH model is that it allows *different* mechanisms to determine: (i) whether or not a household buys commercial improved maize seed; and (ii) the quantity purchased by households that do decide to buy commercial seed (Wooldridge 2002). The DH nests the Tobit model as a special case where the *same* mechanism determines decisions (i) and (ii). However, in this article, we are interested in the overall average partial effect (APE) of subsidized seed on commercial purchases (the combined effect on (i) and (ii)), and a Tobit model is adequate to consistently estimate that APE. Another reason for favoring the Tobit model in the current application is that dealing with two endogenous corner solution variables in a DH model is much more complex than in a Tobit model. After careful review we determined that in the present application the benefit of the DH model's flexibility is out-weighed by the cost of its additional complexity when dealing with two endogenous variables.

In other words, the two potentially endogenous explanatory variables take on corner solution properties just like the dependent variable. We therefore combine CRE Tobit estimation of equation (2) with the control function (CF) approach to test and control for that endogeneity.

The CF approach entails estimating separate reduced form CRE Tobit models for subsidized improved maize seed and subsidized fertilizer. The explanatory variables in these models are all of the exogenous variables from the structural model (equation (2)) and at least one instrumental variable (IV) for each suspected endogenous variable (Rivers and Vuong 1988; Vella 1993). The full set of IVs is included in both reduced form models (Wooldridge 2010). The reduced form Tobit residuals are then generated and subsequently included as additional regressors in the structural model of commercial improved maize seed demand. If the residual for the suspected endogenous explanatory variable (SEEV) is statistically significant ($p<0.10$), then we reject the hypothesis that the SEEV is exogenous. However, inclusion of the residual controls for that endogeneity. If we fail to reject the hypothesis that the SEEV is exogenous, then the Tobit residuals for that SEEV can be excluded from the structural model. Because the Tobit residuals are generated via first stage regressions, valid inference requires that the standard errors for the structural model parameter estimates be obtained via bootstrapping (Wooldridge 2010).

The IVs used in the reduced form models for Malawi are (i) a dummy variable equal to one if the ruling party won the household's district in the 2004 presidential election, and zero otherwise; and (ii) the administratively determined kilograms of subsidized fertilizer distributed to a household's district (in kilograms of subsidized fertilizer per rural household). The IVs used in the reduced form models for Zambia are: (i) a dummy variable equal to one if the ruling party won the household's constituency in the last presidential election, and zero otherwise; (ii) the absolute value of the percentage point spread between the ruling party and the lead opposition in the household's constituency in the last presidential election; (iii) the interaction between (i) and (ii); and (iv) the administratively determined kilograms of subsidized hybrid maize seed distributed to the household's district (in kilograms of subsidized seed per rural household).[8]

For Malawi, the ruling party wins IV is statistically significant (p-value < 0.01) in the reduced form CRE Tobits for both subsidized seed and subsidized fertilizer (Table 4). The IV for district level subsidized fertilizer distribution is also statistically significant in the subsidized fertilizer reduced form model (p-value < 0.01, Table 4). Therefore, the district level subsidized fertilizer distribution IV identifies the household level subsidized fertilizer SEEV, and the ruling party wins IV identifies the household level subsidized seed SEEV.

For Zambia, the ruling party wins IV and the interaction effect between it and the percentage point spread IV identify the household level subsidized fertilizer SEEV (p-value <0.05 for both, Table 5). The administratively determined district-level allocation of subsidized seed IV identifies the household level subsidized seed SEEV (p-value < 0.05, Table 5).

[8] Note that the instrumental variables are different in Malawi and Zambia for empirical reasons. For example, the variable for the absolute value of the percentage point spread between the ruling party and the lead opposition was not statistically significant in our Malawi model so was not included.

Table 4. Malawi: Factors Affecting Kilogram of Subsidized Fertilizer and Subsidized Seed Acquired by Households

	(1) Kilograms of Subsidized Improved Maize Seed Acquired CRE-TOBIT		(2) Kilograms of Subsidized Fertilizer Acquired CRE-TOBIT	
EXPLANATORY VARIABLES	APE	P-Value	APE	P-Value
IV: =1 if Ruling Party won HH's district in last presidential election	1.690***	(0.000)	11.391***	(0.000)
IV: Gov't-subsidized fertilizer allocated to HH's district (kilograms /rural HH)	0.013	(0.620)	0.621***	(0.001)
distance to paved road (km)	-0.002	(0.803)	-0.022	(0.678)
distance to main market (km)	-0.004	(0.507)	-0.007	(0.865)
real value of HH assets in Malawian Kwacha *1,000	0.000	(0.190)	-0.021	(0.157)
landholding (ha)	0.369	(0.423)	11.952***	(0.000)
Age of household head in 2004	0.011	(0.286)	0.055	(0.451)
=1 if primary (grades 1 to 4)	0.349	(0.474)	3.091	(0.351)
=1 if upper primary (grades 5 to 8)	1.306***	(0.006)	13.451***	(0.000)
=1 if secondary (grades 8 to 12)	0.232	(0.720)	11.126**	(0.011)
=1 if post-secondary	-3.490*	(0.087)	-3.753	(0.743)
=1 if female headed HH	-0.087	(0.941)	6.084	(0.451)
adult equivalents	0.732	(0.286)	-2.005	(0.664)
adult equivalents, squared	-0.062	(0.306)	0.195	(0.632)
=1 if death of head or spouse over past 2 yrs.	0.521	(0.744)	4.965	(0.641)
Log of real price of hybrid maize (MWK/kg)	0.406	(0.287)	-0.731	(0.774)
Log of real price of local maize (MWK/kg)	-0.273*	(0.059)	0.721	(0.453)
Log of real price of tobacco (MWK/kg)	-0.011	(0.550)	0.129	(0.307)
Log of real commercial fertilizer price	-0.012	(0.143)	-0.292***	(0.000)
Log of real ag labor wage rate	-0.001	(0.243)	0.005	(0.327)
5 year avg growing season rainfall (Oct-May, '00 mm)	-0.002	(0.873)	0.003	(0.972)
CV of 5 year growing season rainfall (Oct-May, %)	-1.221	(0.920)	0.992	(0.215)
=1 if year is 2006/07	-2.090	(0.546)	-4.875	(0.835)
Observations.	2,750			2,750
Pseudo R-squared	0.03			0.02
Chi sq.: Joint sign. of all regressors	252***	(0.000)	758***	(0.000)

