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What are the effects of input subsidy programs on 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 2000–2001 to 2011–2012 maize marketing years. Results indicate that roughly doubling the size of Malawi's subsidy program reduces maize prices by 1.2–2.5% on average. In Zambia, roughly doubling the scale of the country's subsidy program reduces maize prices by 1.8–2.8% 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 retail maize prices.

JEL classifications: G38, O13, O20, Q18

Keywords: Input subsidies; Maize prices; Malawi; Zambia; sub-Saharan Africa

1. 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, 2000). Input subsidy programs, while normally analyzed in terms of their direct impact on recipient households, may also have powerful indirect 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 price impacts affect the behavior and welfare of the control group (nonrecipients of the subsidy) as well as the direct recipients of the subsidy through the prices of food and nontradable inputs. As a result, the food price effects from input subsidy programs are a crucial yet still under-examined determinant of their overall benefits, costs, and distributional effects.

Empirical investigation of the food price effects of input subsidy programs is especially important considering the high proportion of government budgets currently being allocated to such programs. For example, in Malawi input subsidies averaged greater than 65% of the Ministry of Agriculture and Food Security's budget between 2006–2007 and 2008–2009; between 2005–2006 and 2008–2009 the input subsidy program was equivalent to 3.8% of Malawi's gross domestic product (Dorward and 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

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Data Appendix Available Online

A data appendix to replicate main results is available in the online version of this article.

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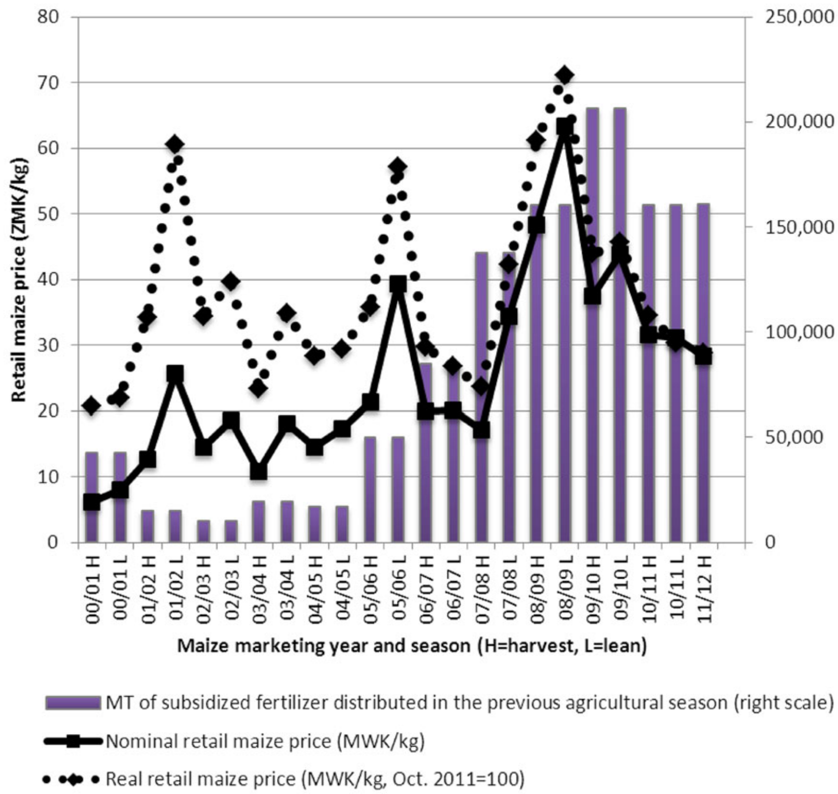


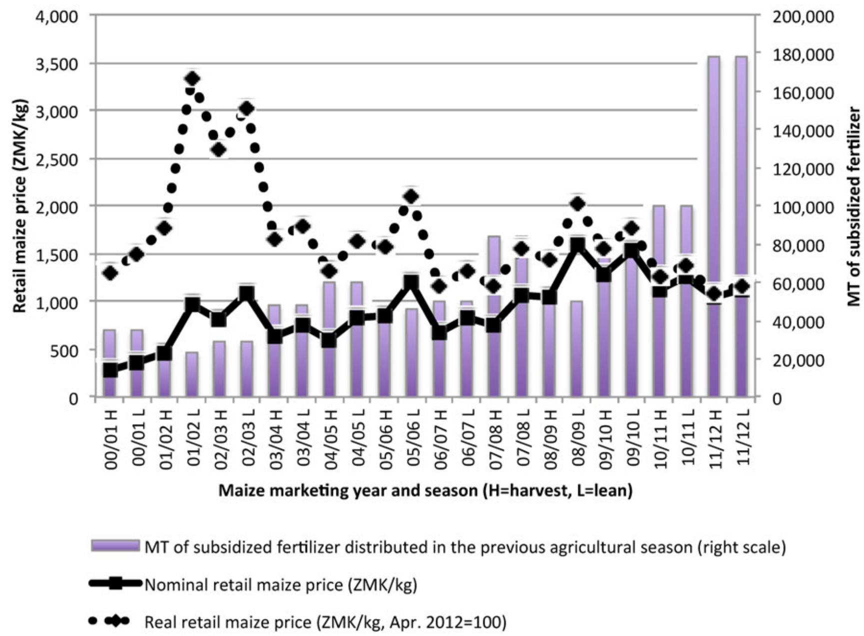
Source: Subsidized fertilizer quantities from the Logistics Unit Reports for various years. Maize prices come from the Malawi Ministry of Agriculture and Food Security (various years).

Fig. 1. Subsidized fertilizer distribution and maize price trends in Malawi.

