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What are the effects of input subsidy programs on equilibrium maize prices? Evidence from Malawi and Zambia

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168- What are the effects of input subsidy programs on equilibrium maize prices? Evidence from Malawi and Zambia.

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Abstract

An important hypothesized benefit of large-scale input subsidy programs in Africa is that by raising maize production, the subsidies should put downward pressure on retail maize prices to the benefit of urban consumers and the rural poor who tend to be net food buyers. To inform debates related to this rationale for input subsidies, this study estimates the effects of fertilizer subsidies on retail maize prices in Malawi and Zambia using market or district-level panel data covering the 2000/01 to 2011/12 maize marketing years. Results indicate that roughly doubling the size of Malawi's subsidy program (i.e., increasing the amount of subsidized fertilizer distributed to each district by 4,000 metric tons per year) reduces maize prices by 1.2% to 1.6% on average. In Zambia, roughly doubling the scale of the country's subsidy program (i.e., increasing the amount of subsidized fertilizer distributed to each district by 1,000 metric tons per year) reduces maize prices by 1.8% to 2.4% on average. The results are robust across countries and model specifications, and indicate that the fertilizer subsidy programs in Malawi and Zambia have had a minimal effect on reducing retail maize prices.

Note: The article currently contains 7,490 words for text from Introduction through Conclusions

Introduction

Millions of smallholder farm households in sub-Saharan Africa (SSA) are net consumers of staple crops, and millions of poor urban households spend a significant share of their income purchasing staple foods. Recent research has underscored the major effects of changes in food prices on poverty, with the weight of the evidence indicating that rising food prices exacerbate poverty and food insecurity (Ivanic and Martin 2008; Ravallion, 1990; Ravallion, 2000). Input subsidy programs, while normally analyzed in terms of their direct impact on recipient households, may also have powerful general equilibrium effects by reducing the price of food. Therefore, the ability of input subsidy programs to lower food prices could have major impacts on the well-being of millions of households in SSA. Understanding these impacts using household survey data is problematic not least because of the difficulty in identifying the counterfactual, since potential general equilibrium price impacts affect the behavior and welfare of the control group (non-recipients of the subsidy) as well as the direct recipients of the subsidy through the prices of food and non-tradable inputs. As a result, the food price effects from input subsidy programs is a crucial yet still under-examined determinant of their overall benefits, costs, and distributional effects.

Empirical investigation of the potential general equilibrium effects of input subsidy programs is especially important considering the high proportion of government budgets currently being allocated to such programs. For example, between 2005/06 and 2008/09, Malawi spent an average of 9.8% of its annual national budget on fertilizer and seed subsidies. These expenditures ranged from a low of 5.6% of the national budget in 2005/06 to a high of 16.2% in 2008/09 (Dorward & Chirwa, 2011). In Zambia, input subsidies averaged 30% of total government agricultural sector spending per year between 2004 and 2011 (Government of the Republic of Zambia, various years). In 2010 and 2011, spending on these subsidies was equivalent to nearly 1% of Zambia's gross domestic product (IMF, 2012). Due to the high costs of input subsidies, knowing how these programs affect maize prices can help policy makers fully understand the potential benefits in order to weigh them against program costs.

The objective of this study is to estimate the effects of fertilizer subsidies on domestic retail maize prices based on the cases of two countries with large-scale and well-known input subsidy programs: Malawi and Zambia. To our knowledge, the present article is the first to quantify the effects of fertilizer subsidies on food prices in SSA. Malawi and Zambia are ideal case studies to measure the impacts of fertilizer subsidies on maize prices. Both countries have large input subsidy programs, where the quantities distributed vary spatially and over time. Also, the scale of the subsidy programs was large enough in both countries to have substantially affected national maize production, and hence have potentially discernible effects on domestic food prices.

Malawi scaled up its fertilizer subsidy program in 2005/06 to wide acclaim from many and criticism from others (Dugger, 2007; Sachs, 2012). National statistics in Malawi indicate that maize production has increased markedly since the country devoted more resources to subsidizing fertilizer. However, maize prices have risen at the same time that production has increased. While this is a bivariate relationship only, it goes against what we might expect (see figure 1). A number of explanations have been given for rising maize prices in the face of increased production, including i) increased maize exports by the Malawian government and purchases for the strategic grain reserve; ii) rising real household income; iii) increased storage losses as a result of increasing production of hybrid maize; iv) changes in informal cross-border trade flows; and v) over-estimates of national maize production following the implementation of the subsidy program (Dorward et al. 2010). While these explanations may be plausible, empirical analysis of how the subsidy programs affect maize prices that provides a counterfactual is the only way to address the apparent higher maize production-higher maize price paradox in Malawi.

In Zambia, large-scale fertilizer subsidies were reintroduced in 2002/03 and have been implemented in every subsequent year to date. The volume of subsidized inputs and the numbers of beneficiaries have increased dramatically over time. For example, while the program aimed to distribute 48,000 MT of fertilizer to 120,000 farmers in its first year, by 2012/13 the scale of the program had increased to 180,000 MT of fertilizer to 900,000 farmers (MAL, 2012). As the program has grown over time, so has national maize production, and Zambia recorded three consecutive bumper harvests in the 2009/10 to 2011/12 agricultural years. However, during the same period, weather patterns were unusually favorable and the government ramped up its maize purchases at above-market prices through the Food Reserve Agency (FRA). Thus fertilizer subsidies were not the only factor driving increased maize production in the country (Burke et al., 2010; Mason et al., 2011; Mason et al., 2012). Despite the market price-raising effects of FRA activities (Mason and Myers, 2013), real retail maize prices trended significantly downward in four of Zambia's nine provincial capitals between the 2003/04 and 2011/12 maize marketing years.[1] Our study seeks to determine if the quantity of fertilizer distributed through the subsidy program was a significant factor contributing to these declines in real retail maize prices.

The main contribution of this paper is a consistent estimate of the potential general equilibrium effects of input subsidy programs, both in terms of providing estimates in two important countries in Africa and in terms of developing a sound analytical approach for empirically estimating such effects. We use two estimators to model factors affecting maize prices: (i) the first difference (FD) estimator, which removes time-constant, unobserved heterogeneity from the model; and (ii) the Arellano-Bond (AB) estimator, which controls for unobserved heterogeneity via first differencing *and* enables consistent estimation of a *dynamic* panel data model (i.e., a model including lagged retail maize prices) (Arellano and Bond, 1991). In the AB approach, maize prices lagged at least two periods earlier serve as instruments for lagged first-differenced maize prices.

Results from this study indicate that roughly doubling the size of Malawi's subsidy program (i.e., increasing the amount of subsidized fertilizer distributed to each district by 4,000 metric tons per year) only reduces maize prices by 1.2% to 1.6% on average. In Zambia, roughly doubling the scale of the country's subsidy program (i.e., increasing the amount of subsidized

[1] The maize marketing year in Zambia and Malawi is from May through April. The 2003/04 to 2011/12 marketing years correspond to the 2002/03 to 2010/11 agricultural years. The four provincial capitals with significant downward trends in real retail maize prices are Kabwe, Chipata, Lusaka, and Mongu. Price trends are not statistically different from zero in the other provincial capitals (p>0.10).

fertilizer distributed to each district by 1,000 metric tons per year) only reduces maize prices by 1.8% to 2.4% on average. These results are marginally statistically significant but economically small in magnitude, indicating that the fertilizer subsidy programs in Malawi and Zambia exert minimal downward pressure on retail maize prices in those countries

Data

Malawi

Data from Malawi used in this study come from a variety of sources. Maize grain, and rice prices come from 72 markets located in Malawi's 26 districts. The prices are collected weekly over the years of our study by the Malawi Ministry of Agriculture and Food Security. The Consumer Price Index of retail prices comes from Malawi's National Statistical Office. Information on district-level subsidized fertilizer distribution comes from the Logistics Unit annual reports. Rainfall data are from the Malawian meteorological service's district-level experiment station records. Maize prices from Zambia's Chipata district on the Malawi-Zambia border come from the Zambian Central Statistical Office.

Zambia

The Zambia data come from a number of sources. District-level retail maize grain, bread, rice, and diesel prices are from the Central Statistical Office's Consumer Price Index retail prices database. These monthly data are consistently available throughout the period of analysis (May 2000-April 2012) for 50 of Zambia's 72 districts. District-level subsidized fertilizer allocations are from the Ministry of Agriculture and Cooperatives (MACO, various years). The rainfall data are from the Zambia Meteorological Department and are district-level estimates based on data collected from 36 rainfall stations throughout the country. District-level FRA maize purchases are from the FRA. Maize prices from Malawi's Mchinji district on the Zambia-Malawi border come from the Malawian Ministry of Agriculture and Food Security.

Background

Input subsidies and maize prices in Malawi

Input subsidies have existed in the Republic of Malawi for decades. However, the modern wave of targeted input subsidies began with the Starter Pack program in 1998, which was in place in 1998/99 and 1999/00. Officially, 2.8 million households were reached each year under the Starter Pack, and beneficiary farmers were supposed to receive 10-15 kilograms of free fertilizer and 2 kilograms of hybrid seed (Harrigan, 2008). The Starter Pack program was rebranded as the Targeted Inputs Program (TIP) in 2000/01, and it ran through the 2004/05 season. Under the TIP, the Malawian government distributed between 15,000 metric tons and 54,000 metric tons of fertilizer, and targeted 1-2 million households per season depending on the year (see table 1, column B). Each recipient household was supposed to receive 10 kilograms of fertilizer for free, and between 2 and 4 kilograms of hybrid or open pollinated seed varieties (OPV) for free.