Note: *, **, *** indicates that corresponding APEs are statistically significant at the 10%, 5%, and 1% level respectively; regional dummies included in the model; CRE includes time averages of time varying explanatory variables; APE = average partial effect.

The IVs used in this analysis are highly correlated with the SEEVs and thus are strong instruments for identifying the reduced form models. It is logical that official district-level subsidized seed and subsidized fertilizer allocations per rural household affect how much subsidized fertilizer and seed a household acquires. The locality election variables are also clearly strong instruments as they reflect the political nature of the subsidy programs in Malawi and Zambia. Similar variables have been used in other applications that address input subsidy targeting issues across Africa (Banful 2011; Mason 2011). The argument for these variables being exogenous is that they are determined at an administrative level that is high above the rural household. Furthermore, given the lack of mobility of many rural households in Malawi and Zambia it is unlikely that they would move districts to get more subsidized inputs. Therefore, we maintain that the IVs used in this analysis should be exogenous in the structural equation of household demand for commercial improved maize seed, particularly after controlling for observed covariates and time invariant unobserved heterogeneity c_i.

Table 5. Zambia: Factors Affecting Kilogram of Subsidized Fertilizer and Subsidized Seed Acquired by Households

	(1) Kilograms of Subsidized Improved Maize Seed Acquired CRE-TOBIT		(2) Kilograms of Subsidized Fertilizer Acquired CRE-TOBIT	
EXPLANATORY VARIABLES	APE	P-value	APE	P-value
IV: Gov't-subsidized maize seed allocated to HH's district (kg/rural HH)	0.226**	(0.012)	0.687	(0.549)
IV: =1 if ruling party won HH's constituency in last pres. election	0.117	(0.743)	10.798**	(0.022)
IV: %-point spread between ruling party & lead opposition	0.000	(0.989)	-0.035	(0.707)
IV: Interaction effect – ruling party won × % point spread	0.007	(0.635)	0.528***	(0.001)
Km from center of SEA to nearest district town (as of 2000)	0.002	(0.466)	-0.099***	(0.005)
Km from center of SEA to nearest tarred/main road (as of 2000)	-0.003	(0.212)	-0.006	(0.791)
Km from center of SEA to nearest feeder road (as of 2000)	0.015	(0.434)	-0.669**	(0.013)
Km from homestead to nearest point to get vehicular transport	-0.005	(0.476)	0.103	(0.384)
Real HH farm assets ('000,000 ZMK, 2006=100)	0.001	(0.805)	0.047	(0.212)
Landholding (ha)	0.172**	(0.012)	1.583*	(0.092)
Age of household head	-0.032*	(0.065)	0.458**	(0.046)
=1 if lower primary (grades 1 to 4)	0.137	(0.694)	-2.131	(0.661)
=1 if upper primary (grades 5 to 7)	0.428	(0.298)	1.696	(0.730)
=1 if secondary (grades 8 to 12)	0.103	(0.834)	9.249	(0.221)
=1 if post-secondary	-0.383	(0.585)	-3.671	(0.682)
=1 if female headed HH	0.206	(0.631)	-0.519	(0.925)
Adult equivalents	0.010	(0.872)	0.266	(0.742)
=1 if disease-related prime-age death in HH in past 3-4 yrs.	0.653	(0.168)	2.509	(0.589)
Log of lagged real price of maize (2006=100)	-0.718	(0.284)	2.328	(0.808)
Log of lagged real price of ground nuts (2006=100)	0.741	(0.387)	-6.554	(0.590)
Log of lagged real price of mixed beans (2006=100)	0.215	(0.866)	-12.44	(0.449)
Log of lagged real price of sweet potatoes (2006=100)	-0.131	(0.759)	4.078	(0.410)
Log of real commercial fertilizer price (2006=100)	1.013	(0.239)	32.87**	(0.004)
Log of real wage to weed 0.25 ha field (2006=100)	-0.507	(0.274)	0.722	(0.888)
5 year avg growing season rainfall (Nov-Mar, '00 mm)	0.130	(0.442)	-2.504	(0.140)
CV of 5 year growing season rainfall (Nov-Mar, %)	-0.035**	(0.045)	-0.255	(0.346)
=1 if year is 2006/07	-0.068	(0.912)	3.598	(0.669)
Observations	8,562		8,562	
Pseudo R-squared	0.152		0.137	
F-stat: Joint sign. of all regressors	64.56***	(0.000)	26.88***	(0.000)

Note: *, **, *** indicates that corresponding APEs are statistically significant at the 10%, 5%, and 1% level respectively; CRE includes time averages of time varying explanatory variables; APE = average partial effect. Prime-age refers to ages 15-59. CV=coefficient of variation.