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 2005–2006 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 in a number of years when significant quantities of subsidized fertilizer were distributed and production reportedly increased. While this is a bivariate relationship only, it goes against what we might expect (see Fig. 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). In addition, global food prices also rose during this time period, which affects food prices in Malawi to the extent that it is integrated into international markets. 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 2002–2003 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 2012–2013 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 2009–2010 to 2011–2012 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



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.

Fig. 2. Average harvest season and lean season retail maize prices and total subsidized fertilizer distributed during the period agricultural season, 2000–2001 to 2011–2012 maize marketing years (1999–2000 to 2010–2011 agricultural years)—Zambia.

in the country (Burke et al., 2010; Mason et al., 2011, 2012). Despite the market price-raising effects of FRA activities (Mason and Myers, 2013), real retail maize prices trended significantly downward in Zambia between 2003–2004 and 2011–2012 (see Fig. 2). 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 article is a better understanding of the potential maize price 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 measure the effects of subsidized fertilizer and other factors on 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 every district by 4,000 MT per year) only reduces maize prices by 1.2–1.6% on average. Doubling the scale of the program in *per capita* terms would reduce maize prices by approximately 2.5%.

In Zambia, roughly doubling the scale of the country's subsidy program (i.e., increasing the amount of subsidized fertilizer distributed to every district by 1,000 MT per year) only reduces maize prices by 2.0–2.8% on average. Doubling the scale of the program in per capita terms would reduce maize prices by approximately 1.8%. These results are 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. The absence of large price effects suggests that the welfare benefits of fertilizer subsidies accrue almost exclusively to farmers who receive the subsidy. Other farmers and urban consumers are not affected in any significant way.

2. Data

2.1. 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

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; 2000–2001 to 2012–2013 agricultural years—Malawi

Agricultural year	Subsidy rate	MT of subsidized fertilizer*	Intended number of beneficiary households in '000*	Total smallholder maize production**	ADMARC maize purchases (MT)***	Mean retail maize price in year after harvest (real ZMK/kg, October 2011 = 100)****: Harvest season (May–Oct.)	Lean season (Nov.–Apr.)
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
1999–2000	100	42,478	2,860	2,479,410	198,021	20.73	22.02
2000–2001	100	15,000	1,500	2,501,310	0	34.21	60.62
2001–2002	100	14,928	1,000	1,713,060	2,890	34.42	39.60
2002–2003	100	35,000	2,000	1,556,980	0	23.38	34.87
2003–2004	100	22,000	1,700	1,983,440	0	28.32	29.36
2004–2005	100	54,000	2,000	1,608,350	7,000	35.81	57.08
2005–2006	64	131,388	NA	1,225,230	9,097	29.64	26.75
2006–2007	72	174,688	3,000	2,611,490	75,622	23.64	42.23
2007–2008	79	216,553	1,500	3,226,420	32,728	61.26	71.17
2008–2009	91	202,278	1,500	2,634,700	69,485	43.96	45.64
2009–2010	88	161,495	1,600	3,582,500	44,268	34.54	30.35
2010–2011	93	160,531	1,600	3,419,410	45,248	28.80	NA

Source: *Logistics Unit Reports (various years); **FAOSTAT; ***National Statistical Office (2011); ****Ministry of Agriculture and Food Security, price series begins in January 2000 and ends in December 2011.

district-level experiment station records. Maize prices from Zambia's Chipata district on the Malawi–Zambia border come from the Zambian Central Statistical Office. Maize prices from Mozambique's northern Nampula market come from the Mozambique Ministry of Agriculture's retail price database (SIMA, various years).

2.2. 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.

3. Background

3.1. Input subsidies 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 1998–1999 and 1999–2000. Officially, 2.8 million households were reached each year under the Starter Pack, and beneficiary farmers were supposed to receive 10–15 kg of free fertilizer and 2 kg of hybrid seed (Harrigan, 2008). The Starter Pack program was rebranded as the Targeted Inputs Program (TIP) in 2000–2001, and it ran through the 2004–2005 season. Under the TIP, the Malawian government distributed between 15,000 MT and 54,000 MT 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 kg of fertilizer for free, and between 2 and 4 kg of hybrid or open pollinated seed varieties (OPV) for free.

Unfortunately there was a severe drought during the 2004–2005 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 MT in 2004–2005 under TIP to 131,388 MT in 2005–2006 under AISP. In addition, the official amount of subsidized fertilizer distributed increased to 100 kg per household on average per year (Table 1, column B).

The AISP program continued to be scaled up every year until the 2007–2008 season, when more than 216,000 MT of subsidized fertilizer were distributed to households. In 2008–2009, the AISP was renamed the Farm Input Support Program (FISP), and was scaled down to 202,000 MT due to high fertilizer costs. From 2008–2009 to present, the quantity of subsidized fertilizer distributed to smallholders in Malawi has remained around 160,000 MT per year (Table 1, column B). See Table 2 for the share of total subsidized fertilizer distributed to each of Malawi's three regions during each year of the study period.

Table 2
Percentage of total subsidized fertilizer allocated to each Region, 1999–2000 to 2011–2012 agricultural years—Malawi

Agricultural year	Northern	Central	Southern	Total quantity (MT)
1999–2000	10.7	40.7	48.7	42,478
2000–2001	9.6	38.1	52.3	15,000
2001–2002	9.6	39.7	50.7	14,928
2002–2003	9.6	39.2	51.2	35,000
2003–2004	9.6	37.5	52.9	22,000
2004–2005	9.6	37.5	53.0	54,000
2005–2006	12.0	48.3	39.8	131,388
2006–2007	15.6	46.7	37.7	174,688
2007–2008	19.4	45.4	35.3	216,553
2008–2009	18.9	37.7	43.4	202,278
2009–2010	13.5	40.3	46.1	161,495
2010–2011	13.7	40.3	46.0	160,531
2011–2012	–	–	–	160,834
Average	12.65	41.95	46.43	1,391,173

Source: Logistics Unit Reports (various years).