Unfortunately there was a severe drought during the 2004/05 growing season, resulting in a poor harvest. In response, the Malawian government decided to re-package and scale up its targeted fertilizer subsidy program under the name of the Agricultural Input Subsidy Program (AISP). The amount of subsidized fertilizer distributed to farmers increased from 54,000 metric tons in 2004/05 under TIP to 131,388 metric tons in 2005/06 under AISP. In addition, the official amount of subsidized fertilizer distributed increased to 100 kilograms per household on average per year (table 1, column B).

The AISP program continued to be scaled up every year until the 2007/08 season, when more than 216,000 metric tons of subsidized fertilizer were distributed to households. In 2008/09 the AISP was renamed the Farm Input Support Program (FISP), and was scaled down to 202,000 metric tons due to high fertilizer costs. From 2008/09 to present, the quantity of subsidized fertilizer distributed to smallholders in Malawi has remained around 160,000 metric tons per year (table 1, column B).

Official statistics from Malawi report that maize production has increased substantially in the years of the AISP and the FISP, averaging between 2.6 million and 3.7 million metric tons per year (see figure 1). Conversely and curiously as mentioned in the introduction, maize prices have also increased in Malawi during that time (figure 2). The fact that maize prices increased at the same time that production increased may mean that actual production has been below national estimates and/or that Malawi is more spatially integrated with the region than is commonly believed. Spatial market integration studies for maize in Malawi, Mozambique, and Zambia (Goletti and Babu, 1994; Chirwa, 1999; Tostau and Brorsen, 2005; Loy and Wichern, 2000; Awudu, 2007; Myers, 2008; Burke 2012; Myers and Jayne 2012) and for the wider region (Rashid, 2004; van Campenhout, 2008) are broadly consistent in their conclusions: maize markets are reasonably well integrated, are becoming more efficient over time, and marketing costs are declining. Monitoring of cross-border trade in the region by the Famine Early Warning Systems Network (FEWSNET) indicates that Malawi has imported maize from Mozambique and often from other countries in almost every month since the monitoring started in 2004 (Jayne et al 2010). However, some markets in Malawi continue to be poorly integrated mainly due to high transport costs and government activities in the maize market. For example, the Malawian government arranged for export of 400,000 MT of maize to Zimbabwe after anticipating a bumper harvest in 2007; maize prices shot up within several months of government attempts to source this quantity on domestic markets. Controlling for this and other policy shocks is one of the important modeling and estimation challenges to derive accurate estimates for the impact of the subsidy program on maize prices.

Input subsidies and maize prices in Zambia

The Government of the Republic of Zambia (GRZ) has subsidized agricultural inputs in most years since independence. The universal subsidies that were prominent prior to structural adjustment were eliminated in 1991 but GRZ never fully abandoned input subsidies (Jayne and Jones, 1997; Govereh et al., 2008). Throughout the early-to-mid 1990s, GRZ experimented with several approaches to building private sector capacity and promoting private sector participation in the fertilizer value chain. Then, in 1997/98, GRZ established the Fertilizer Credit Program, which was administered through the Food Reserve Agency (FRA) (MACO et al., 2002).

Under the Fertilizer Credit Program, which ran through the 2001/02 agricultural season, participating farmers could obtain 200 to 800 kg of fertilizer on credit, with approximately 10% of the market cost of the fertilizer due upon receipt and the remaining 90% due in cash or in kind at harvest. The fertilizer was not subsidized *per se* (as farmers were to pay the full market price) but loan repayment rates were dismally low, so defaulting farmers received the fertilizer at an effective 90% subsidy (ibid). An average of 29,000 MT of fertilizer per year were distributed through the Fertilizer Credit Program during the three years of the program that fall into our study period (1999/2000-2001/02 agricultural years) (Table 3, col. B). Of this total, over two thirds of the fertilizer went to Central, Eastern, and Southern Provinces – the major maizeproducing areas in the country (Table 4). Most of the remaining fertilizer was allocated to Copperbelt, Lusaka, and Northern Provinces.

In response to the low loan repayment rates under the Fertilizer Credit Program and severe droughts during the 2000/01 and 2001/02 agricultural years, GRZ moved to a cash-only (no credit) input subsidy program with the establishment of the Fertilizer Support Program in 2002/03. Under the program, selected beneficiary farmers paid 50% of the full cost of the inputs in cash. (The subsidy rate has increased over time – see Table 3, col. A.) A standard input pack consisted of 400 kg of fertilizer and 20 kg of hybrid maize seed to be used to plant one hectare of maize. The Fertilizer Support Program ran through the 2008/09 agricultural year and an average of 60,000 MT of fertilizer were distributed through the program each year – roughly double the average volumes distributed through the Fertilizer Credit Program (Table 3, col. B). In addition to the volumes being larger, the provincial shares of total subsidized fertilizer were also more even under the Fertilizer Support Program than under its predecessor program. Whereas Central, Eastern, and Southern accounted for an average of 68% of the total subsidized fertilizer under the Fertilizer Credit Program, that share dropped to 53% under the Fertilizer Support Program. Northern Province registered the greatest increase in subsidized fertilizer receipts, while Southern Province saw the largest drop in its share (Table 4).

The Fertilizer Support Program was renamed the Farmer Input Support Program in 2009/10 and that program has continued to run to the present day. Under the Farmer Input Support Program, the input pack size was halved to 200 kg of fertilizer and 10 kg of hybrid maize seed, in principle doubling the number of beneficiary farmers per MT of inputs. Fertilizer subsidy rates have generally been higher and the volumes of subsidized inputs distributed have been substantially larger under the Farmer Input Support Program than under the two previous subsidy programs (Table 3). Provincial shares of the total inputs, however, have not changed substantially under the new program (Table 4).

Increases over time in the volumes of fertilizer distributed through Zambia's input subsidy programs have generally coincided with increases in smallholder maize production and sales (Table 3, cols. D and E; Figure 3). However, the size of the population and the volumes of maize purchased at typically above-market prices by the parastatal FRA have also increased over time (Table 3, col. F).[2] Moreover, Zambia was blessed with unusually favorable weather conditions for maize production in the 2009/10 through 2011/12 growing seasons (Burke et al., 2010; Mason et al., 2011). Subsidized fertilizer is therefore just one of several factors contributing to the rise in maize production in Zambia over the last decade. Holding FRA purchases, rainfall, and other factors constant, Mason et al. (2012) find statistically significant, small positive impacts of subsidized fertilizer on maize output and yields in Zambia.

Consistent with rising maize production and sales, real retail maize prices in Zambia have declined over the last decade (Figure 4). In addition to input subsidies for maize and maize purchases by the FRA, the Zambian government used several other maize marketing and price policy tools during the period of analysis. These include: (i) sales of FRA maize on the domestic market, often at subsidized prices to select large-scale millers; (ii) exports of FRA maize to other countries in eastern and southern Africa, often at prices below the FRA purchase price; (iii) government-arranged maize imports in deficit production years and subsequent sales to select large-scale millers at subsidized prices; (iv) explicit maize export bans or implicit export bans through restrictions on the numbers of export licenses granted; (v) tariffs on maize imports; and

[2] FRA began purchasing maize from farmers at a pan-territorial price in the 2002/03 marketing year but private maize trade remains legal and private sector maize prices are not regulated. See Mason and Myers (2013) for details.

(vi) levies on inter-district maize trade, which were in place between 2002 and 2009. See Govereh et al. (2008), Nkonde et al. (2011), and Chapoto (2012) for further details on maize marketing and price policies in Zambia.

Conceptual Framework

Conceptually, large-scale fertilizer subsidy programs, such as those in Malawi and Zambia, may have direct and/or indirect effects on households. For example, recipient households directly benefit from the subsidies because they acquire fertilizer at a reduced price, and in turn may use more fertilizer and produce more maize. Furthermore, by increasing maize production, input subsidies may generate the indirect effect of lower maize prices. Lower maize prices would affect all households that participate in maize markets as buyers and/or sellers but would be particularly beneficial to the rural and urban poor who are net-buyers of maize. At the same time, lower maize prices would negatively affect net-sellers of maize, including larger, better-off farmers.

Several factors influence the extent to which fertilizer subsidy programs affect retail maize prices. The first is the degree to which fertilizer subsidies increase maize production. Increases in maize production depend in part on how much new fertilizer the subsidy program adds to total fertilizer use in the country, which in turn depends on how much commercial fertilizer gets crowded out by the subsidy. The empirical evidence from Malawi suggests that on average, 100 additional kilograms of subsidized fertilizer add 78 new kilograms to total fertilizer use, as 22 kilograms of commercial fertilizer are displaced by the subsidy (Ricker-Gilbert, et al., 2011). When this number is adjusted for leakages based on a 33% leakage estimate in Holden and Lunduka (2013) and the approach developed by Mason and Jayne (forthcoming), 100 kilograms of subsidized fertilizer only adds 45 kilograms of new fertilizer to farmers' fields. In Zambia, Mason and Jayne (forthcoming) find that 100 kilograms of subsidized fertilizer increases total fertilizer use by 54 kilograms after accounting for leakage.

In addition to crowding out, the extent to which subsidized fertilizer raises maize production also depends on the management ability of subsidy recipients, soil quality, and rainfall, among other factors. The existing literature generally suggests that subsidized fertilizer has positive but small impacts on maize production and crop income in Malawi and Zambia (Holden and Lunduka, 2010; Ricker-Gilbert and Jayne, 2011; Shively et al., 2012; Mason et al., forthcoming).