4. DATA

4.1. Malawi

The Malawi data used in this study come mainly from two nationally representative surveys of rural smallholder farm households, the Agricultural Inputs Support Survey 1 (AISS1) collected during 2006/07 and the AISS2 collected during 2008/09. Both surveys were collected by the Malawian National Statistical Office (NSO) in conjunction with Wadonda Consulting. The AISS1 and AISS2 were collected in order to evaluate the input subsidy program, and built off of an earlier survey called the Second Integrated Household Survey (IHS2). Unfortunately the IHS2 cannot be used for this analysis because the survey did not ask respondents about where they acquired maize seed (e.g., either from the government subsidy program or on the commercial market), so the purchasing channel cannot be identified. Respondents to the three surveys were asked questions about farm and non-farm activities, along with demographic, asset and other related details.

The IHS2 was a nationally representative survey conducted during the 2002/03 and 2003/04 growing seasons that covered 26 districts and surveyed 11,280 smallholder households. The subsequent budget for AISS1 was much smaller than the budget for IHS2, so of the 11,280 households interviewed in IHS2, only 3,485 of them lived in enumeration areas that were re-visited in 2006/07. Of these 3,485 households, 2,968 were re-interviewed in AISS1, which gives us an attrition rate of 14.8% between the IHS2 and AISS1 surveys. The AISS2 survey in 2008/09 had a subsequently smaller budget than the AISS1 survey in 2006/07, so of the 2,968 households first sampled in 2003 and again in 2007, 1,642 of them lived in enumeration areas that were revisited in 2009. Of the 1,642 households in revisited areas, 1,375 were found for re-interview in 2009, which gives us an attrition rate of 16.3% between 2006/07 and 2008/09.

Ultimately the analysis conducted for Malawi in this study uses the information from AISS1 and AISS2 for the 1,375 households that were interviewed in all three surveys in Malawi. Although the rate of re-interview is around 85% across waves of the survey, attrition bias is an issue that must be addressed. Unfortunately, there is no formal regression-based test for attrition bias when panel data methods such as FE or CRE are used with only two time periods of data. At least three time periods of data are needed for such tests (Wooldridge 2010). In this study, attrition bias is controlled for to the extent that (i) attrition is correlated with the observed covariates; and (ii) FE and CRE control for time constant unobserved factors that affect both commercial seed purchases and household attrition between survey waves.

In addition to information from the AISS1 and AISS2 surveys, the analysis in Malawi includes daily rainfall data provided by the Malawian Ministry of Natural Resources, Energy, and Environment, collected at 21 experiment stations across the country. District-level election results for the 2004 presidential election come from the Malawi Electoral Commission.

4.2. Zambia

The data used in the Zambia analysis are drawn mainly from the second and third waves of the Supplemental Survey to the 1999/2000 Post-Harvest Survey (SS). The SS is a three-wave, nationally-representative panel survey of smallholder farm households in 70 districts conducted by the Zambia Central Statistical Office (CSO) and Ministry of Agriculture and Cooperatives (MACO) in conjunction the Food Security Research Project (FSRP). The first wave of the SS, which covers the 1999/2000 agricultural year, is not used in the analysis because respondents were not asked about the source of their maize seed (e.g., commercial purchase versus government subsidy program). A total of 6,922 smallholders were interviewed in the first wave of the survey and information was collected on their farm and non-farm activities, household demographics, assets, and other household details. See Megill (2005) for details on the sampling frame.

The second wave of the panel survey was conducted in May 2004 and covered the 2002/03 agricultural year. A total of 5,358 households (77.4%) were successfully re-interviewed. The third and most recent wave of the SS was conducted in mid-2008 and covered the 2006/07 agricultural year. Of the 5,358 households interviewed for the 2004 SS, 4,286 (80.0%) were successfully re-interviewed for the 2008 SS. In the analysis, we use a balanced panel of 4,281 households that were interviewed in both the 2004 and 2008 SSs. (Five households are excluded from the analytical sample due to data problems.)

Although the re-interview rates for the SSs are relatively high, attrition bias is a potential concern. As mentioned with the Malawi data, there is no formal regression-based test for attrition bias when panel data methods such as FE or CRE are used with only two time periods of data because three time periods are needed for the test. However, Mason (2011) uses all three waves of the SS to estimate the effects of GRZ fertilizer subsidy programs on commercial fertilizer purchases and finds no statistically significant evidence of attrition bias based on the test described in Wooldridge (2002, p. 585). This somewhat allays fears about attrition bias in the current study.

In addition to the SS data, several other data sources are used in the Zambia analysis. These are: (i) dekad (10-day) rainfall data for the 1997/98-2005/06 growing seasons from 36 rainfall stations in the country from the Zambia Meteorological Department; (ii) maize, groundnut, mixed bean and sweet potato prices from the 2001/02 and 2005/06 CSO/MACO Post-Harvest Surveys; (iii) data on district-level allocations of GRZ-subsidized hybrid maize seed in 2002/03 and 2006/07 from MACO (various years); and (iv) constituency-level results from the 2001 and 2006 presidential elections from the Electoral Commission of Zambia.