3.2. Input subsidies in Zambia

During the study period, there were three main Government of the Republic of Zambia (GRZ) input subsidy programs in place: the Fertilizer Credit Program (1997–1998 to 2001–2002), the Fertilizer Support Program (2002–2003 to 2008–2009), and the Farmer Input Support Program (2009–2010 to present). See Mason et al. (2013) for a detailed discussion of these three programs.

Under the Fertilizer Credit Program, 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. 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 to 2001–2002 agricultural years) (Table 3, column B). See Table 4 for the share of total subsidized fertilizer distributed to each of Zambia's nine provinces each year during the study period.

Loan repayment rates were low under the Fertilizer Credit Program, and GRZ moved to a cash-only (no credit) input subsidy program with the establishment of the Fertilizer Support Program in 2002–2003. 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, column 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 2008–2009 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, column B).

The Fertilizer Support Program was renamed the Farmer Input Support Program in 2009–2010 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).

4. 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, which generally includes 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 kg of subsidized fertilizer add 78 new kg to total fertilizer use, as 22 kg of commercial fertilizer are displaced by the subsidy (Ricker-Gilbert et al., 2011). When this number is adjusted for diversion based on a 33% estimate in Holden and Lunduka (2013) and the approach developed by Mason and Jayne (2013), 100 kg of

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 2012–2013 agricultural years—Zambia

Agricultural year (marketing year in parenthesis)	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 (2000–2001)	Loan	34,999	–	1,282,352	323,387	0	0%	1,302	1,499
2000–2001 (2001–2002)	Loan	23,227	–	938,539	197,915	0	0%	1,773	3,337
2001–2002 (2002–2003)	Loan	28,985	–	947,825	195,407	23,535	12.0%	2,595	3,013
2002–2003 (2003–2004)	50%	48,000	120,000	1,365,455	370,332	54,847	14.8%	1,659	1,779
2003–2004 (2004–2005)	50%	60,000	150,000	1,216,943	356,750	105,279	29.5%	1,328	1,626
2004–2005 (2005–2006)	50%	46,000	115,000	800,574	206,092	78,667	38.2%	1,564	2,106
2005–2006 (2006–2007)	50%	50,000	125,000	1,339,479	454,676	389,510	85.7%	1,154	1,328
2006–2007 (2007–2008)	60%	84,000	210,000	1,960,692	762,093	396,450	52.0%	1,169	1,558
2007–2008 (2008–2009)	60%	50,000	125,000	1,392,180	522,033	73,876	14.2%	1,427	2,021
2008–2009 (2009–2010)	75%	80,000	200,000	1,657,117	613,356	198,630	32.4%	1,548	1,770
2009–2010 (2010–2011)	75%	100,000	500,000*	2,463,523	1,062,010	883,036	83.1%	1,259	1,374
2010–2011 (2011–2012)	76%	178,000	891,500*	2,786,896	1,429,911	1,751,660	122.5%	1,087	1,153
2011–2012 (2012–2013)	79%	182,454	914,670*	2,731,843	1,440,944	1,034,000***	71.8%	–	–
2012–2013 (2013–2014)	–	183,634**	900,000**	–	–	–	–	–	–

Note: – Information not yet available.
*Pack size reduced from eight 50-kg bags to four 50-kg bags.
**Planned distribution and number of intended beneficiaries (2012–2013 agricultural year not yet complete at time of writing). 2010–2011 through 2012–2013 total fertilizer and intended beneficiaries are for all crops. Other crops were included in the program beginning in 2010–2011 (rice beginning in 2010–2011, and sorghum, cotton, and groundnuts beginning in 2012–2013). Varying quantities of fertilizer were distributed along with these crops. Values in the table are for the Fertilizer Credit Programme for 2000–2001 to 2001–2002, the Fertilizer Support Program for 2002–2003 to 2008–2009, and the Farmer Input Support Program for 2009–2010 to 2012–2013.
***Preliminary figure. Final figure not yet released by FRA.
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.

Table 4
Percentage of total subsidized fertilizer allocated to each province, 1999–2000 to 2012–2013 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
2000–2001	14.5	7.3	21.4	2.2	7.7	10.8	1.7	32.9	1.5	0	23,227
2001–2002	22.1	7.4	21.9	2.0	7.4	10.7	2.0	24.7	1.8	0	28,985
2002–2003	13.9	5.7	26.0	5.5	3.5	15.2	4.4	19.0	6.9	0	48,000
2003–2004	15.3	9.1	25.7	5.7	6.7	16.7	5.9	10.7	4.2	0	60,000
2004–2005	18.1	13.3	21.1	4.6	7.3	17.0	3.7	12.3	2.6	0	46,000
2005–2006	18.0	13.0	20.0	4.1	6.8	16.5	5.5	13.9	2.1	0	50,000
2006–2007	15.7	11.7	16.0	4.3	5.7	17.3	3.7	19.0	2.5	4.1	84,000
2007–2008	16.5	12.3	18.5	4.8	6.2	13.7	5.0	17.7	2.3	3.0	50,000
2008–2009	17.1	12.5	18.8	7.3	4.4	14.2	5.1	18.1	2.5	0	80,000
2009–2010	17.6	10.5	19.5	5.1	6.9	14.5	6.2	15.4	4.4	0	100,000
2010–2011	16.9	9.6	19.5	5.8	6.4	14.9	6.2	17.0	2.5	1.1	178,000
2011–2012	16.7	9.8	17.7	5.9	6.3	15.9	6.0	16.7	3.0	2.0	182,454
2012–2013	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