A second factor influencing the effect of fertilizer subsidies on retail maize prices is vertical price transmission, or the extent to which changes in farm-level maize prices translate into changes in retail maize prices. Therefore, marketing margins will affect the spread between farm and retail maize prices. Evidence suggests that marketing margins in SSA are often a function of transport costs, interest rates, and transactions costs.

A third factor mediating the effects of input subsidies on maize prices is the degree of integration between domestic markets and international markets. If Malawi and Zambia were perfectly integrated into the world market, then an increase in maize production from the subsidy would have no effect (or only a very small, short-lived effect) on maize prices in those countries because both are small economies. Conversely, if both countries were completely closed off from the world market then a boost in maize production from the subsidy program would be expected to lower domestic maize prices.

The central research question of this article is whether or not, and to what extent, an increase in the quantity of subsidized fertilizer allocated to a district in Malawi and/or Zambia affects retail maize prices in that district. In order to effectively answer this question and guide our empirical model specification, we first present an economic model of the potential pathways through which subsidized fertilizer affects maize prices. From there we explain the empirical model and estimation strategy used to obtain consistent estimates of the subsidy programs' average partial effects on maize prices in Malawi and Zambia.

The first component of the economic model is an output supply function for maize in the presence of an input subsidy program.

$$Q^s = Q^S(p^{f*}, FISP \quad, \boldsymbol{z^s} \ ) \tag{1}$$

where Q^s is maize quantity produced, p^{f*} is the expected producer price of maize, $FISP$ is the quantity of subsidized fertilizer, and $\boldsymbol{z^s}$ is a vector of other supply shifters.

In addition to being influenced by maize supply, equilibrium maize prices are also affected by maize demand. Since we are modeling the effects of fertilizer subsidies on *retail* maize prices, we consider a retail consumer demand function for maize:

$$Q^d = Q^d(p^r, \boldsymbol{z^d} \ ) \tag{2}$$

where Q^d is maize quantity demanded, p^r is the retail price of maize, and $\boldsymbol{z^d}$ is a vector of other demand shifters.

The equilibrium retail maize price is a function of the realized producer price (p^f) and the marketing price margin ($M(\boldsymbol{z^m})$):

$$p^r = p^f + M(\boldsymbol{z^m}) \tag{3}$$

The variables that might affect the price margin are represented by $\boldsymbol{z^m}$**.** From there we use the market clearing condition:

$$Q_t^d = Q_t^s \tag{4}$$

and then plug (1), (2) and (3) into (4). Solving for p^r as a function of the exogenous variables and noting that the realized producer price (p_{it}^f) is a function of realized maize production level gives:

$$p^r = p^r(p^{f*}, FISP \quad , \boldsymbol{z^s}, \boldsymbol{z^d}, \boldsymbol{z^m}) \tag{5}$$

Equation (5) is our reduced form model of the retail maize price as a function of subsidized fertilizer and other factors.

Empirical model

The empirical form of our economic model of factors affecting retail maize prices (equation 5) is:

$$p_{i,t}^r = \Psi + \alpha \quad FISP_{i,t} \; + \sum_{j=0}^{J} \Upsilon_j \, p_{i,t-j}^r + \mathbf{X_{i,t}\beta} + \mathbf{Z_t\theta} + \mathrm{c_i} + \mu_{i,t} \tag{6}$$

where *i* indexes 72 markets in Malawi's 26 districts, and 50 districts in Zambia.[3,4] In addition, *t* indexes the time period. We include retail maize prices during two time periods in each maize marketing year: i) the mean maize price during the harvest season (May-October) when maize stocks are high; and ii) the mean maize price during the hungry (lean) season (November-April) when maize stocks dwindle. We match up the marketing year/season maize price observations with variables affecting maize production in the corresponding agricultural year (October-September). For example, maize prices in the 2010/11 marketing year (May 2010-April 2011)

[3] We were able to obtain sub-district market prices for maize and rice in Malawi. In Zambia prices are only available at the district level. Therefore, the Malawi unit of analysis is more disaggregated than it is in Zambia. However we feel it is worth keeping the analysis at market-level in Malawi, rather than aggregating prices up to the district-level. Doing the analysis at market-level takes full advantage of the intra-district variation in the price data.
[4] There were 72 districts in Zambia during the period of analysis but retail maize prices were consistently collected by the Central Statistical Office in only 50 of the 72 districts.

should be affected by maize production (and factors affecting it) in the 2009/10 agricultural year (October 2009-September 2010).

The retail maize price is denoted by $p^r_{i,t}$. Up to *J* lags of the dependent variable are included in the model, and the associated parameters are the Υ_j's. The retail maize prices are in local currency units (LCU) per kg. LCUs are Malawian Kwacha (MWK) and Zambian Kwacha (ZMK). The key explanatory variables of interest are the quantities of subsidized fertilizer, in metric tons, allocated to a given district ($FISP_{i,t}$). The corresponding parameter is α.

The coefficient estimate, $\hat{\alpha}$, gives the short-run effect of an additional metric ton of subsidized fertilizer on the retail maize price. Additionally, $\frac{\hat{\alpha}}{1-\sum_{j=1}^{J}\hat{\gamma}_j}$ is the estimate of the long run effect of an additional metric ton of subsidized fertilizer on the retail maize price (Chow, 1975). The short-run and long-run effects allow us to answer the key testable hypotheses and research questions of this article: how and to what extent does an additional metric ton of subsidized fertilizer distributed to a district in Malawi and Zambia affect retail maize prices in that market or district.

A set of district-level control variables that are thought to affect maize prices are represented by the vector **X**. The supply shift factors in **X**, represented by $\boldsymbol{z}^s$ in equations (1) and (5), include rainfall during the growing season (November – March) in millimeters, and rainfall stress, measured as the number of 20-day periods during the growing season with less than 40 millimeters total rainfall. For Zambia, we also include district-level FRA maize purchases in metric tons.[5, 6] The demand shift factors in **X**, represented by $\boldsymbol{z^d}$ in equations (2) and (5), include the retail price of rice in LCU per kilogram in both the Malawi and Zambia models, and the retail price of bread in ZMK per loaf in the Zambia model. Also included in **X** is a set of district-level dummy variables. The district-level dummy variables serve as a district fixed effects and capture unobserved district-level factors, such as road access, and the level of spatial market integration in a given district, which can impact maize prices. The vector of corresponding parameters is represented by **β**.

The vector of national-level factors that affect maize prices are represented by **Z**. The marketing margin variables, represented by $\boldsymbol{z^m}$ in equations (3) and (5), include national commercial lending interest rates and petrol prices in LCU per liter. (For Zambia, district-level diesel prices are used instead of national-level petrol prices, and the model also includes national-level electricity prices in ZMK/kilowatt hour.). We also include prices in international markets, which could affect domestic prices through formal and informal trade. The inclusion of these external prices should also help to control for the level of spatial market integration and price transmission. The external prices included in the model are first, Zambian border prices (Chipata retail) in the Malawi model, and Malawian border prices (Mchinji retail) in the Zambia

[5] Comprehensive data on FRA *sales* are not available for the full period of analysis are so are excluded from the model. ADMARC purchase and sales data are only available at the national level in Malawi so are not included in the Malawi model. This should be of little consequence since table 1 shows that ADMARC maize purchases in Malawi were minimal relative to production during the years of our analysis. Therefore, ADMARC activities should have little to no effect on maize prices in Malawi.

[6] Readers may be concerned about high correlation between district-level FRA purchases and subsidized fertilizer receipt in Zambia, which would result in multicollinearity and increase the standard errors of both coefficient estimates. However, the correlation coefficient between the two variables is just 0.52. Therefore, although there is some correlation, it is not high enough to raise serious concerns about multicollinearity. Moreover, the coefficient estimates are still unbiased and consistent in the presence of multicollinearity; only the standard errors are affected.

model. Second, we include lagged maize spot prices on the South African Futures Exchange (SAFEX) in the models for both Malawi and Zambia. (See Appendices A and B for summary statistics for the Malawi and Zambia models, respectively.) Moreover, both models include maize marketing year dummies, a hungry/lean season dummy (=1 if November-April and 0 otherwise), time period dummies, and a linear time trend. These variables should control for other national- and international level factors and policies affecting retail maize prices in Malawi and Zambia. These include many of the maize marketing and price policies discussed in the background section, such as changes over time in import tariffs, export bans, levies on inter-district maize trade, maize marketing board pan-territorial prices, the Malawian government's decision to source 400,000 MT of maize for export to Zimbabwe in 2007, etc. The parameter vector for **Z** is represented by **θ**.

The error term in equation (6) has two components: c_i represents time constant unobserved heterogeneity, while $\mu_{i,t}$ represents the unobserved time-varying shocks that affect maize prices. We give thorough treatment to potential correlation between the errors and the observable covariates in the following section.

Estimation Strategy

In order to obtain consistent and efficient estimates of the factors affecting maize prices, there are several estimation challenges that we must address. The first is dealing with correlation between the observed covariates and the unobserved time-constant heterogeneity, c_i. In order to do so we convert equation (6) into first difference (FD) form as follows:

$$\Delta p^r_{i,t} = \Psi + \alpha \ \ \Delta FISP_{i,t} \ + \ \sum_{j=0}^{J} \Upsilon_j \Delta p^r_{i,t-j} + \mathbf{\Delta X_{i,t}\beta} + \mathbf{\Delta Z_t\theta} + \Delta\mu_{i,t} \qquad (7)$$

where Δ represents the change in the variables of interest between one time period and the next. First-differencing removes the c_i from the model. However, we face an additional modeling challenge because in FD form $\Delta\mu_{i,t}$ is correlated with $\Delta p^r_{i,t-1}$, since $\Delta p^r_{i,t-1}$ depends on $\mu_{i,t-1}$. Fortunately, if $\Delta\mu_{i,t}$ is uncorrelated with $\Delta p^r_{i,t-j}$ for j ≥ 2, then we can use lagged values of $p^r_{i,t-j}$ where j≥2 to instrument for $\Delta p^r_{i,t-j}$. The resulting framework is known as the Arellano-Bond estimator following Arellano and Bond (1991).