5. RESULTS

We begin this section by presenting descriptive statistics on seed subsidy recipients versus non-recipients in Malawi and Zambia. We then present the econometric results. Table 6 illustrates the fact that the Malawian seed subsidy program reaches a larger percentage of households (38.6%) than the Zambian program (8.4%). However, in Zambia, households who acquire subsidized seed obtain significantly more than their Malawian counterparts. The average beneficiary household in the Zambia acquires 23.0 kg of subsidized seed, while the average beneficiary household in Malawi acquires 5.7 kg of subsidized seed. This is not surprising given that a subsidy pack in Zambia includes 20 kg of maize seed, whereas the Malawi subsidy pack contains only two kg of hybrid or four kg of OPV seed. Recipients of subsidized seed also purchase 0.9 kg of commercial seed on average in both Malawi and Zambia. Non-recipients of subsidized seed purchase 7.6 kg of commercial seed in Zambia and 5.5 kg in Malawi. The higher commercial seed purchases among households not receiving subsidized seed compared to subsidy recipients indicates that crowding out may be a potential problem in both countries.

Subsidized seed recipients farm slightly larger plots on average than non-recipients in Malawi, with 1.2 hectares and 1.0 hectares respectively. The same is true in Zambia where subsidized seed recipients farm 2.4 hectares and non-recipients farm 2.0 hectares on average. To the extent that landholding is positively correlated with a household's ability to purchase improved maize seed at commercial prices, these findings again suggest that crowding out may be a potential problem.

Recipients of the seed subsidy have fewer assets on average in Malawi than do non-recipients. In Zambia the opposite is true, as subsidy recipients have more assets than non-recipients. Female-headed households make up a smaller percentage of recipients than non-recipients in both Malawi and Zambia, and in both countries recipients are slightly better educated than non-recipients (Table 6).

Table 6. Socioeconomic Characteristics of Smallholder Households by Receipt of Government-subsidized Improved Maize Seed in Malawi and Zambia

	MALAWI		ZAMBIA	
	Received subsidized seed?		Received subsidized seed?	
Descriptive result	Yes	No	Yes	No
% of smallholder households	38.6	61.4	8.4	91.6
Mean kg of subsidized seed received	5.7	0	23.0	0
Median kg of subsidized seed received	2	0	11.6	0
Mean kg of commercial seed purchased	0.9	5.5	0.9	7.6
Median kg of commercial seed purchased	0	0	0	0
Mean landholding size (ha)	1.2	1.03	2.4	2.0
Mean real value of assets[a]	53.5	61.8	30.1	25.7
% female-headed	26.5	29.2	21.0	23.1
Median education of HH head (highest grade completed)	5	4	6	5

Malawi data source: 2006/07 AISS1 and 2008/09 AISS2 Surveys
Zambia data source: 2004 and 2008 CSO/MACO/FSRP Supplemental Surveys
Note: Malawi results for 2006/07 and 2008/09 agricultural years. Zambia results for 2002/03 and 2006/07 agricultural years. [a]for Malawi, assets are in '000 MWK, 2009=100; for Zambia, assets are in '000,000 ZMK, 2006=100.

Table 4 presents the Malawian results of the reduced form models of factors affecting the kilograms of subsidized improved maize seed that households acquire (column 1), and the kilograms of subsidized fertilizer that households acquire (column 2). Results in column 1 indicate that the IV for whether or not the ruling party won the previous election is statistically significant at the 1% level in the subsidized seed model. The average household in a district where the ruling party won the 2004 presidential election acquires 1.69 kg more subsidized improved maize seed than households in other districts. The statistical significance of this IV identifies the subsidized seed SEEV, and the coefficient also demonstrates the political nature of the subsidy program. Column 1 also shows that smaller farms did not acquire significantly more subsidized seed than larger farms. Households with heads who have primary education acquire significantly more subsidized improved maize seed than households whose head did not go to school. Also, households whose head has a post-secondary education acquire 3.49 kg less subsidized seed than households whose head did not go to school. This may indicate that highly educated households are not targeted by the program, likely because these households are engaged in activities other than subsistence maize production, and/or have the ability to purchase seed on the commercial market.

Column 2 of Table 4 indicates that both IVs are statistically significant at the 1% level. Households in districts where the ruling party won the 2004 election acquire 11.39 kg more subsidized fertilizer on average than households in other districts. Also, a one kilogram increase in the official amount of subsidized fertilizer distributed per rural household in the district leads to the household acquiring 0.62 kg more subsidized fertilizer on average. It is also interesting that households with more land get significantly more subsidized fertilizer: an extra hectare of land gets the household nearly 12 more kilograms of subsidized fertilizer. Households with heads who have upper primary and secondary education acquire significantly more subsidized fertilizer than households with a head who did not go to school. This may indicate that the program targets households with some education who can potentially use the fertilizer more effectively. Columns 1 and 2 both indicate that female headed households do not acquire significantly more subsidized fertilizer than other households in Malawi, even though they are officially supposed to be targeted beneficiaries of the subsidy program.

Table 5 presents the Zambian results of the reduced form models of factors affecting the kilograms of subsidized improved maize seed that households acquire (column 1), and the kilograms of subsidized fertilizer that households acquire (column 2). Results in column 1 indicate that the IV, kilograms of subsidized maize seed allocated to the household’s district, is statistically significant at the 5% level. An extra kilogram of subsidized maize seed distributed to the household’s district according to the official records gets that household an extra 0.23 kg of subsidized seed on average. Column 1 also shows that in Zambia, larger farms acquire more subsidized improved seed: an additional hectare of land gets the household 0.17 extra kilograms of improved maize seed on average. Households with older heads acquire less subsidized seed than other households in Zambia, other factors constant.