Note: Backup fertilizer is additional fertilizer intended for the program but not allocated to a particular province or district.
Source: MACO (various years); MAL (2012).

subsidized fertilizer only adds 45 kg of new fertilizer to farmers' fields. In Zambia, Mason and Jayne (2013) find that 100 kg of subsidized fertilizer increases total fertilizer use by 54 kg after accounting for crowding out and diversion.[1]

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 in Malawi and Zambia (Holden and Lunduka, 2010; Mason et al., 2013; Ricker-Gilbert and Jayne, 2012; Ricker-Gilbert and Jayne, 2011; Shively et al., 2012). For example, in Malawi (Zambia), a household's maize quantity harvested increases by only 2.71 kg (1.88 kg) on average given a 1-kg increase in subsidized fertilizer (Mason et al., 2013; Ricker-Gilbert and Jayne, 2012). Given the small magnitude of the maize production increase stimulated by subsidized fertilizer, *a priori* we would not expect major effects on maize prices.[2]

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. Spatial market integration studies for maize in Malawi and Zambia (Awudu, 2007; Burke, 2012; Chirwa, 1999; Goletti and Babu, 1994; Loy and Wichern, 2000; Maplia et al., 2013; Myers, 2008; Myers and Jayne, 2012; Tostau and Brorsen, 2005) 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. However, some markets in Malawi and Zambia continue to be poorly integrated mainly due to high transport costs and government activities in the maize market. Therefore, in modeling the effects of fertilizer subsidies on maize prices, we need to account for the linkage between domestic prices and prices in regional reference markets.

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 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

[1] We define diversion as the amount of subsidized fertilizer that is taken by program implementers somewhere along the procurement chain and re-sold as commercial fertilizer. Diversion is a problem to the extent that diverted subsidized fertilizer takes the place of what would have been commercial sales.

[2] See Mason et al. (2013) for a discussion of the reasons for the small effects of Zambia's fertilizer subsidy program on maize production there.

program

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

where Q^s is maize quantity produced, p^{f*} is the expected producer price of maize, *FISP* is the quantity of subsidized fertilizer, and 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:

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

where Q^d is maize quantity demanded, p^r is the retail price of maize, and 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 ($M(z^m)$):

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

The variables that might affect the price margin are represented by z^m. From there we use the market clearing condition:

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

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^f) is a function of realized maize production level gives

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

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

5. Empirical model

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

$$p^r_{i,t} = \Psi + \alpha\, FISP_{i,t} + \sum_{j=0}^{J} \Upsilon_j\, p^r_{i,t-j} + X_{i,t}\beta + Z_t\theta + c_i + \mu_{i,t}, \tag{6}$$

where i indexes 72 markets in Malawi's 26 districts, and 50 districts in Zambia.[3,4] In addition, t indexes the time period, which includes two seasons in each marketing year. These are (i) the harvest season (May–October) when maize stocks are high; and (ii) the lean (hungry) season (November–April) when maize stocks dwindle.[5] 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 2010–2011 marketing year (May 2010 to April 2011) should be affected by maize production (and factors affecting it) in the 2009–2010 agricultural year (October 2009 to 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.

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 z^s in Eqs. (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.[6,7] The demand shift factors in **X**, represented by z^d in Eqs. (2) and (5), include the retail

[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.

[5] We estimate a seasonal model instead of a quarterly or monthly model because the temporal variation is only once per year for our key covariate of interest, kilograms of subsidized fertilizer distributed to each district. Therefore, most intra-year dynamic effects of subsidized fertilizer on maize prices will be captured in a two-season model. Estimating the model as quarterly or monthly introduces extra dynamics that create additional complications, without doing a better job of estimating conditional effects.

[6] A variable capturing FRA maize sales (as opposed to FRA maize purchases) is not included in the Zambian model due to lack of data. For Malawi, although there is some evidence that an increase in the ADMARC pan-territorial price has a positive effect on retail maize prices in local markets (Mapila et al., 2013), Agricultural Development and Marketing Corporation purchase, sales, and price data are only available at the national level. These variables are excluded from the Malawi model because including them would be equivalent to a year fixed effect.

[7] 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

price of rice in LCU per kilogram and the retail price of bread in LCU per loaf. 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 $\boldsymbol{\beta}$.

The vector of national-level factors that affect maize prices are represented by **Z**. The marketing margin variables, represented by z^m in Eqs. (3) and (5), include diesel prices in LCU per liter. (For Zambia, district-level diesel prices are used instead of national-level prices, and the model also includes national-level electricity prices in ZMK/kilowatt hour, and national commercial lending interest rates.). 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, Malawian border prices (Mchinji retail) in the Zambia model, and Zambian border prices (Chipata retail) and maize prices in the northern Mozambique market of Nampula in the Malawi model. Second, we include lagged maize spot prices on the South African Futures Exchange (SAFEX) in the models for both Malawi and Zambia.[8] (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), interactions between the hungry/lean season dummy and the marketing year dummies, and a linear time trend. These variables vary over time but not over space, and help control for other national- and international-level factors and policies affecting retail maize prices in Malawi and Zambia that are not explicitly included in the model. The parameter vector for **Z** is represented by $\boldsymbol{\theta}$.

The error term in Eq. (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.

estimates are still unbiased and consistent in the presence of multicollinearity; only the standard errors are affected.