The AB framework allows us to designate variables as strictly exogenous (e.g., rainfall levels and stress), predetermined but weakly endogenous (e.g., subsidized fertilizer, FISP), or contemporaneously endogenous (e.g., border prices, rice/bread prices, and FRA purchases). The AB framework then uses lagged levels and/or differences as instruments for the contemporaneously endogenous and predetermined/weakly endogenous variables in order to consistently estimate the model parameters. In the AB framework, we treat subsidized fertilizer (FISP) as a pre-determined variable because FISP levels are determined before maize prices in the subsequent maize marketing year are realized. However, FISP may violate strict exogeneity if there is feedback from current retail maize prices to future levels of subsidized fertilizer. For example, if retail maize prices are high in a given season, the government may decide to increase FISP levels in the next season in an attempt to reduce maize prices. The AB framework allows us to correct for the potential endogeneity of FISP and other variables in the model. We estimate two sets of models: one via FD but excluding the lagged dependent variables (LDVs), and one via AB including the LDVs. Standard errors in both the FD and AB models are made robust to heteroskedasticity, and the FD standard errors are also made robust to serial correlation.

Serial correlation

While serial correlation only affects the *efficiency* of the FD estimates, the AB estimates are *inconsistent* in the presence of serial correlation. Therefore, eliminating serial correlation is of critical importance in the AB models. In the AB models we therefore add lags of the retail maize price until the serial correlation (in the first-differenced errors) is eliminated.[7] Test results indicate that serial correlation is eliminated once we include three lags of the retail maize price in the Malawi model, and eight lags in the Zambia model (see Appendices C and D).

Functional form

The maize price variable in our model is in log form, while the key explanatory variable of interest (FISP) is in levels.[8] Therefore, the coefficient $\hat{\gamma}$ should be interpreted as a semi-elasticity (or in this case a semi-flexibility). The other price variables are in log form, so the coefficients can be interpreted directly as flexibilities. In our main models, all prices are converted to real terms by dividing by the CPI in the respective countries. We also run robustness checks where the models are estimated using nominal prices, and/or in level-level form.

Results

Table 5 presents the results for factors affecting real retail maize prices in Malawi. The four columns in table 5 present different versions of the model. Columns A) and C) present the "sparse" model specification, where maize prices are a function of subsidized fertilizer receipt and rainfall along with district fixed effects, time and season fixed effects, a linear time trend,

[7] The AB first-differenced errors are serially correlated by construction at lag order 1 but are serially-uncorrelated at higher lags. See Appendices C and D.
[8] Subsidized fertilizer is equal to zero in some districts in some years, so it is not possible to transform the variable into logs.

and a constant. Columns B) and D) present the "fully specified" model. In addition to the variables in the "sparse" model, the "fully specified" model also includes rice prices, maize prices at the Zambian border, and lagged maize prices on SAFEX. Columns A) and C) are estimated via FD, while columns B) and D) are estimated via AB.

The coefficient on the subsidized fertilizer variable clearly indicates that, across the four models, subsidized fertilizer has a marginally statistically significant and small negative effect on market-level retail maize prices in Malawi. The coefficients in columns A), B) and D) indicate that an additional 1,000 metric tons of subsidized fertilizer delivered to a district in Malawi reduces retail maize prices by just 0.3% on average in the markets in that district. In column C) the same increase in subsidized fertilizer reduces the maize price by 0.4%, which is still economically small. Between 1999/00 and 2010/11 agricultural years the average district in Malawi received 4,373 metric tons of fertilizer per year (appendix A). Therefore, if Malawi decided to roughly double the size of its input subsidy program by increasing the amount of subsidized fertilizer distributed to each district by 4,000 metric tons per year, it would only reduce the price of maize by 1.2% to 1.6% on average, *ceteris paribus*.

The bottom of columns B) and D) show the long run (three period) impact flexibility of subsidized fertilizer on maize prices. The long run effect is statistically insignificant ($p>0.10$) and economically small in magnitude similar to the current year effect of subsidized fertilizer.

The other coefficients in table 5 generally have the expected signs, although their statistical significance varies by model specification. Cumulative rainfall over the growing season has a negative effect on maize prices, while increased rainfall stress has a positive effect on maize prices. The lean season dummy variable has a statistically significant and positive sign in all models except for the sparse model estimated via FD in column A), which is the most basic and likely least robust of our four specifications. Higher rice prices lead to higher maize prices, indicating that the commodities are complements, as we would expect. Moreover, higher prices on the Zambian border lead to significantly higher prices in Malawi. Recall that the border prices are treated as contemporaneously endogenous, and endogeneity is dealt with by using lagged prices as instruments for current prices with the AB estimator. The finding of higher prices on the Zambian border driving higher prices in Malawi indicates some degree of spatial price transmission and market integration between the two countries.

Table 6 presents the results for factors affecting maize prices in Zambia. Table 6 presents the results in the same way that table 5 does for the Malawi models, except the Zambian model includes eight lags of retail maize prices to remove serial correlation. In addition, the "fully specified" Zambian model has FRA prices, bread prices, and diesel prices as additional controls. Several variables (the log retail electricity price, the log real commercial lending rate, and the lagged log real SAFEX price) drop out of the fully specified models due to perfect collinearity.

In Zambia, an additional 1,000 metric tons of subsidized fertilizer delivered to each district reduces maize prices in that district by 1.8% to 2.4% on average (table 6, columns A through C); however, subsidized fertilizer has no statistically significant effect on retail maize prices in the fully-specified AB model (column D). The subsidy program in Zambia is a bit smaller than in Malawi, and the average amount of subsidized fertilizer distributed in each district between the 1999/00 and 2011/12 production years was 1,108 metric tons (Appendix B). Therefore, the coefficient estimates from table 6 indicate that if Zambia's fertilizer subsidy program were to increase by 1,000 metric tons in each district per year (roughly doubling the size of the program), then maize prices would only decrease between 1.8% and 2.4% on average, other factors constant.

The long run (eight period) impact flexibility indicates that subsidized fertilizer has a negative and small effect on maize prices. The long-run effect is statistically significant at the 1% level in the sparse AB model and indicates that a 1,000 metric ton increase in subsidized fertilizer distributed to a district reduces the retail maize price by 2.8% on average.

Table 6 shows that higher rainfall in a district leads to higher maize prices in that district, but the effect is only statistically significant in the FD specifications. Higher rainfall stress also leads to statistically significantly higher maize prices in the FD specification, which is what we would expect. The lean season dummy is positive and statistically significant in all models, as expected *a priori*. Increases in FRA purchases are found to have a negative effect on maize prices. This finding may seem counterintuitive but could be explained by the fact that heavy FRA purchases are generally associated with large subsidized sales to millers, which put downward pressure on maize market prices.

Table 7 shows robustness checks for the Malawi models, and table 8 presents the same robustness checks for the Zambia models. The three additional specifications in these tables are: 1) level-level form with real prices, 2) log-log form with nominal prices, and 3) level-level form with nominal prices. When the models are estimated in level-level form the results are interpreted as Malawian or Zambian Kwacha changes in the maize price given a change in the quantity of subsidized fertilizer distributed to a district. The degree of statistical significance in tables 7 and 8 varies by functional form specification, but the direction and magnitude of the coefficient is the same. The long-run impact flexibilities of subsidized fertilizer are negative but not statistically significant in any specification for Malawi but the current year impact flexibilities are statistically significant in 7 of the 12 specifications. In Zambia, the long-run impact flexibilities are statistically significant in the sparsely specified AB models regardless of functional form, while the current year effects are statistically significant in 5 of the 12 specifications. The robustness checks (tables 7 and 8) show that subsidized fertilizer has essentially the same effect on maize prices as it does in our base specification (tables 5 and 6) where the model is estimated in real terms in log-log form. Overall, subsidized fertilizer has a negative and statistically significant ($p<0.10$) short-run effect on retail maize prices in 11 of the 16 models estimated for Malawi and in eight of the 16 models estimated for Zambia.

Overall the results from Malawi and Zambia indicate that the maize price effects from the fertilizer subsidy programs in both countries are very small. This finding is consistent with literature showing that input subsidies crowd out commercial fertilizer in Malawi (Ricker-Gilbert et al. 2011) and in Zambia (Xu et al. 2009; Mason and Jayne, forthcoming). It is also supported by the literature showing that inputs subsidies have positive but quite small effects on maize production in both countries. (See Holden and Lunduka (2010), Ricker-Gilbert and Jayne (2011), and Shively et al. (2012) for estimates of program impacts in Malawi; and Mason et al. (forthcoming) for estimates for Zambia.) Our findings are also in line with recent studies demonstrating that markets in the southern Africa region are reasonably well integrated (Myers and Jayne 2011, Burke 2012).

Conclusions

Input subsidy programs are currently gaining substantial attention as a strategy for boosting staple crop production and improving household food security in sub-Saharan Africa (SSA). While emerging literature is beginning to quantify the impacts of input subsidies on maize production, it is sometimes argued that the most important welfare effects of input subsidy programs operate through the price of maize. To the extent that the rural poor tend to be net buyers of maize, government programs that expand the supply of food and exert downward pressure on food prices may have important poverty reducing effects. However, to date there has been little quantitative evidence about how input subsidies affect maize prices. The motivation of this study was to empirically investigate and quantify this important potential general equilibrium effect, based on two sub-Saharan African countries, Malawi and Zambia that have both implemented large-scale input subsidy programs and where it would be plausible to detect such general equilibrium effects.