Column 2 of Table 5 indicates that in Zambia the IV for whether or not the ruling party won the previous election in the household’s constituency is statistically significant at the 5% level. The IV interacting the election IV with the absolute value of the vote spread is also statistically significant at the 1% level. The average partial effects (APEs) of the election-related IVs indicate that households in constituencies where the ruling party won the past presidential election acquire 10.8 kg more subsidized fertilizer than other households on average, and that effect increases the larger the ruling party’s margin of victory. These results highlight the political nature of the subsidy program in Zambia, and are consistent with the results in Malawi. Column 2 also indicates that households in areas farther from the main district town and farther from a feeder road acquire significantly less subsidized fertilizer. This indicates that the fertilizer subsidy program may not have targeted people in more remote areas. In addition, households with more land acquire more subsidized fertilizer, and households with older household heads acquire more subsidized fertilizer. Just as in Malawi, columns 1 and 2 both indicate that female headed households in Zambia do not acquire significantly more subsidized seed and fertilizer than other households.

Table 7 presents the results for factors affecting demand for commercial improved maize seed in Malawi. Column 1 presents results using a linear model estimated via fixed effects. Column 2 presents the results using CRE Tobit. Column 3 presents the results using CRE Tobit with the control function residuals obtained from the subsidized seed and subsidized fertilizer reduced form models presented in Table 4. Note in column 3 that the residuals for both subsidized seed and subsidized fertilizer are not statistically significant after bootstrapping. This indicates that we fail to reject the exogeneity of the two SEEVs, and should focus on the results in column 2 for inference on the effects of subsidized seed and fertilizer on commercial seed purchases.

Results in column 1 where the model is estimated via FE indicate that there is no significant crowding out effect from subsidized seed on demand for commercial improved maize seed. However, the FE estimator has a serious drawback in this application because it assumes that the model is linear, when in reality the dependent variable is highly skewed. Therefore the model in column 2 estimated via CRE Tobit likely fits the data better. Results in column 2 indicate that an additional kilogram of subsidized maize seed acquired by the household reduces the quantity of commercial maize seed acquired by 0.56 kg. Another way to interpret this result is that an additional 100 kg of subsidized maize seed distributed by the Malawian government to farmers only add 44 new kilograms to total improved seed use. The other 56 kg of subsidized seed displace an equivalent amount of commercial seed and so do not add to total seed use. Column 2 indicates that subsidized fertilizer has no statistically significant ($p>0.44$) effect on demand for commercial maize seed in Malawi.

Column 2 also shows that households with more land are more likely to purchase commercial improved maize seed. Households where the head has a post-secondary education purchase 10.5 kg more commercial maize seed on average than do households with no education. It is also interesting that households in areas with a higher coefficient of variation on rainfall purchase significantly more commercial improved maize seed. This result is consistent with the notion that rainfall risk causes households to plant improved seeds because many improved varieties have a shorter growing period than local varieties.

Table 8 presents the results for factors affecting demand for commercial improved maize seed in Zambia. As in Table 7 from Malawi, column 1 from Table 8 presents results using a linear model estimated via fixed effects. Column 2 presents the results using CRE Tobit, while column 3 presents the results using CRE Tobit with the control function residuals obtained from the subsidized seed and subsidized fertilizer reduced from models presented in Table 5. Note in column 3 that the residuals for the subsidized fertilizer residual is statistically significant at the 10% level. This indicates that there is marginal evidence that subsidized fertilizer is endogenous in the commercial seed demand model. Including the residual in the model controls for endogeneity, so the results in column 3 are consistent. In contrast, the results in column 2 are inconsistent due to the failure to control for endogeneity.

The residual from the subsidized seed reduced form is not statistically significant at the 10% level in column 3, so there is no evidence that subsidized seed is endogenous in the commercial seed demand equation.

Table 7. Malawi, Factors Affecting Kgs of Improved Maize Seed Purchased on the Commercial Market