[8] There is significant informal cross-border trader between Malawi and Zambia, hence our inclusion of border prices in the models. We include the Nampula, Mozambique price in the Malawi model because monitoring of cross-border trade by the Famine Early Warning Systems Network (FEWSNET, 2013) indicates that Malawi has imported maize from northern Mozambique and often from other countries in almost every month since the monitoring started in 2004, up until the 2010–2011 marketing year when Malawi began exporting some maize to Mozambique (Jayne et al., 2010). We include the SAFEX price in the models for both countries because South Africa is a major source of formal maize imports for Zambia and Malawi. Online Appendix Figure A1 shows the price series price series of white maize in Lilongwe, Lusaka, and the SAFEX over the range of our study period. The correlation in our price series between the white maize price in Lilongwe and the SAFEX price is 0.28, while the correlation between the white maize price in Lusaka and the SAFEX price is 0.55.

The key parameter estimate of interest in Eq. (6) is $\hat{\alpha}$, which gives the short-run effect of an additional metric ton of subsidized fertilizer allocated to district i on the retail maize price in that district or market. Also of interest is $\frac{\hat{\alpha}}{1-\sum_{j=1}^{J}\hat{\gamma}_j}$, which gives the estimated long-run effect 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.

6. 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 Eq. (6) into FD form as follows:

$$\Delta pr_{i,t} = \alpha \Delta FISP_{i,t} + \sum_{j=0}^{J} \Upsilon_j np^r_{i,t-j} + \Delta X_{i,t}\beta + \Delta Z_t \theta + \Delta\mu_{i,t}, \tag{7}$$

where Δ represents the change in the variables of interest between one time period and the next. The FD estimator is useful in this application because price data are often nonstationary. Estimating the model in FD form helps solve the issue of nonstationarity and also 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 $j \geq 2$, then we can use lagged values of $p^r_{i,t-j}$ where $j \geq 2$ to instrument for $\Delta p^r_{i,t-1}$. The resulting framework is known as the Arellano-Bond estimator following Arellano and Bond (1991).

The AB framework first differences the data and 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.

6.1. 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.[9] 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 D and E).

6.2. Functional form

We estimate various model specifications for Eq. (7). In our main model, the maize price variable is specified in log form, while the key explanatory variable of interest (FISP) is in levels.[10] Therefore, the short- and long-run effects of FISP $\hat{\alpha}$ and $\frac{\hat{\alpha}}{1-\sum_{j=1}^{J}\hat{\gamma}_j}$, respectively, should be interpreted as semi-elasticities (or, more precisely, as semi-flexibilities). The other price variables are in log form, so the coefficients can be interpreted directly as flexibilities. In our main model, 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. In total, we estimate 16 different model specifications in both Malawi and Zambia.

6.3. Testing for potential spatial spill-over effects

Equation (7) allows subsidized fertilizer allocated to a given district to affect retail maize prices in that market or district only. However, it is possible that subsidized fertilizer allocated to *other* districts in the country could affect prices in a given market or district. We explored this possibility by including two spatial lags of subsidized fertilizer in our models, i.e., variables capturing subsidized fertilizer allocations to other districts. The first spatial lag variable is: allocations to contiguous (neighboring) districts only. The second spatial lag variable is: allocations to *all* other districts in the country, where allocations are weighted by the inverse of the linear distance between districts such that closer districts have larger weights than more distant districts. Both spatial lag variables are row-standardized.

The empirical evidence, however, suggests that allocations to other districts do not significantly affect retail maize prices in a given market or district in Malawi or Zambia. In the case of Malawi, the first (local) spatial lag is statistically significant at the 10% level in only six of the 16 model specifications estimated in the article, and the second (global) spatial lag is not statistically significant in any of the 16 specifications. In addition, the *P*-value is between 0.05 and 0.10 in five of the six specifications where it is less than 0.10, indicating that the spatial spillover effect is only marginally statistically significant, if at all. Furthermore, adding the spatial lags to the models does not change the estimates of $\hat{\alpha}$ in any meaningful way, and when statistically significant, the coefficient on the spatial lag is often positive, which would go against our expectation. The subsidized fertilizer allocations to other districts also do not have much of an impact in the case of Zambia. The first (local) spatial lag is not statistically significant in any of the 16 specifications, and the second (global) spatial lag is weakly significant in two of 16 specifications. The weight of the empirical evidence for both Malawi and Zambia therefore suggests no significant spillover effects of subsidized fertilizer allocated to a given district on retail maize prices in other districts or markets.

7. Results

Table 5 presents the results for factors affecting log 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; year, season, and year*season fixed effects; a linear time trend; and a constant.[11] 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, bread prices, maize prices at the Zambian border, maize prices in the northern Mozambique market of Nampula, 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 MT

[9] The AB first-differenced errors are serially correlated by construction at lag order 1 but are serially uncorrelated at higher lags. See Appendices D and E.

[10] Subsidized fertilizer is equal to zero in some districts in some years, so it is not possible to transform the variable into logs.

[11] We include the sparsely specified model in order to show the robustness of our results. One of the advantages of the sparse models is that they include the full set of year and time-period dummies, whereas some of these get dropped due to perfect collinearity in the fully specified models. For example, variables like the SAFEX price, border price, etc. vary over time but not over districts, as do the year and time-period dummies.