This study uses market and district-level retail price data, along with data on the quantity of subsidized fertilizer distributed to each district over a 12-year period in both Malawi and Zambia. We control for the effects of other staple food prices, rainfall, marketing board activities, spatial market integration, and factors affecting marketing margins in our econometric models of fertilizer subsidy effects on retail maize prices.

The findings from our article are consistent between Malawi and Zambia. They indicate that fertilizer subsidies have either no statistically significant effect on retail maize prices or, more commonly, a statistically significant but very small negative effect on those prices. The results suggest that roughly doubling the size of Malawi's subsidy program (i.e., increasing the amount of subsidized fertilizer distributed to in each district by 4,000 metric tons per year) only reduces maize prices by 1.2% to 1.6% on average. In Zambia, roughly doubling the scale of the country's subsidy program (i.e., by increasing the amount of subsidized fertilizer distributed to each district by 1,000 metric tons per year) only reduces maize prices by 1.8% and 2.4% on average. These results are in line with the finding that there has been virtually no change in rural poverty rates in either country since these large-scale input subsidy programs were scaled up (see GOM 2012 for Malawi; and Central Statistical Office (CSO) 2009, and 2011 for Zambia).

To our knowledge the results from Malawi and Zambia provide the strongest and most externally valid results to date on how fertilizer subsidy programs influence food price levels. Our findings of no significant or statistically significant but very small negative impacts of input subsidies on retail maize prices are supported by the literature that finds fertilizer subsidies crowd out commercial fertilizer and have a positive but relatively small impact on maize production. The findings are also consistent with the literature showing that maize markets are reasonably well integrated in the region. Ultimately if the fertilizer subsidy programs in both Malawi and Zambia produce modest gains in maize production, and maize markets in both countries are at least partially integrated into international markets, then there is no reason to expect that the subsidy programs would have large impacts on maize prices for more than a relatively short period. Moreover, because food prices in Malawi have been at or near import parity levels for most of the lean season periods over the past 12 years, and the country has been importing maize from neighboring countries almost continuously even since the subsidy program was scaled up in 2005/06 (Myers and Jayne 2012; Jayne et al 2010), it is plausible that any production expansion in Malawi has mainly substituted local production for a reduction in imports without affecting its general import parity position. While increased local production is an important national policy goal, it may not have been large enough to alter the country's import parity pricing position during its lean season period.

Notwithstanding this point, it should be noted that even small decreases in maize prices would benefit the many poor rural and urban households that are net buyers of maize. However, empirical evidence presented here does not support the often-asserted claim that large public expenditures on input subsidies have major poverty reducing effects because the programs produce large spill-over benefits in the form of substantially lower maize prices. The empirical evidence to date suggests that even the large-scale fertilizer subsidy programs in the region may result in very small, if any, reductions in retail food prices in semi-open economies.

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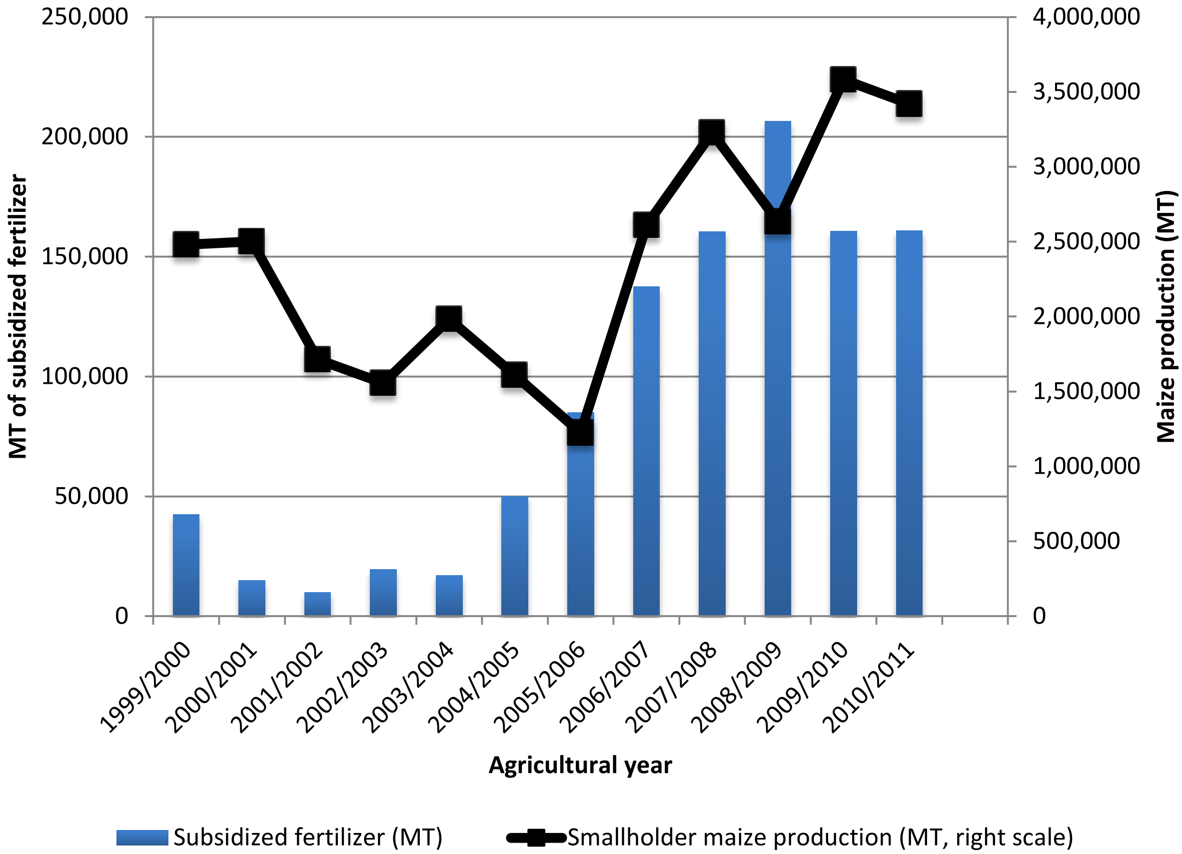
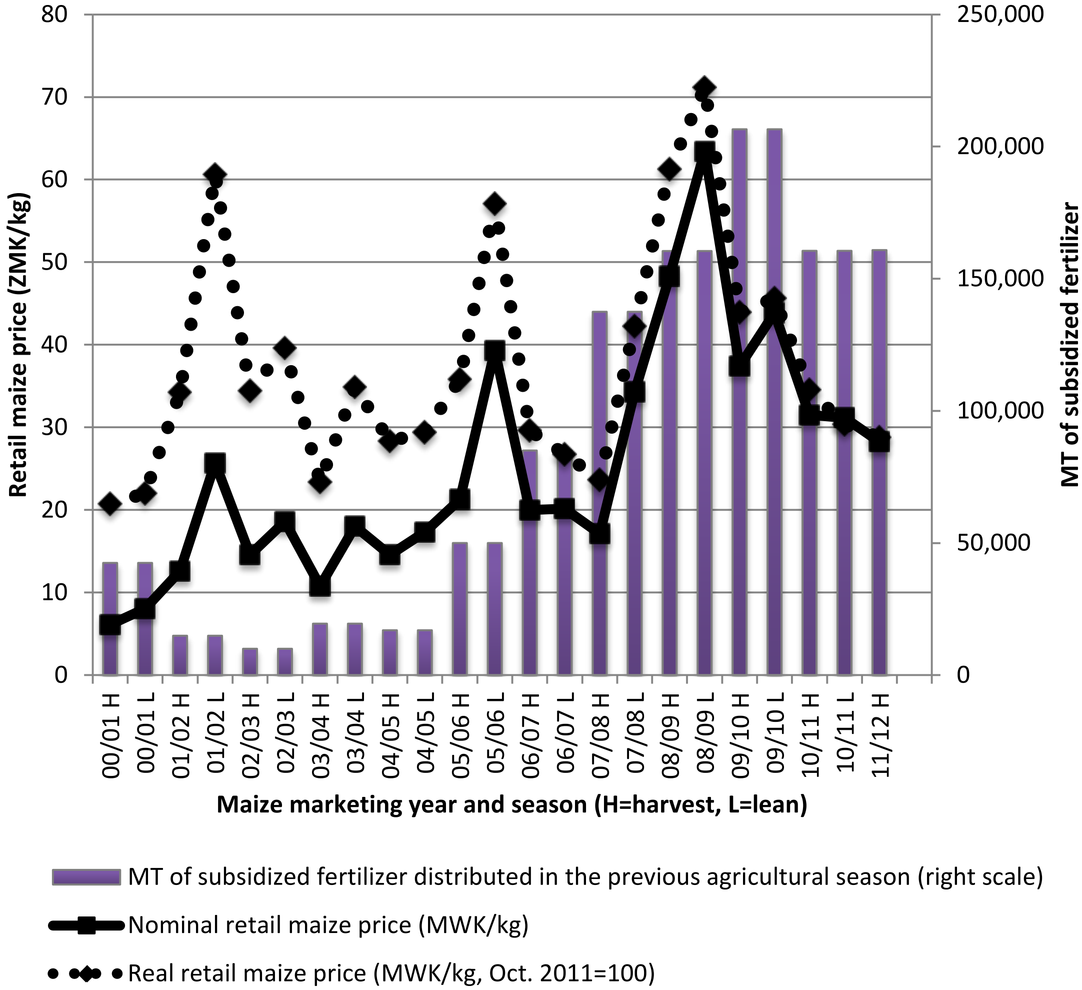
Figure 1: Trends in subsidized fertilizer tonnage and smallholder maize production, 1999/2000 to 2010/11 agricultural years – Malawi