dep var= kgs. of improved maize seed purchased commercially	**(1) Fixed-Effects**		**(2) CRE-Tobit**		**(3) CRE Tobit w/CF Residual**	
EXPLANATORY VARIABLES	APE	P-Value	APE	P-Value	APE	P-Value
Residuals from subsidized improved seed reduced form Tobit					0.514	(0.971)
Residuals from subsidized fertilizer reduced form Tobit					-0.030	(0.990)
Kgs. Of subsidized seed acquired	-0.021	(0.328)	-0.561***	(0.000)	-0.547	(0.460)
Kgs. Of subsidized fertilizer acquired	0.020	(0.198)	0.005	(0.446)	0.004	(0.479)
distance to paved road	NA		-0.017	(0.218)	-0.010	(0.933)
distance to main market	NA		0.005	(0.635)	0.005	(0.934)
real value of HH assets in Mw Kwacha *1,000	0.000	(0.932)	0.000	(0.546)	0.004	(0.992)
real HH assets, squared *1,000	0.000	(0.878)				
landholding (ha)	1.066	(0.260)	1.13	(0.141)	2.077	(0.968)
landholding, squared	0.169	(0.277)				
Age of household head in 2004	NA		-0.057***	(0.006)	-0.042	(0.944)
=1 if primary (grades 1 to 4)	NA		0.042	(0.963)	0.276	(0.992)
=1 if upper primary (grades 5 to 8)	NA		0.421	(0.639)	2.143	(0.937)
=1 if secondary (grades 8 to 12)	NA		1.173	(0.311)	1.057	(0.985)
=1 if post-secondary	NA		10.523***	(0.000)	5.217	(0.985)
=1 if female headed HH	7.510	(0.334)	2.181	(0.331)	1.794	(0.982)
adult equivalents	0.545	(0.552)	-0.406	(0.745)	0.960	(0.968)
adult equivalents, squared	-0.084	(0.378)	0.037	(0.733)	-0.081	(0.973)
=1 if death of head or spouse over past 2 yrs.	1.178	(0.679)	2.049	(0.501)	2.892	(0.945)
Log of real price of hybrid maize (MWK/kg)	30.763	(0.208)	-0.266	(0.659)	0.530	(0.993)
Log of real price of local maize (MWK/kg)	-3.880	(0.724)	0.230	(0.312)	-0.313	(0.991)
Log of real price of tobacco (MWK/kg)	-9.879	(0.411)	0.043	(0.190)	0.015	(0.997)
Log of real commercial fertilizer price	-0.973	(0.717)	-0.004	(0.771)	-0.010	(0.982)
Log of real ag labor wage rate	-0.438	(0.684)	0.000	(0.891)	-0.002	(0.957)
5 yr. avg growing season rainfall (Oct-May, '00 mm)	-32.19*	(0.061)	-0.044**	(0.047)	-0.045	(0.983)
5 year avg growing season rainfall, squared	0.016	(0.101)				
CV of 5 year growing season rainfall (Oct-May, %)	0.650**	(0.017)	0.390*	(0.069)	28.732	(0.928)
=1 if year is 2006/07	21.93*	(0.057)	-0.827	(0.899)	-3.892	(0.993)
Chi sq.: Joint significance of all regressors			195***	(0.000)	212***	(0.000)
Standard Errors	Huber-White		Non-Adjusted		Non-Adj. w/bootstrap	

Note: *, **, *** indicates that corresponding APEs are statistically significant at the 10%, 5%, and 1% level respectively; regional dummies included in the model; CRE includes time averages of time varying explanatory variables; APE = average partial effect; intercept not show.

Table 8. Zambia, Factors Affecting Kgs of Improved Maize Seed Purchased on the Commercial Market

Dep var = kgs. of improved maize seed purchased commercially	(1) Fixed-Effects		(2) CRE-Tobit		(3) CRE Tobit w/CF Residual	
EXPLANATORY VARIABLES	APE	P-value	APE	P-value	APE	P-value
Residuals from subsidized improved seed reduced form Tobit					-0.036	(0.545)
Residuals from subsidized fertilizer reduced form Tobit					-0.019***	(0.009)
Kg of subsidized improved maize seed acquired	-0.286***	(0.000)	-0.488***	(0.000)	-0.488***	(0.000)
Kg of subsidized fertilizer acquired	0.021***	(0.000)	0.007***	(0.000)	0.007***	(0.000)
Km from center of SEA to nearest district town (as of 2000)			-0.038**	(0.013)	-0.024	(0.142)
Km from center of SEA to nearest tarred/main road (as of 2000)			-0.006	(0.639)	-0.004	(0.766)
Km from center of SEA to nearest feeder road (as of 2000)			-0.181	(0.124)	-0.086	(0.472)
Km from homestead to nearest point to get vehicular transport	-0.005	(0.801)	-0.029	(0.402)	-0.042	(0.230)
Real HH farm assets ('000,000 ZMK, 2006=100)	0.041**	(0.040)	0.012**	(0.026)	0.005	(0.435)
Real HH farm assets, squared	0.000	(0.119)				
Landholding (ha)	2.289***	(0.000)	0.946***	(0.000)	0.646***	(0.002)
Landholding, squared	-0.006	(0.643)				
Age of household head	-0.025	(0.559)	-0.001	(0.973)	-0.057	(0.333)
=1 if lower primary (grades 1 to 4)	0.396	(0.635)	0.509	(0.601)	0.776	(0.447)
=1 if upper primary (grades 5 to 7)	0.294	(0.734)	1.892*	(0.092)	1.376	(0.224)
=1 if secondary (grades 8 to 12)	1.247	(0.344)	3.076**	(0.042)	1.584	(0.274)
=1 if post-secondary	-0.240	(0.938)	4.002	(0.119)	5.366*	(0.057)
=1 if female headed HH	0.232	(0.803)	-0.215	(0.826)	-0.24	(0.808)
Adult equivalents	0.84	(0.157)	0.393***	(0.008)	0.365**	(0.016)
Adult equivalents, squared	-0.03	(0.545)				
=1 if disease-related prime-age death in HH, past 3-4 yrs.	-0.137	(0.861)	0.197	(0.772)	-0.464	(0.53)
Log of lagged real price of maize (2006=100)	-3.142	(0.270)	-0.65	(0.745)	-1.185	(0.586)
Log of lagged real price of ground nuts (2006=100)	-3.248	(0.277)	3.487	(0.118)	4.719**	(0.040)
Log of lagged real price of mixed beans (2006=100)	8.176**	(0.047)	4.287	(0.119)	4.492	(0.105)
Log of lagged real price of sweet potatoes (2006=100)	0.555	(0.389)	0.245	(0.787)	-1.004	(0.359)
Log of real commercial fertilizer price (2006=100)	10.618***	(0.002)	6.228***	(0.003)	3.058	(0.161)
Log of real wage to weed 0.25 ha field (2006=100)	-0.965	(0.375)	-0.617	(0.500)	-0.678	(0.509)
5 year avg growing season rainfall (Nov-Mar, '00 mm)	-5.577**	(0.018)	-0.929***	(0.006)	-0.595	(0.119)
5 year avg growing season rainfall, squared	0.217**	(0.046)				
CV of 5 year growing season rainfall (Nov-Mar, %)	0.055	(0.371)	0.007	(0.859)	0.062	(0.225)
=1 if year is 2006/07	3.582*	(0.064)	4.766***	(0.005)	3.78**	(0.029)
F-stat: Joint significance of all regressors	5.18***	(0.000)	14.03***	(0.000)	13.79***	(0.000)
Standard errors	Huber-White		Huber-White		Bootstrap	