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	Coeff.	Sig.	*P*-val.	Coeff.	Sig.	*P*-val.	Coeff.	Sig.	*P*-val.	Coeff.	Sig.	*P*-val.
Subsidized fertilizer (‘000 MT)	−0.003	*	0.069	−0.003	*	0.093	−0.004	***	0.013	−0.003	*	0.054
Growing season rainfall (‘00 mm, Nov.−Mar.)	−2.11E-04	*	0.073	−1.93E-04	*	0.099	−3.038E-04	***	0.016	−1.91E-04		0.103
Rainfall stress (# of 20-day periods with <40 mm)	9.03E-03		0.249	0.008		0.123	3.532E-03		0.641	6.75E-03		0.232
Lean season (Nov.–Apr.) = 1; harvest season (May–Oct.) = 0	−0.144	***	0.000	0.170	***	0.000	−0.182	***	0.000	0.108	***	0.013
Linear time trend	N/A			−0.032	***	0.000	N/A			−0.024	***	0.000
Log real retail maize price (MK, *t*-1)				0.203	***	0.002				0.187	***	0.003
Log real retail maize price (MK, *t*-2)				0.099	**	0.031				0.092	*	0.057
Log real retail maize price (MK, *t*-3)				−0.034		0.427				−0.035		0.379
Log real retail rice price (MK/kg)							0.119		0.123	0.103	*	0.061
Log real retail bread price (MK/loaf)							−0.224		0.229	−0.416	***	0.001
Constant	0.017	***	0.000	3.336	***	0.000	−0.008	*	0.076	4.731	***	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		0.114	N/A			−0.004	*	0.073
Observations	1,122			969			1,020			969		
Overall model F-test for FD, Wald test for AB	2,615.86	***	0.000	26,668.00	***	0.000	2,245.48	***	0.000	36,499.95	***	0.000
R^2	0.798			N/A			0.819			N/A		

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, Zambia prices, Northern Mozambique prices, and lags of log real SAFEX prices).
Source: Own calculations.

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 the 1999–2000 and 2010–2011 agricultural years the average district in Malawi received 4,373 MT of fertilizer per year (see online Appendix Table A1). Therefore, if Malawi decided to roughly double the size of its input subsidy program by increasing the amount of subsidized fertilizer distributed to every district by 4,000 MT per year, it would only reduce the price of maize by 1.2–1.6% on average, *ceteris paribus*.

The bottom of columns (B) and (D) show the long run (three period) impact semi-flexibility of subsidized fertilizer on maize prices. The long run effect is close to statistically significant in column (B) (P-value = 0.11) and marginally significant in column (D) (P-value = 0.073). Regardless, the economic magnitude is small and is similar to the coefficient on 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. The lean season dummy variable has a statistically significant and positive sign in the AB models, which are more robust than the FD models where the variable's coefficient is negative. Higher rice prices lead to higher maize prices, indicating that the commodities are substitutes, as we would expect.

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 purchases 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 MT of subsidized fertilizer delivered to every district reduces maize prices by 2.0–2.8% 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). Until 2010–2011, the subsidy program in Zambia distributed less fertilizer to farmers than the Malawi program did, so the average amount of subsidized fertilizer distributed in each district in Zambia between the 1999–2000 and 2011–2012 production years was 1,107 MT (see online Appendix Table A2). Therefore, the coefficient estimates from Table 6 indicate that if Zambia's fertilizer subsidy program were to increase by 1,000 MT in every district per year (roughly doubling the size of the program), then maize

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	Coeff.	Sig.	*P*-val.	Coeff.	Sig.	*P*-val.	Coeff.	Sig.	*P*-val.	Coeff.	Sig.	*P*-val.
Subsidized fertilizer (‘000 MT)	−0.0277	**	0.014	−0.0202	***	0.007	−0.0227	**	0.026	−0.00500		0.486
Growing season rainfall (‘00 mm, Nov.−Mar.)	−5.16E-04	***	0.000	−2.08E−04	**	0.032	−4.97E−04	***	0.000	−1.98E−04	*	0.088
Growing season rainfall, squared	2.53E-07	***	0.000	1.04E−07	**	0.016	2.43E−07	***	0.000	1.08E−07	**	0.048
Rainfall stress (# of 20-day periods with <40 mm)	−0.00353		0.440	0.00187		0.648	−0.00381		0.409	0.00280		0.548
Lean season (Nov.−Apr.) = 1; harvest season (May-Oct.) = 0	0.457	***	0.000	0.0645	*	0.066	0.535	***	0.000	0.106	***	0.001
Linear time trend	N/A			−0.00602	*	0.062	N/A			−0.0113	**	0.015
Log real retail maize price (ZMK, *t*-1)				0.373	***	0.000				0.336	***	0.000
Log real retail maize price (ZMK, *t*-2)				0.150	***	0.000				0.139	***	0.000
Log real retail maize price (ZMK, *t*-3)				−0.232	***	0.000				−0.235	***	0.000
Log real retail maize price (ZMK, *t*-4)				0.176	***	0.000				0.172	***	0.000
Log real retail maize price (ZMK, *t*-5)				−0.118	***	0.000				−0.130	***	0.000
Log real retail maize price (ZMK, *t*-6)				0.120	***	0.004				0.116	***	0.005
Log real retail maize price (ZMK, *t*-7)				−0.0920	**	0.036				−0.107	**	0.012
Log real retail maize price (ZMK, *t*-8)				−0.0408		0.289				−0.0601		0.108
FRA maize purchases (‘000 MT)							−7.72E-04		0.294	−0.00139	**	0.031
Log real retail rice price (ZMK/kg)							0.0693	**	0.026	−0.0516		0.134
Log real retail bread price (ZMK/700 g loaf)							0.0431		0.660	−0.0638		0.581
Log real retail diesel price (ZMK/liter)							0.212		0.215	−0.513	***	0.000
Log real Malawi border retail maize price (ZMK/kg)							0.297	***	0.000	−0.0615	*	0.087
Constant	−0.00103		0.559	4.945	***	0.000	−0.0210	***	0.000	11.858	***	0.000
Marketing year dummies?	Yes			Yes			Yes			Yes		
Time period dummies?	Yes			Yes			Yes			Yes		
Long-run effect of subsidized fertilizer	N/A			−0.0304	***	0.003	N/A			−0.00650		0.483
Observations	1,145			745			1,145			745		
Overall model *F*-test for FD, Wald test for AB	448.3	***	0.000	20,697.4	***	0.000	477.85	***	0.000	31,368.0	***	0.000
R^2	0.804			N/A			0.805			N/A		

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).
Source: Own calculations.

prices would only decrease between 2.0% and 2.8% on average, other factors constant.