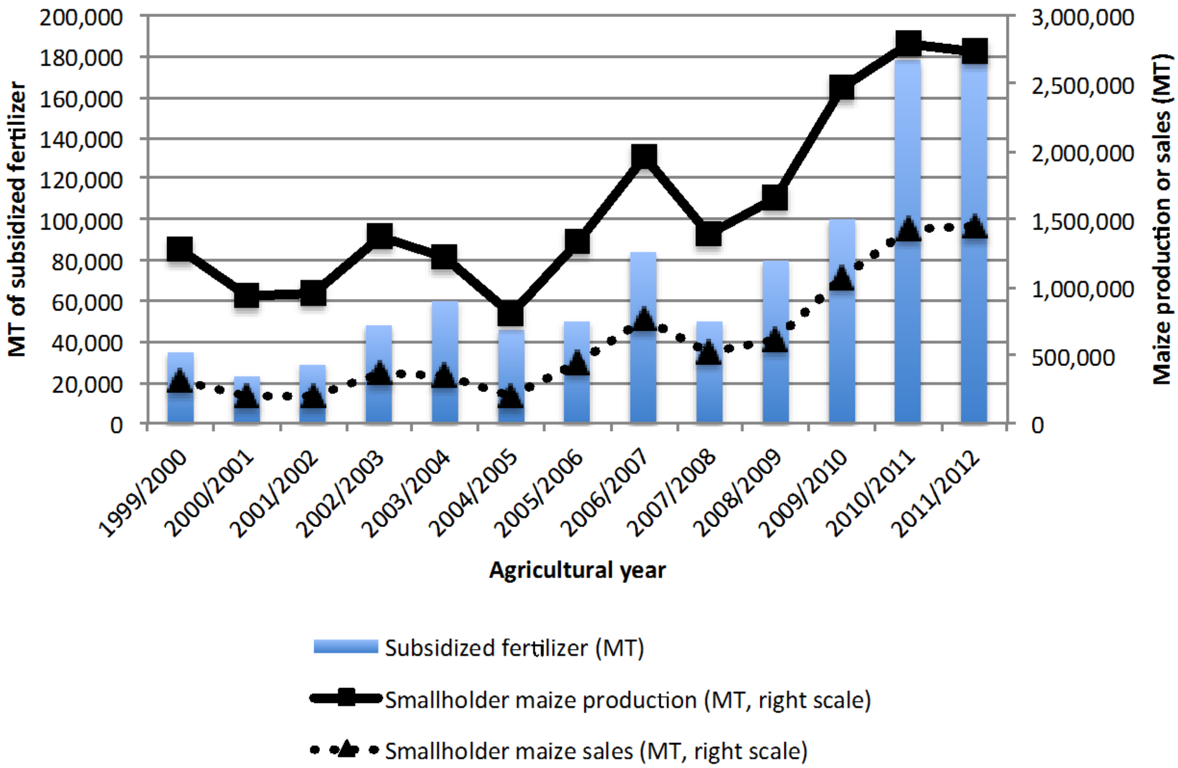
Source: Maize production from FAOSTAT. Subsidized fertilizer quantities are from Logistics Unit Reports for various years.

Figure 2: Subsidized Fertilizer Distribution and Maize Price Trends in Malawi.



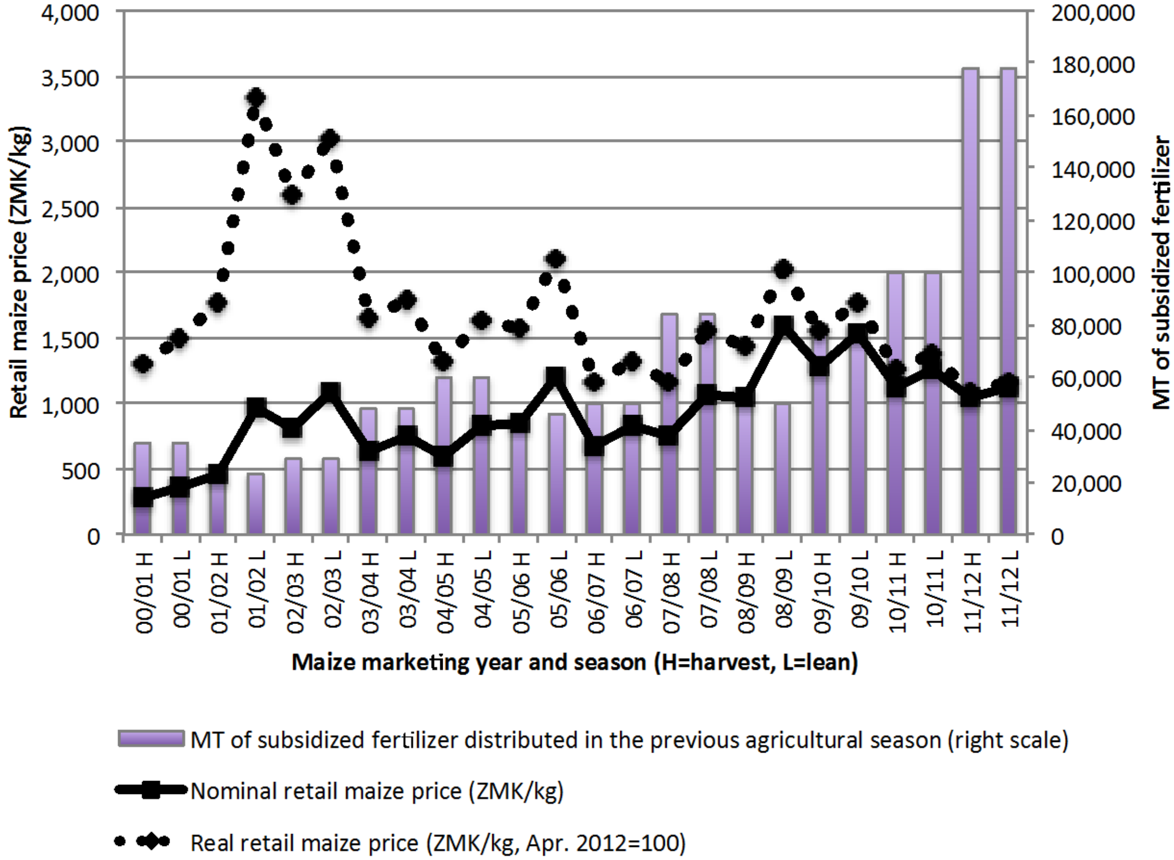
Source: Subsidized fertilizer quantities from the Logistics Unit Reports for various years. Maize prices come from the Malawi Ministry of Agriculture and Food Security.

Figure 3: Trends in subsidized fertilizer tonnage and smallholder maize production and sales, 1999/2000 to 2011/12 agricultural years – Zambia



Source: MAL (2012); CSO/MACO Crop Forecast Survey data (various years); CSO/MACO Post-Harvest Survey data (various years); CSO/MACO/FSRP Supplemental Survey data (various years).

Figure 4: Average harvest season and lean season retail maize prices and total subsidized fertilizer distributed during the period agricultural season, 2000/01 to 2011/12 maize marketing years (1999/2000 to 2010/11 agricultural years) – Zambia



Source: MAL (2012); CSO retail price database.

Note: Prices are seasonal averages across 50 districts in Zambia. Harvest season = May-October; lean season = November-April.

Table 1: Fertilizer subsidy program subsidy rates, volumes, and numbers of intended beneficiaries; total smallholder maize production; and mean harvest season and lean season retail maize prices; 2000/01 to 2012/13 agricultural years – Malawi

Agricultural year	Subsidy Rate	MT of subsidized fertilizer[a]	Intended number of beneficiary households in '000[a]	Total smallholder maize production[b]	ADMARC maize purchases (MT)[c]	Mean retail maize price in year after harvest (real MK/kg, October. 2011=100)[d] Harvest season (May-Oct.)	Lean season (Nov.-Apr.)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1999/00	100	42,478	2,860	2,479,410	198,021	NA	NA
2000/01	100	15000	1,500	2,501,310	0	20.19	26.59
2001/02	100	14,928	1,000	1,713,060	2,890	41.6	84.75
2002/03	100	35,000	2,000	1,556,980	0	48.05	61.34
2003/04	100	22,000	1,700	1,983,440	0	35.58	59.53
2004/05	100	54,000	2,000	1,608,350	7,000	48.03	57.22
2005/06	64	131,388	NA	1,225,230	9,097	70.24	129.76
2006/07	72	174,688	3,000	2,611,490	75,622	65.94	66.51
2007/08	79	216,553	1,500	3,226,420	32,728	56.5	113.23
2008/09	91	202,278	1,500	2,634,700	69,485	159.34	209.26
2009/10	88	161,495	1,600	3,582,500	44,268	123.42	144.77
2010/11	93	160,531	1,600	3,419,410	45,248	104.03	102.78
2011/12	NA	160,834	NA	3,699,150	17,420	NA	NA

Source:

a. Logistics Unit Reports (Various Years)
b. FAO statistics
c. National Statistical Office (2011)
d. Ministry of Agriculture and Food Security

Table 2: Percentage of total subsidized fertilizer allocated to each Region, 1999/2000 to 2011/12 agricultural years – Malawi

Agricultural year	Northern	Central	Southern	Total Quantity (MT)
1999/00	10.7	40.7	48.7	42,478
2000/01	9.6	38.1	52.3	15,000
2001/02	9.6	39.7	50.7	14,928
2002/03	9.6	39.2	51.2	35,000
2003/04	9.6	37.5	52.9	22,000
2004/05	9.6	37.5	53.0	54,000
2005/06	12.0	48.3	39.8	131,388
2006/07	15.6	46.7	37.7	174,688
2007/08	19.4	45.4	35.3	216,553
2008/09	18.9	37.7	43.4	202,278
2009/10	13.5	40.3	46.1	161,495
2010/11	13.7	40.3	46.0	160,531
2011/12	--	--	--	160,834
Average	12.65	41.95	46.43	1,391,173

Source: Logistics Unit Reports (various years).