Note: *, **, *** indicates that corresponding APEs are statistically significant at the 10%, 5%, and 1% level respectively; CRE includes time averages of time varying explanatory variables; APE = average partial effect; CRE models also include province and agro-ecological region dummies. APEs for farm assets, landholding, and rainfall in Tobit models include effects of squared term. Prime-age refers to ages 15-59. CV=coefficient of variation. Bootstrap standard errors based on 100 replications.

Results in column 1 where the model is estimated via FE indicate that an additional kilogram of subsidized maize seed crowds out nearly 0.29 kg of commercial improved maize seed. However, as in the Malawi results, the model in column 3 estimated via CRE Tobit likely fits the data better than the FE estimator. Results in column 3 indicate that an additional kilogram of subsidized maize seed acquired by the average household in Zambia reduces the quantity of commercial maize seed that they purchase by nearly 0.49 kg. Another way to interpret this result is that an additional 100 kg of subsidized maize seed distributed by the Zambian government to farmers only adds 51 new kilograms to total improved seed use, because the other 49 kg of subsidized seed displace an equivalent amount of commercial seed.

Column 3 also indicates that subsidized fertilizer may crowd in commercial maize seed purchases in Zambia, as the APE of subsidized fertilizer is positive and statistically significant at the 1% level. The economic significance of the effect is small, however, as an additional kilogram of subsidized fertilizer causes the household to purchase only 0.007 kg more commercial maize seed on average. Therefore, if a Zambian smallholder obtains 400 kg of subsidized fertilizer (the standard quantity under FSP), he or she is only likely to purchase 2.8 more kilograms of improved maize seed on the commercial market. In addition, column 3 indicates that households with more land purchase significantly more commercial maize seed in Zambia, just as in Malawi.

6. CONCLUSIONS AND POLICY IMPLICATIONS

Targeted input subsidies for fertilizer and improved maize seed are currently being used by governments throughout SSA to improve smallholder farmers' access to inputs, raise on-farm productivity, and increase food security and incomes. An important determinant of how much additional fertilizer and improved maize seed ends up on farmers' fields as a result of these programs is the extent to which they crowd in or crowd out farmers' purchases of inputs at market prices from commercial retailers. Previous studies in Malawi and Zambia show that fertilizer subsidies generally crowd out commercial fertilizer purchases (Xu et al. 2009; Ricker-Gilbert, Jayne, and Chirwa 2011; Mason 2011). However, the current study is the first to measure the effects of input subsidies on commercial improved maize seed purchases. Recent evidence from Malawi suggests that nearly half the maize yield gains from the input subsidy program come from uptake of improved maize seed (Chibwana et al. 2012). This makes it essential to understand the extent to which seed subsidies contributed to increasing improved seed use.

In this paper, we use nationally-representative panel household survey data from Malawi and Zambia to estimate the crowding in/out effects of both subsidized improved maize seed and subsidized fertilizer on smallholders' purchases of commercial improved maize seed. The cross-country nature of the study adds to the external validity and robustness of the results and associated conclusions. The paper also provides a useful empirical application of the control function approach to deal with multiple endogenous corner solution explanatory variables in non-linear panel data models (Rivers and Vuong 1988; Vella 1993; Wooldridge 2010).

We use fixed effects and correlated random effects Tobit estimators to measure the average partial effect of a one kg increase in the quantity of subsidized improved maize seed or subsidized fertilizer acquired by smallholder households on their demand for commercial improved maize seed. Both the FE and CRE Tobit estimators allow us to control for correlation between the covariates in this model and time invariant unobserved household-level heterogeneity. However, subsidized seed and fertilizer may be endogenous to household demand for commercial seed. The CF approach to test and control for this potential endogeneity entails first estimating separate reduced form CRE Tobit models for the kilograms of subsidized improved maize seed and subsidized fertilizer acquired by the household. Included as regressors in these reduced forms are instrumental variables for subsidized seed and subsidized fertilizer related to past presidential election results and administratively-determined district-level allocations of subsidized inputs. Then, the Tobit residuals from the reduced forms are included as additional regressors in the structural model, household demand for commercial improved maize seed.