The long-run (eight period) impact semi-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 MT increase in subsidized fertilizer distributed to a district reduces the retail maize price by 3.0% on average.

Table 6 shows that higher rainfall leads to lower maize prices but at a decreasing rate. 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 several 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 effects of subsidized fertilizer are negative and statistically significant in two of the 12 specification for Malawi, and the current year effects are statistically significant in eight of the 12 specifications. In Zambia, the long-run effects are statistically significant in the sparsely specified AB

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†	Coeff.	Sig.	*P*-val.	Coeff.	Sig.	*P*-val.	Coeff.	Sig.	*P*-val.	Coeff.	Sig.	*P*-val.
Real, level-level												
Subsidized fertilizer ('000 MT)	−0.114		0.130	−0.064		0.327	−0.139	*	0.064	−0.092		0.129
Long-run effect of subsidized fertilizer	N/A			−0.068		0.360	N/A			−0.096		0.169
Nominal, log-log												
Subsidized fertilizer ('000 MT)	−0.003	*	0.069	−0.003	*	0.093	−0.004	**	0.013	−0.003	*	0.054
Long-run effect of subsidized fertilizer	N/A			−0.004		0.114	N/A			−0.004	*	0.073
Nominal, level-level												
Subsidized fertilizer ('000 MT)	−0.103	*	0.085	−0.062		0.198	−0.138	**	0.017	−0.102	**	0.019
Long-run effect of subsidized fertilizer	N/A			−0.061		0.214	N/A			−0.097	**	0.025

Note: **$P < 0.05$, *$P < 0.10$. Real prices are in October 2011 terms.
†Subsidized fertilizer is in levels in all models.
Source: Own calculations.

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†	Coeff.	Sig.	*P*-val.	Coeff.	Sig.	*P*-val.	Coeff.	Sig.	*P*-val.	Coeff.	Sig.	*P*-val.
Real, level-level												
Subsidized fertilizer ('000 MT)	−28.326	*	0.079	−18.463	*	0.069	−30.737	**	0.04	−1.440		0.881
Long-run effect of subsidized fertilizer	N/A			−28.371	*	0.057	N/A			−1.935		0.881
Nominal, log-log												
Subsidized fertilizer ('000 MT)	−0.0277	**	0.014	−0.0199	***	0.007	−0.0227	**	0.025	−0.00467		0.515
Long-run effect of subsidized fertilizer	N/A			−0.0298	***	0.003	N/A			−0.00607		0.512
Nominal, level-level												
Subsidized fertilizer ('000 MT)	−17.881		0.130	−18.992	**	0.02	−16.048		0.108	−4.622		0.548
Long-run effect of subsidized fertilizer	N/A			−26.140	***	0.010	N/A			−5.523		0.539

Note: ***$P < 0.01$, **$P < 0.05$, *$P < 0.10$. Real prices are in April 2012 terms.
†Subsidized fertilizer is in levels in all models.
Source: Own calculations.

models regardless of functional form, while the current year effects are statistically significant in seven of the 12 specifications. These 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 12 of the 16 models estimated for Malawi and in 10 of the 16 models estimated for Zambia.

Although Malawi's input subsidy program is larger than Zambia's, the smaller maize price effects of Malawi's program are roughly consistent with trade theory in semi-open economies. Malawi has been at or near import parity levels for most of the lean season periods over the past 12 years. As a result, the country has been importing maize from its neighbors almost every month since the subsidy program was scaled up in 2005–2006, until the 2010–2011 marketing year (FEWSNET, 2013; Jayne et al., 2010; Myers and Jayne, 2012). Therefore, any expansion of production in Malawi would have mainly substituted local production for a reduction in imports without affecting its general import parity position, thus having a minimal effect on maize prices. By contrast, domestic maize production in Zambia was insufficient for national requirements in only four of the 12 marketing years during our study period (2000–2001 to 2011–2012), and the country had maize surpluses in excess of 1 million MT in 2010–2011 and 2011–2012. We would thus expect subsidized fertilizer to have larger maize price effects in Zambia than in Malawi.

Overall the results from Malawi and Zambia indicate that the maize price effects from the fertilizer subsidy programs in both countries are small. This is the case both with regard to the percentage reduction in maize price, and in terms of total consumer surplus (CS) for the national economy. For example, in Malawi between 2000–2001 and 2010–2011 the average real lean season price was US$341 per MT. Our upper bound estimate of a 1.6% reduction in maize price from doubling the subsidy amounts to a CS gain of $5.46 per MT of marketed maize. In addition, Jayne et al. (2010) estimate that 580,000 MT of maize are marketed after a good harvest in Malawi, while 491,000 MT are marketed after an average harvest. Therefore, during a good harvest the aggregate CS gain is US$5.46 per MT * 580,000 MT marketed maize = US$3.167 million; in an average harvest the aggregate CS gain is US$5.46 per MT * 491,000 MT marketed maize = US$2.681 million. The gain in CS is small compared to the total social cost of Malawi's subsidy program, which averaged US$129.708 million per year between 2005–2006 and 2009–2010 (Dorward and Chirwa, 2011).[12] Therefore, the CS gain from the price reduction even a good year (US$3.167 million) is equivalent to just 2.4% of the program cost.