Table 3: Fertilizer subsidy program subsidy rates, volumes, and numbers of intended beneficiaries; total smallholder maize production and sales; FRA purchases; and mean harvest/lean season retail maize prices; 1999/2000 to 2012/13 agricultural years – Zambia

Agricultural year (marketing year in paren.)	Fertilizer subsidy rate	MT of subsidized fertilizer	Intended number of beneficiary households	Total smallholder maize production (MT)	Total smallholder maize sales in the subsequent marketing year (MT)	FRA maize purchases in the subsequent marketing year (MT)	FRA maize purchases as % of smallholder maize sales	Mean retail maize price in the subsequent marketing year (real ZMK/kg, Apr. 2012=100) Harvest season (May-Oct.)	Lean season (Nov.-Apr.)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)
1999/2000 (2000/01)	Loan	34,999	--	1,282,352	323,387	0	0%	1,302	1,499
2000/01 (2001/02)	Loan	23,227	--	938,539	197,915	0	0%	1,773	3,337
2001/02 (2002/03)	Loan	28,985	--	947,825	195,407	23,535	12.0%	2,595	3,013
2002/03 (2003/04)	50%	48,000	120,000	1,365,455	370,332	54,847	14.8%	1,659	1,779
2003/04 (2004/05)	50%	60,000	150,000	1,216,943	356,750	105,279	29.5%	1,328	1,626
2004/05 (2005/06)	50%	46,000	115,000	800,574	206,092	78,667	38.2%	1,564	2,106
2005/06 (2006/07)	50%	50,000	125,000	1,339,479	454,676	389,510	85.7%	1,154	1,328
2006/07 (2007/08)	60%	84,000	210,000	1,960,692	762,093	396,450	52.0%	1,169	1,558
2007/08 (2008/09)	60%	50,000	125,000	1,392,180	522,033	73,876	14.2%	1,427	2,021
2008/09 (2009/10)	75%	80,000	200,000	1,657,117	613,356	198,630	32.4%	1,548	1,770
2009/10 (2010/11)	75%	100,000	500,000[a]	2,463,523	1,062,010	883,036	83.1%	1,259	1,374
2010/11 (2011/12)	76%	178,000	891,500[a]	2,786,896	1,429,911	1,751,660	122.5%	1,087	1,153
2011/12 (2012/13)	79%	182,454	914,670[a]	2,731,843	1,440,944	1,034,000[c]	71.8%	--	--
2012/13 (2013/14)	--	183,634[b]	900,000[b]	--	--	--	--	--	--

Source: MAL (2012); CSO/MACO Crop Forecast Survey data (various years); CSO/MACO Post-Harvest Survey data (various years); CSO/MACO/FSRP Supplemental Survey data (various years); CSO retail price database; FRA.

Note: -- Information not yet available. [a]Pack size reduced from eight 50 kg bags to four 50 kg bags. [b]Planned distribution and number of intended beneficiaries (2012/2013 agricultural year not yet complete at time of writing). 2010/11 through 2012/13 total fertilizer and intended beneficiaries are for all crops. Other crops were included in the program beginning in 2010/11 (rice beginning in 2010/11, and sorghum, cotton, and groundnuts beginning in 2012/13). Varying quantities of fertilizer were distributed along with these crops. Values in the table are for the Fertilizer Credit Programme for 2000/01-2001/02, the Fertilizer Support Program for 2002/03-2008/09, and the Farmer Input Support Program for 2009/10-2012/2013. [c]Preliminary figure. Final figure not yet released by FRA.

Table 4: Percentage of total subsidized fertilizer allocated to each province, 1999/2000 to 2012/13 agricultural years – Zambia

Agricultural year	Central	Copperbelt	Eastern	Luapula	Lusaka	Northern	North-western	Southern	Western	Backup	Total Quantity
1999/2000	20.1	6.3	24.2	2.2	9.4	11.3	2.0	23.2	1.3	0	34,999
2000/01	14.5	7.3	21.4	2.2	7.7	10.8	1.7	32.9	1.5	0	23,227
2001/02	22.1	7.4	21.9	2.0	7.4	10.7	2.0	24.7	1.8	0	28,985
2002/03	13.9	5.7	26.0	5.5	3.5	15.2	4.4	19.0	6.9	0	48,000
2003/04	15.3	9.1	25.7	5.7	6.7	16.7	5.9	10.7	4.2	0	60,000
2004/05	18.1	13.3	21.1	4.6	7.3	17.0	3.7	12.3	2.6	0	46,000
2005/06	18.0	13.0	20.0	4.1	6.8	16.5	5.5	13.9	2.1	0	50,000
2006/07	15.7	11.7	16.0	4.3	5.7	17.3	3.7	19.0	2.5	4.1	84,000
2007/08	16.5	12.3	18.5	4.8	6.2	13.7	5.0	17.7	2.3	3.0	50,000
2008/09	17.1	12.5	18.8	7.3	4.4	14.2	5.1	18.1	2.5	0	80,000
2009/10	17.6	10.5	19.5	5.1	6.9	14.5	6.2	15.4	4.4	0	100,000
2010/11	16.9	9.6	19.5	5.8	6.4	14.9	6.2	17.0	2.5	1.1	178,000
2011/12	16.7	9.8	17.7	5.9	6.3	15.9	6.0	16.7	3.0	2.0	182,454
2012/13	16.6	10.0	18.3	5.9	6.3	16.2	5.9	17.0	3.3	0.4	183,634
Average	16.9	10.2	19.6	5.3	6.3	15.3	5.3	17.2	3.0	1.0	1,149,299

Source: MACO (various years); MAL (2012).

Note: Backup fertilizer is additional fertilizer intended for the program but not allocated to a particular province or district.

Table 5: First-difference and Arellano-Bond estimation results on the effects of subsidized fertilizer on log real retail maize prices – Malawi

Model specification:	Sparse						Fully-specified					
Estimator:	(A) First-difference			(B) Arellano-Bond			(C) First-difference			(D) Arellano-Bond		
Explanatory variables:	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.
Subsidized fertilizer ('000 MT)	-0.003	*	0.069	-0.003	*	0.099	-0.004	**	0.049	-0.003	*	0.088
Growing season rainfall ('00 mm, Nov.-Mar.)	-2.11E-04	*	0.073	-1.92E-04		0.101	-2.10E-04	*	0.069	-1.85E-04		0.105
Rainfall stress (# of 20-day periods with <40 mm)	9.03E-03		0.249	0.008	**	0.120	7.87E-03		0.332	6.13E-03		0.255
Lean season (Nov.-Apr.)=1; harvest season (May-Oct.)=0	-0.144	***	0.000	0.170	***	0.000	0.121	***	0.000	0.172	***	0.000
Linear time trend	N/A			-0.017	***	0.000	N/A			-0.034	***	0.000
Log real retail maize price (MK, t-1)				0.202	***	0.002				0.192	***	0.002
Log real retail maize price (MK, t-2)				0.099	**	0.032				0.090	*	0.056
Log real retail maize price (MK, t-3)				-0.034		0.422				-0.037		0.358
Log real retail rice price (MK/kg)						**	0.10739	*	0.076	0.117	**	0.032
Log real Zambia border retail maize price (MK/kg)							0.800	***	0.000			
Log real SAFEX maize spot price, (MK/kg, 2 quarter lag)							-0.039		0.104			
Constant	0.017	***	0.000	3.336	***	0.000	-0.005		0.114	2.845	***	0.000
Marketing year dummies?	Yes			Yes			Yes			Yes		
Time period dummies?	Yes			Yes			Yes			Yes		
Long-run effect of subsidized fertilizer	N/A			-0.004		0.120	N/A			-0.003		0.105
Observations	1,122			969			1,070			969		
Overall model F-test for FD, Wald test for AB	2615.86	***	0.000	26,874.68	***	0.000	1,991.60	***	0.000	27,680.49	***	0.000
R-squared	0.798			N/A			0.815			N/A		

Source: Own calculations.

Note: ***p < 0.01, **p < 0.05, *p <0.10. Real prices are in October 2011 terms. Three lags of the dependent variable required to eliminate serial correlation in the errors of both Arellano-Bond models. Several variables dropped due to perfect collinearity (diesel prices, and lags of log real SAFEX prices).