The results of these models highlight four key findings. First, based on the reduced form CRE Tobit estimates, the distribution of subsidized inputs across smallholder households appears to be politically motivated in both Malawi and Zambia. In Malawi, other factors constant, households in districts won by the ruling party in the last presidential election receive 1.7 kg more subsidized maize seed and 11.4 kg more subsidized fertilizer than households in districts lost by the ruling party. In Zambia, households in constituencies won by the ruling party receive 10.8 kg more subsidized fertilizer, and that quantity increases by 0.5 kg for each percentage point increase in the ruling party's margin of victory. This finding is consistent with findings from other studies of input subsidy programs in Africa (Banful 2011; Chibwana, Fisher, and Shively 2011). Both the Malawian and Zambian governments appear to be using subsidized inputs to reward patronage.

Second, the reduced form results point to other subsidy targeting problems as well. Households with larger landholdings receive significantly more subsidized fertilizer in both Malawi and Zambia, and more subsidized seed in Zambia. On average an additional hectare of land gets the household nearly 12 more kilograms of subsidized fertilizer in Malawi, and 1.58 more kilograms of subsidized fertilizer in Zambia. In addition, an extra hectare of land in Zambia gets the average household nearly 0.18 kg more subsidized maize seed. To the extent that landholding size is correlated with the household's ability to purchase inputs at market prices, these results suggest that targeting larger farmers may cause significant crowding out by the input subsidy programs. Targeting female-headed households might reduce the potential for crowding out of commercial purchases, but we find no evidence that female-headed households received significantly more subsidized inputs than male-headed households in either Malawi or Zambia.

Third, our results indicate that subsidies for improved maize seed do in fact crowd out commercial seed purchases by smallholders in Malawi and Zambia. Each one kg increase in subsidized seed acquired by the household reduces commercial improved maize seed purchases by 0.56 kg in Malawi and by 0.49 kg in Zambia. Put differently, for each metric ton of subsidized seed distributed by the government, total improved maize seed usage increases by only 0.44 MT in Malawi and 0.51 MT in Zambia.

Fourth, receipt of subsidized fertilizer has no economically significant effect on commercial improved maize seed demand in Malawi or Zambia. In Malawi, a one kg increase in the quantity of subsidized fertilizer acquired by the household has no statistically significant effect on demand for commercial improved maize seed (p-value>0.44). In Zambia, a one kg increase in subsidized fertilizer raises commercial seed demand by just 0.007 kg (p-value<0.01). This increase is very small in magnitude. To put it in perspective, this result implies that if a Zambian smallholder household received 400 kg more subsidized fertilizer (the standard subsidized input pack size under the Fertilizer Support Program), its demand for commercial seed would increase by just 2.8 kg, or enough seed to plant approximately 0.14 ha based on government-recommended seeding rates.

The answers to this study's central research questions "what are the effects of subsidized improved maize seed and subsidized fertilizer on smallholder demand for commercial improved maize seed?" are very similar for Malawi and Zambia. This is despite considerable differences in the scale and mechanism of delivery for input subsidies in the two countries. For example, a much larger percentage of smallholders received subsidized seed in Malawi (38.6%) than in Zambia (8.4%). However, seed subsidy participants in Malawi received significantly less seed on average (5.7 kg) than their Zambian counterparts (23.0 kg). And while the seed component of the Malawian input subsidy program was implemented through vouchers that farmers redeemed at commercial retailers, the Zambian program was implemented through a government distribution system that operated in parallel to the commercial market.

Although the rates of crowding out are similar under the Malawian and Zambian subsidy distribution systems, the Malawian voucher system is more likely to have stimulated private sector investment in seed retailing than the Zambia parallel marketing channel system. Even if the subsidy program reduced demand for commercial seed in Malawi, at least a large number of dispersed seed retailers received business when farmers redeemed their vouchers for subsidized seed. In Zambia, however, a very small number of firms won tenders to implement the government subsidy program. Thus, not only did the subsidy program reduce demand for commercial seed but it also sidelined the vast majority of seed retailers in Zambia from involvement in the program.

How does the magnitude of the crowding out effect of seed subsidies on commercial seed demand compare to the magnitude of the crowding out effect of fertilizer subsidies on commercial fertilizer demand? Ricker-Gilbert, Jayne, and Chirwa (2011) find that each kg of subsidized fertilizer received by a Malawian smallholder crowds out commercial fertilizer purchases by 0.22 kg. Using methods analogous to those of Ricker-Gilbert, Jayne, and Chirwa (2011); Mason (2011) estimates a commercial fertilizer displacement rate of 0.14 kg for Zambia. While the crowding out effect of seed subsidies on commercial seed demand (0.49-0.56) is considerably larger than the crowding out effect of fertilizer subsidies on commercial fertilizer demand in both countries (0.14-0.22), these findings provide strong cross-country evidence that crowding out of commercial seed and fertilizer is a significant problem with input subsidy programs.

Evidence from our study shows that part of why crowding out of commercial seed occurs is because some of the subsidized inputs are targeted to households that would otherwise buy the inputs at market prices. Therefore, the subsidy programs are not having as large an impact on increasing input use as they otherwise might. Depoliticizing the distribution of subsidized seed and fertilizer may be one potential way to reduce displacement and increase the effectiveness and equity of these programs. Given that the subsidy programs are funded by taxpayer and donor money, the allocation of subsidized inputs should not be allowed to be politically motivated. This is difficult to achieve in practice as one likely reason for the resurgent popularity of input subsidies in SSA is the political dividends that they pay to the ruling party. Targeting female-headed households and households with smaller landholdings may be another way to reduce crowding out. And in Zambia, conversion to a voucher-based input subsidy system might better incentivize private investment in fertilizer and seed retailing than the current parallel government input distribution system.

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