In Zambia, the average real lean season price in 2010–2011 marketing year was US$289 per MT. Our upper bound estimate of a 2.8% reduction in the retail maize price from doubling the scale of the subsidy suggests a CS gain of approximately US$8 per MT of maize purchased. In addition, rural and urban consumers are estimated to have purchased approximately 726,307 MT of maize (grain equivalents) during the 2010–2011 marketing year.[13] Therefore, the total CS gain is US$5.81 million (= US$8 per MT * 726,307 MT maize purchased). The total social cost of the fertilizer subsidy program during the corresponding agricultural year was US$111.65 million (Jayne et al., 2013). The CS gain from the price reduction (US$5.81 million) was therefore equivalent to 5.2% of the total cost of the program.

In their benefit–cost analysis of the fertilizer subsidy programs in Malawi and Zambia, Jayne et al. (2013) incorporate the maize price reduction in their calculations of the benefits of the program. It is also important to note that the CS gains generated by the subsidy programs' reduction in maize prices represent a transfer from producers to consumers and not an additional gain to the economy. However, the majority of the CS benefits would likely accrue to small farm households and urban consumers who are net buyers of maize.

7.1. Robustness check: Subsidized fertilizer per capita

As an additional robustness check, we estimate all of the models for Malawi and Zambia with the key variable of interest specified as kilograms of subsidized fertilizer allocated to a district divided by the population of that district (i.e., kg of subsidized fertilizer per capita). Population numbers come from the census that is closest to the first year in our dataset (1998 census for Malawi and 2000 census for Zambia). In addition to being another way to measure the scale of the subsidy program in each district, the per capita specification implicitly controls for population, which affects maize demand, which in turn may influence the retail maize price.

The results from this specification are generally similar to the results in our main specifications. In Malawi the subsidized fertilizer per capita variable is statistically significant in six of the 16 specifications. The largest statistically significant coefficient estimate indicates that a 1-kg/capita increase in subsidized fertilizer allocated to every district reduces the retail maize price by 0.26% on average. Since the average per capita distribution of subsidized fertilizer in a district is 9.5 kg, then doubling the size of the subsidy program in every district would reduce maize prices by just under 2.5% on average. This is somewhat larger than the upper bound estimate from the models where subsidized fertilizer is specified in total MT terms (1.6%).

In Zambia, the subsidized fertilizer per capita variable is statistically significant in 11 of the 16 specifications. The largest statistically significant coefficient estimate indicates that a 1-kg/capita increase in subsidized fertilizer allocated to every district reduces the retail maize price by 0.22% on average. Since the average per capita distribution of subsidized fertilizer in a district is 8.2 kg, then doubling the size of the subsidy program in every district of Zambia would reduce maize prices by just under 1.8% on average. This is somewhat smaller than the upper bound estimate from the models where subsidized fertilizer is specified in total MT terms (2.8%).

8. Conclusions

Input subsidy programs are currently gaining substantial attention as a strategy for boosting staple crop production and improving household food security in 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 quantify this 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 a price effect.

The 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, factors affecting marketing margins, and time invariant unobserved effects in our econometric models of fertilizer subsidy effects on retail maize prices.

[12] Total social cost refers to the (net) cost to government plus the cost to program participants.

[13] This is based on per capita maize consumption requirements of 99.27 kg/year per MACO (2010) and Zambia's 2010 total population estimate of 13,046,508 people, of which 56.08% are assumed to be net buyers of maize. (All urban residents, or 39% of the population, are assumed to be maize net buyers. Rural residents were 61% of the population in 2010 and household survey evidence suggests that approximately 28% of rural residents are maize net buyers in bumper harvest years such as 2010 (CSO, 2011; CSO/MAL/IAPRI, 2012).) The estimate of 726,307 MT of maize purchased is 13,046,508*0.5608*99.27/1,000.

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 scale of Malawi's subsidy program in total MT terms (i.e., increasing the total allocation to every district by 4,000 MT per year) only reduces maize prices by 1.2–1.6% on average. Doubling the scale of the program in *per capita* terms would reduce maize prices by approximately 2.5%. In Zambia, roughly doubling the scale of the country's subsidy program in total MT terms (i.e., increasing the total allocation to every district by 1,000 MT per year) only reduces maize prices by 2.0–2.8% on average. Doubling the scale of the program in per capita terms would reduce maize prices by approximately 1.8%. The lack of large fertilizer subsidy effects on maize prices suggests that the welfare benefits of the programs are limited almost exclusively to farmers who receive the subsidy. Other farmers and urban consumers are not affected in a major way. Another way to view these results is that removing the subsidy program in Malawi would have raised retail maize prices by 1.2–2.5% on average, while removing the subsidy program in Zambia would have raised maize prices by 1.8–2.8% on average.

To our knowledge, the results from Malawi and Zambia provide the strongest and most externally valid results to date on how fertilizer subsidy programs affect food prices. 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 purchases and have a positive but 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 little reason to expect the subsidy programs to have large impacts on maize prices for more than a relatively short period. 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. Rather, the empirical evidence suggests that even the large-scale fertilizer subsidy programs in the region result in very small, if any, reductions in retail food prices in semi-open economies.

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