Table 6: First-difference and Arellano-Bond estimation results on the effects of subsidized fertilizer on log real retail maize prices – Zambia

Model specification:	Sparse						Fully-specified					
Estimator:	(A) First-difference			(B) Arellano-Bond			(C) First-difference			(D) Arellano-Bond		
Explanatory variables:	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.
Subsidized fertilizer ('000 MT)	-0.0241	**	0.042	-0.0187	***	0.010	-0.0184	*	0.072	-0.00459		0.534
Growing season rainfall ('00 mm, Nov.-Mar.)	0.00528	**	0.044	0.00288		0.282	0.00477	*	0.062	0.00468		0.103
Rainfall stress (# of 20-day periods with <40 mm)	0.00778	*	0.059	0.00572		0.126	0.00700	*	0.086	0.00679		0.107
Lean season (Nov.-Apr.)=1; harvest season (May-Oct.)=0	0.446	***	0.000	0.0631	*	0.077	0.545	***	0.000	0.107	***	0.000
Linear time trend	N/A			-0.00586	*	0.056	N/A			-0.0110	**	0.013
Log real retail maize price (ZMK, t-1)				0.381	***	0.000				0.342	***	0.000
Log real retail maize price (ZMK, t-2)				0.149	***	0.000				0.136	***	0.000
Log real retail maize price (ZMK, t-3)				-0.234	***	0.000				-0.238	***	0.000
Log real retail maize price (ZMK, t-4)				0.176	***	0.000				0.171	***	0.000
Log real retail maize price (ZMK, t-5)				-0.118	***	0.000				-0.131	***	0.000
Log real retail maize price (ZMK, t-6)				0.125	***	0.003				0.120	***	0.003
Log real retail maize price (ZMK, t-7)				-0.0939	**	0.034				-0.109	**	0.011
Log real retail maize price (ZMK, t-8)				-0.0433		0.266				-0.0630		0.101
FRA maize purchases ('000 MT)							-0.000881		0.218	-0.00137	**	0.032
Log real retail rice price (ZMK/kg)							0.0730	**	0.020	-0.0545		0.116
Log real retail bread price (ZMK/700g loaf)							0.0428		0.664	-0.0694		0.539
Log real retail diesel price (ZMK/liter)							0.246		0.157	-0.511	***	0.000
Log real Malawi border retail maize price (ZMK/kg)							0.296	***	0.000	-0.0628	*	0.077
Constant	-0.00126		0.468	4.765	***	0.000	-0.0212	***	0.000	11.796	***	0.000
Marketing year dummies?	Yes			Yes			Yes			Yes		
Time period dummies?	Yes			Yes			Yes			Yes		
Long-run effect of subsidized fertilizer	N/A			-0.0284	***	0.004	N/A			-0.00595		0.529
Observations	1,145			745			1,145			745		
Overall model F-test for FD, Wald test for AB	490.5	***	0.000	17,381.2	***	0.000	573.7	***	0.000	29,561.7	***	0.000
R-squared	0.800			N/A			0.802			N/A		

Source: Own calculations.

Note: ***p < 0.01, **p < 0.05, *p <0.10. Real prices are in April 2012 terms. Eight lags of the dependent variable required to eliminate serial correlation in the errors of both Arellano-Bond models. Several variables dropped due to perfect collinearity (log retail electricity price, log real commercial lending rate, and lagged log real SAFEX prices).

Table 7: Robustness checks (partial effects of subsidized fertilizer on retail maize prices) – Malawi

Model specification:	Sparse						Fully-specified					
Estimator:	(A) First-difference			(B) Arellano-Bond			(C) First-difference			(D) Arellano-Bond		
Nominal vs. real, prices log-log vs. level-level[a]	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.
Real, level-level:												
Subsidized fertilizer ('000 MT)	-0.114		0.130	-0.064		0.335	-0.119		0.111	-0.078		0.196
Long-run effect of subsidized fertilizer	N/A			-0.067		0.367	N/A			-0.081		0.228
Nominal, log-log:												
Subsidized fertilizer ('000 MT)	-0.003	*	0.069	-0.003	*	0.099	-0.004	*	0.054	-0.003	*	0.088
Long-run effect of subsidized fertilizer	N/A			-0.004		0.120	N/A			-0.003		0.105
Nominal, level-level:												
Subsidized fertilizer ('000 MT)	-0.103	*	0.085	-0.062		0.207	-0.105	*	0.072	-0.073	*	0.099
Long-run effect of subsidized fertilizer	N/A			-0.060		0.222	N/A			-0.071		0.108

Source: Own calculations.

Note: ***p < 0.01, **p < 0.05, *p <0.10. Real prices are in October 2011 terms. [a]Subsidized fertilizer is in levels in all models.

Table 8: Robustness checks (partial effects of subsidized fertilizer on retail maize prices) – Zambia

Model specification:	Sparse						Fully-specified					
Estimator:	(A) First-difference			(B) Arellano-Bond			(C) First-difference			(D) Arellano-Bond		
Nominal vs. real, prices log-log vs. level-level[a]	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.	Coef.	Sig.	p-val.
Real, level-level:												
Subsidized fertilizer ('000 MT)	-20.449		0.253	-17.292	*	0.084	-21.362		0.199	-3.767		0.704
Long-run effect of subsidized fertilizer	N/A			-26.295	*	0.068	N/A			-5.024		0.703
Nominal, log-log:												
Subsidized fertilizer ('000 MT)	-0.0241	**	0.041	-0.0184	**	0.011	-0.0185	*	0.071	-0.00431		0.559
Long-run effect of subsidized fertilizer	N/A			-0.0279	***	0.005	N/A			-0.00559		0.554
Nominal, level-level:												
Subsidized fertilizer ('000 MT)	-14.743		0.235	-18.368	**	0.024	-12.270		0.243	-4.413		0.576
Long-run effect of subsidized fertilizer	N/A			-24.893	**	0.013	N/A			-5.193		0.567

Source: Own calculations.

Note: ***p < 0.01, **p < 0.05, *p <0.10. Real prices are in April 2012 terms. [a]Subsidized fertilizer is in levels in all models. If FRA purchases are added to sparse Arellano-Bond model, subsidized fertilizer ceases to be statistically significant (p>0.10) in all four specifications (real log-log, real level-level, nominal log-log, and real level-level).

Appendix A: Summary statistics – Malawi

Variables	Mean	Std. dev.	Percentiles 10th	25th	50th	75th	90th
Dependent variable:							
Real retail maize price (MK/kg)	37.300	15.456	21.428	26.934	33.537	43.944	59.919
Explanatory variables:							
Subsidized fertilizer ('000 MT)	4.373	5.834	0.407	0.708	1.728	5.617	10.713
Growing season rainfall ('00 mm, Nov.-Mar.)	835.001	112.371	707.058	750.194	820.674	911.771	988.961
Rainfall stress (# of 20-day periods with <40 mm)	0.925	1.116	0.000	0.000	1.000	2.000	3.000
Real retail rice price (MK/kg)	141.977	39.369	96.108	113.751	135.923	168.576	195.098
Real retail diesel price (MK/liter)	194.932	58.674	120.490	133.358	195.267	240.553	253.372
Real Zambia border retail maize price (MK/kg)	38.724	11.169	23.723	31.980	38.405	45.667	50.949
Real SAFEX maize spot price in the previous quarter (MK/kg)	29.867	9.342	19.432	24.006	29.473	35.895	42.022

Source: Own calculations.

Note: N=1,173. Real prices are in October 2011 terms.

Appendix B: Summary statistics – Zambia

Variables	Mean	Std. dev.	Percentiles 10th	25th	50th	75th	90th
Dependent variable:							
Real retail maize price (ZMK/kg)	1,686.531	622.657	1,094.402	1,264.013	1,538.381	1,903.208	2,596.529
Explanatory variables:							
Subsidized fertilizer ('000 MT)	1.108	1.227	0.027	0.225	0.738	1.600	2.627
Growing season rainfall ('00 mm, Nov.-Mar.)	1,002.625	277.228	639.600	837.038	991.950	1,177.500	1,332.025
Rainfall stress (# of 20-day periods with <40 mm)	1.344	1.682	0	0	1.000	2.000	4.000
FRA maize purchases ('000 MT)	2.688	9.457	0	0	0	0.915	5.599
Real retail rice price (ZMK/kg)	8,145.144	1,852.134	6,072.096	6,857.067	7,999.106	9,121.189	10,373.800
Real retail bread price (ZMK/700g loaf)	5,179.944	931.310	4,142.568	4,584.456	5,038.741	5,638.660	6,400.811
Real retail diesel price (ZMK/liter)	9,682.974	2,153.108	7,679.091	8,144.514	9,114.011	10,511.230	13,154.530
Real Malawi border retail maize price (ZMK/kg)	1,784.797	1,249.260	792.936	1,058.940	1,388.091	1,751.680	3,176.874
Real SAFEX maize spot price in the previous quarter (ZMK/kg)	1,368.107	398.366	924.214	1,072.957	1,315.966	1,574.35	1,924.196

Source: Own calculations.

Note: N=1,200. Real prices are in April 2012 terms.

Appendix C

Arellano-Bond tests for zero serial correlation in the first-differenced errors - Malawi

Model specification:	Sparse		Fully-specified	
Order	Z	p-val.	z	p-val.
1	-3.824	0.000	-3.677	0.000
2	0.732	0.464	0.822	0.411
3	-0.779	0.436	-0.872	0.383
4	0.908	0.364	1.034	0.301
5	-0.438	0.662	-0.443	0.658

Source: Own calculations.

Note: H_0: no autocorrelation; H_1: serial correlation at order *m.*

Appendix D

Arellano-Bond tests for zero serial correlation in the first-differenced errors - Zambia

Model specification:	Sparse		Fully-specified	
Order	Z	p-val.	z	p-val.
1	-5.510	0.000	-5.256	0.000
2	1.065	0.287	0.982	0.326
3	-0.906	0.365	-1.065	0.287
4	0.439	0.661	0.475	0.635
5	0.302	0.763	0.526	0.599
6	-1.401	0.161	-1.441	0.150
7	0.401	0.689	0.354	0.724
8	0.617	0.537	0.425	0.671
9	1.493	0.136	1.386	0.166
10	-0.009	0.993	-0.206	0.837

Source: Own calculations.

Note: H_0: no autocorrelation; H_1: serial correlation at order *m.*